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Quantification of the deltoid muscle height in the region of the coraco-acromial ligament – An ultrasonographical study

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SUMMARY

Although the triangular deltoid muscle has three distinct portions originating from the scapula and acromion, the underlying coraco-acromial ligament presents as the stabilizing factor for the anterior deltoid, thus bridging the interval within the coraco-acromial arch. As the deltoid muscle integrity is vulnerable during the resection of the coraco-acromial ligament from the acromion, the purpose of this study was to quantify the height of the deltoid muscle over the region of the coraco-acromial ligament.

The superior shoulder region in seventeen normal female individuals (n = 34) were bilaterally examined through an ultrasonographic system (Medelec Synergy: Acertys T2 EDX, 2012). In addition to the length of the coraco-acromial ligament, the height of the deltoid muscle was measured at three selected areas between the posterior aspect of the coracoid process and the anterior acromial tip, just superior to the coraco-acromial ligament.

The mean coraco-acromial length was found to be 24.8±7.6mm. The mean deltoid height at regions 1, 2 and 3 were 8.4±2.7mm, 9.1±2.1mm and 8.4±3.0mm, respectively.

The height of the deltoid muscle was recorded to be constant across all three regions related to the coraco-acromial ligament. Moreover, the specific height of the deltoid muscle in the region of the coraco-acromial ligament was not reported in the literature reviewed. In addition, this study was done to complement the introduction of the delto-fulcral triangle model by Naidoo et al. (2017). The provision of data regarding the specific deltoid height may assist to preserve the deltoid muscle and the accompanying coraco-acromial ligament during operative procedures.

Key words: Deltoid muscle – Coraco-acromial ligament – Height – Stabilizer – Acromion – Coracoid process – Ultrasonography

INTRODUCTION

As it constitutes the greatest proportion of the upper limb muscle mass, the deltoid muscle has a considerable effect on the glenohumeral joint in rotator cuff deficient shoulders (Holzbaur et al., 2007; Audenaert et al., 2009; Meyer et al., 2013).

Geometrically, the deltoid muscle appears triangular and has three distinct portions arising from the antero-superior lateral one-third of the clavicle, the supero-lateral acromion and the inferior border of the scapular spine to insert infero-laterally at the radial tuberosity of the humerus (Williams and Warwick, 1980; Lorne et al., 2001; Leijnse et al.,

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2008; Audenaert et al., 2009; Sakoma et al., 2011; Meyer et al., 2013; Moser et al., 2013; Rosso et al., 2014; Standring et al., 2016). Although Audenaert et al. (2009) reported the thickness of the deltoid muscle to be equally distributed as it wraps over the osseous outline of the shoulder, segments of the anterior and intermediate deltoid portions are stabilised by the underlying coraco-acromial ligament (CAL) in order to account for the interrupted osseous continuity of the coraco-acromial arch (Moser et al., 2013; Standring et al., 2016).

Since the CAL originates from the anterior acromial margin and inserts onto the posterior aspect of the coracoid process, it completes an arch superior to the humeral head (Ciochon and Corruccini, 1977; Edelson and Taitz, 1992; Edelson and Luchs, 1995; Fealy et al., 2005; Standring et al., 2016). Despite representing an anatomical site of stenosis, the CAL forms a “tension band” between the osseous attachments for the underlying and overlying structures of the glenohumeral joint (Neer, 1972; Edelson and Taitz, 1992; Standring et al., 2016).

With the increasing complexity of arthroscopic surgery, thorough knowledge of the morphometric anatomy is considered to be important for the successful operative outcome, as the integrity of the superior-lying deltoid muscle is often vulnerable during the resection of the CAL from the acromion (Edelson and Luchs, 1995; Moorman et al., 2012). Therefore, given that the specific height of the deltoid muscle over the coraco-acromial ligamentous region remains unquantified, and in an attempt to preserve these structures, the current study aimed to determine the muscular height of the deltoid in the selected region.

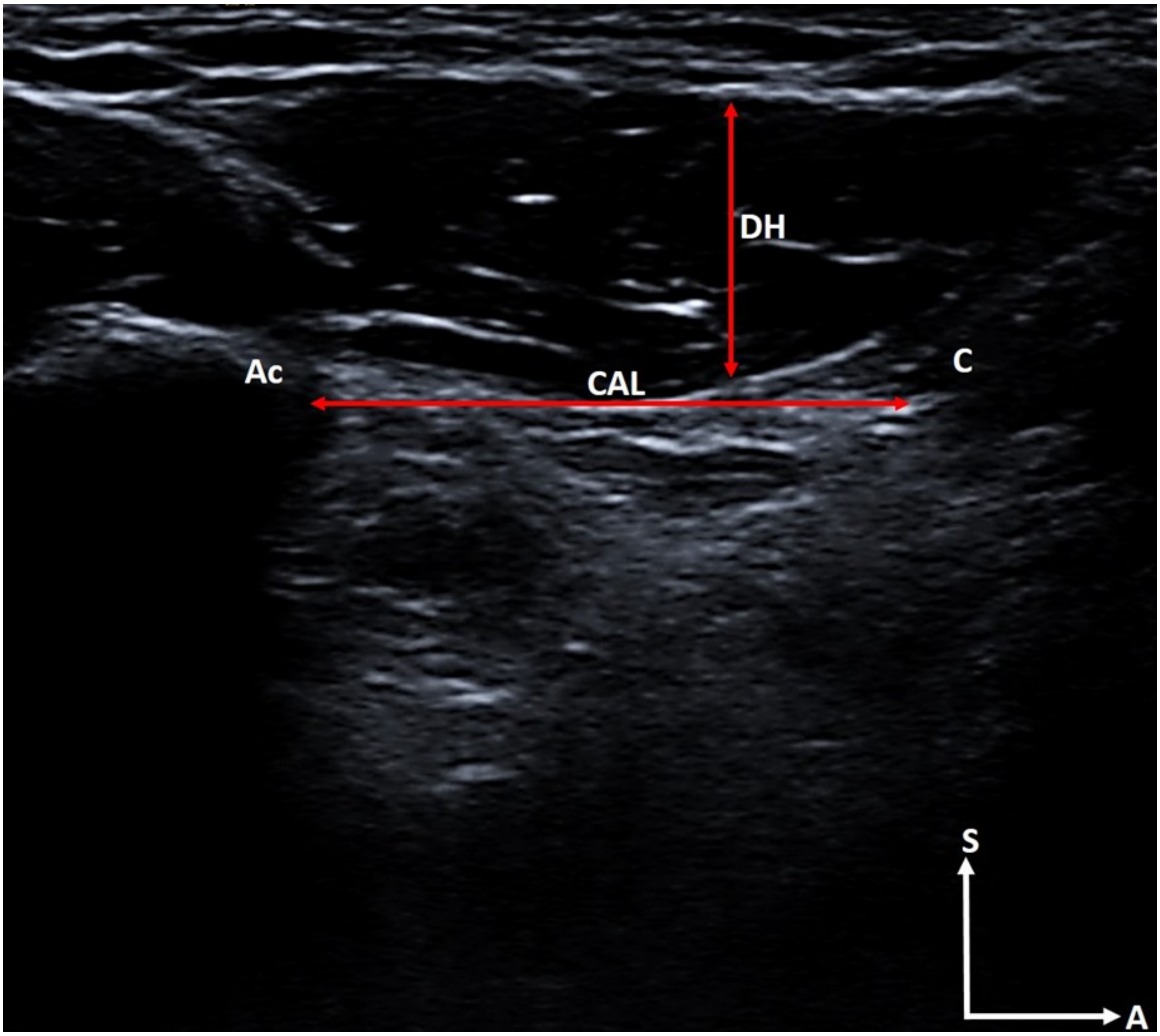

Fig 1. Longitudinal view of the anatomical landmarks in the region of the coraco-acromial ligament in the right shoulder. A - Anterior; Ac - Acromion; C - Coracoid process; CAL - Coraco-acromial ligament; DH - Deltoid muscle height; S - Superior.

MATERIALS AND METHODS

In accordance with the power-analysis, this study comprised of 17 healthy female volunteers (n = 34). While demographic data such as age and ethnicity were not disclosed, inclusion and exclusion criteria were adhered to.

Inclusion criteria: All included female individuals were selected on the basis that they did not undergo previous surgery of the shoulder nor did they exhibit shoulder pathology.

Exclusion criteria: Female individuals who underwent previous surgery within the shoulder region or presented with any evidence of shoulder pathology were excluded.

The protocol for this ultrasonographic study (Medelec Synergy: Acertys T2 EDX, 2012) was determined by a specialised physiatrist.

During bilateral examination, each subject was seated erect with each arm hanging adjacent to the trunk and the forearm supinated and rested on the ipsilateral thigh. The coracoid process and anterior acromial tip were palpated and indicated by skin markers. A water-soluble transmission gel was applied to the contact tip of a linear transducer (9MHz). The transducer was then placed on the skin perpendicular to the tissue interface between the coracoid process and the acromial tip. Once a clear longitudinal image was established, the image was frozen and the CAL was identified.

The height of the deltoid muscle in relation to the CAL was then estimated in three selected fixed regions, *viz*.: Region 1: directly superior to the anterior attachment of CAL at the posterior aspect of coracoid process; Region 2: directly superior to the mid-line of CAL; Region 3: directly superior to the

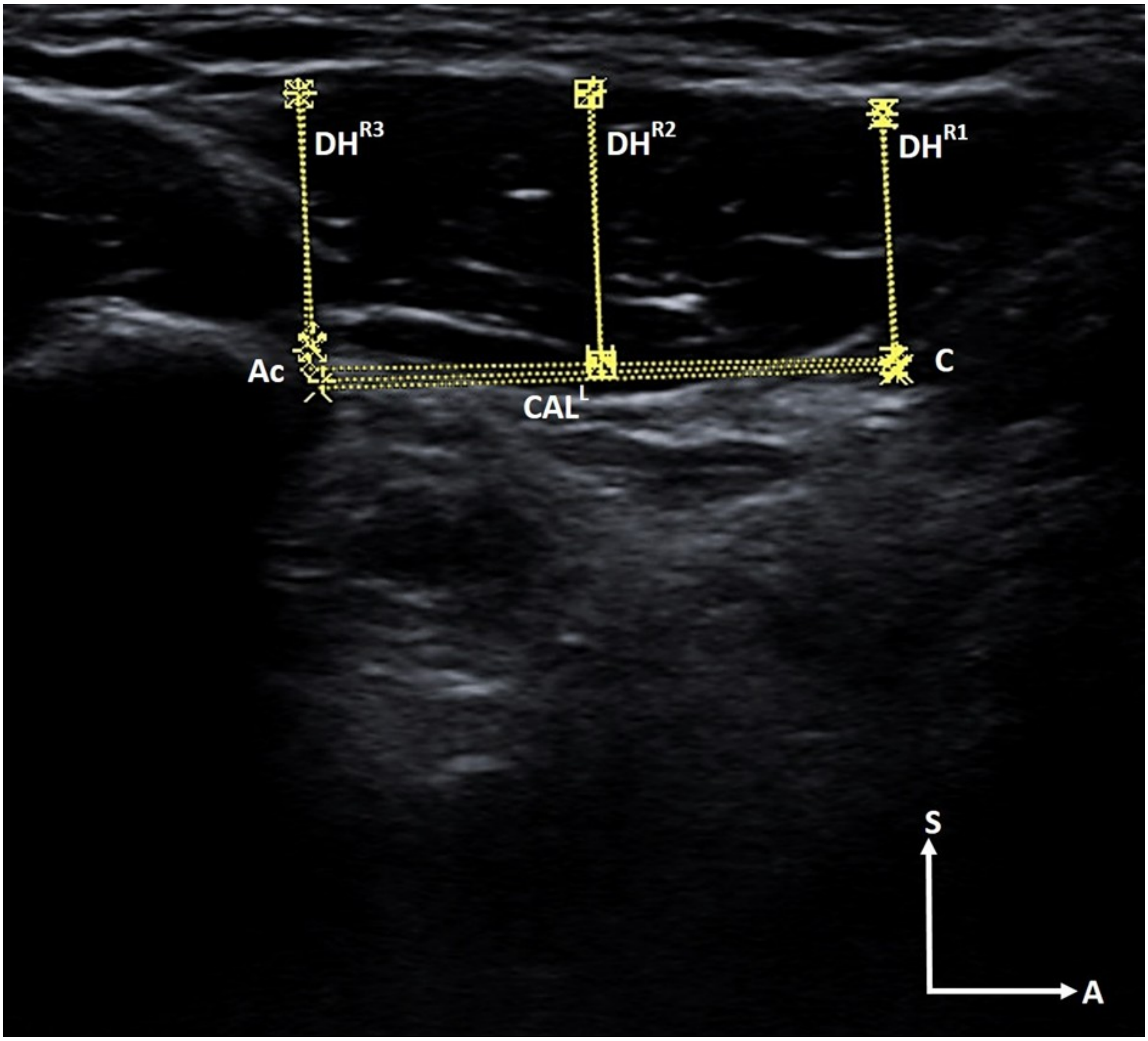

Fig. 2.- Longitudinal view of the deltoid muscle heights and the length of the coraco-acromial ligament in the right shoulder. A - Anterior; Ac - Acromion; C - Coracoid process; CAL^L - Length of the coraco-acromial ligament; DH^{R1} - Deltoid muscle height at region 1; DH^{R2} - Deltoid muscle height at region 2; DH^{R3} - Deltoid muscle height at region 3; S - Superior.

posterior attachment of CAL at the anterior acromion. In addition, the length of the CAL was also measured (Figs. 1-2).

All parameters were measured three times by the same principle investigator in order to reduce intra-observer error. Consent for this study was obtained by the Ghent University Ethics Committee (B279/15; B670201523321). Statistical analysis included the means and standard deviations of all parameters (SPSS, version 21.0). *P* Values reflective of less than 0.05 were considered to be statistically significant.

RESULTS

At the three selected regions of the CAL, the height of the deltoid muscle was found to range from a minimum of 3.2 mm to a maximum of 16.4mm (Table 1). The mean deltoid height at regions 1, 2 and 3 were recorded to be 8.4 ± 2.7 mm, 9.1±2.1 mm and 8.4±3.0 mm, respectively (Table 1). Upon correlation with the deltoid height at the intermediate region 2, the deltoid height at regions 1 (*p* value: 0.000) and 3 (*p* value: 0.009) appeared to be significant at the 0.01 level (Table 2).

The mean length of the CAL was measured to be 24.8 ± 7.6 mm (Range: 15.2-56.6 mm) (Table 1).

DISCUSSION

The osseous scapular processes defining regions 1, 2 and 3, which were represented by the anterior acromion and coracoid process, indicated the area of the coraco-acromial arch that is completed by the CAL and related to the anterior deltoid superiorly.

Classically, the deltoid muscle is divided into three anatomical portions, viz. anterior, middle and posterior, which arise from the anterior acromion and lateral one-third of the clavicle, lateral acromion and the scapular spine, respectively (Williams and Warwick, 1980; Lorne et al., 2001; Leijnse et al., 2008; Audenaert et al., 2009; Sakoma et al., 2011; Meyer et al., 2013; Moser et al., 2013; Rosso et al., 2014; Standring et al., 2016). Recent literature has placed much focus on the fibrous frame of the deltoid, which was initially proposed by Fick (1911) and divides the muscle into seven intramuscular tendons (Fick, 1911; Williams and Warwick, 1980; Lorne et al., 2001; Leijnse et al., 2008; Sakoma et al., 2011; Meyer et al., 2013). According to Lieber and Friden (2001), Huijing (2003) and Finni (2006), it is these intramuscular tendons that are ultimately responsible for the transmission of force to the osseous structures. Although the generic multiple segmented model of Leijnse et al. (2008) is widely accepted and concise, the actual osseous landmarks from which the tendons originate differ (Audenaert and Barbaix, 2008; Meyer et al., 2013; Sakoma et al., 2011). Since the present study was specific to the deltoid muscle height in the region of the CAL, the osseous origins relative to the anterior deltoid aspect were used as the anatomical landmarks of reference.

Although the study conducted by Audenaert et al. (2009) reported the height of the deltoid muscle in relation to the humeral head, no previous study has investigated the specific height of the deltoid muscle in the region of the CAL. Since this aspect of the deltoid represented the anterior deltoid portion, the present study measured the height of the deltoid muscle at three selected regions in accordance with palpable anatomical landmarks. The mean deltoid height appeared to be almost identical at the anterior region 1 and posterior region 3. While the mean deltoid height at the intermediate region 2 was marginally greater than that of regions 1 and 3, it may be postulated that the deltoid height at region 2 is closely associated to that of regions 1 and 3 and thus remains constant across

Table 1. Mean length of the coraco-acromial ligament and the deltoid muscle height.

Parameter		Mean (mm)	Minimum (mm)	Maximum (mm)
	Region 1	8.4±2.7	3.7	14.5
Height of deltoid muscle in region of CAL	Region 2	9.1±2.1	4.5	13.2
	Region 3	8.4±3.0	3.2	16.4
Length of CAL		24.8±7.6	15.2	56.6

Table 2. Comparison of the deltoid height between the three regions related to the coraco-acromial ligament.

Deltoid Height (*P* values)	Region 1	Region 2	Region 3
Region 1	-	0.000*	0.960
Region 2	0.000*	-	0.009*
Region 3	0.960	0.009*	-

the area related to the CAL.

Despite numerous studies of its variable anatomical configuration, the CAL maintains an intimate relationship with the deltoid muscle (Harris and Blackney, 1993; Rockwood and Lyons, 1993; Edelson and Luchs, 1995; Hunt et al., 2000; Fealy et al., 2005) (Table 3). Effectively, the CAL, analogous to the patellar ligament in function, connects two independent osseous landmarks, *viz*., acromion and coracoid process, thus bridging the gap and providing a suspensory function to the overlying deltoid muscle which incidentally stabilizes the glenohumeral joint (Hunt et al., 2000; Lee et al., 2001; Moorman et al., 2012). As a result, it acts as a static stabilizer to prevent superior displacement of the humeral head (Hunt et al., 2000; Lee et al., 2001; Moorman et al., 2012).

The mean length of the CAL in this study was seen to be shorter than that recorded in previous studies (Fealy et al., 2005; Wang et al., 2009; Wu et al., 2010) (Table 3). Accordingly, the sample comprised only of female subjects due to the absence of the participation of male volunteers in this study. Therefore, the difference in the mean length may be due to the gender diversion evident in the bone-muscle relationship (Lang, 2011). Despite this distinction in the mean length of the CAL, the minimum values documented in the present study were similar to that of Fealy et al. (2005).

Interestingly, the CAL manifests ancestral development as it is an anatomical feature present only in hominoids (Ciochon and Corrunccini, 1977; Viosin et al., 2014). In view of the brachiation adapted behaviour of feeding and locomotion, the presence of the CAL in hominoids is considered to be an example of neo-articulation (Ciochon and Corrunccini, 1977; Edelson and Taitz, 1992; Viosin et al., 2014).

This study employed the use of ultrasonography, which has been identified to provide accuracy in biomechanical models and allows for the easy identification of muscle (Juul-Kristensen et al., 2000). Given that a high incidence of variation exists between cadaveric data and that obtained in-vivo due to the effects of aging and dehydration, the current study comprised of live patients (Audenaert et al., 2009). In addition, it was conducted to complement the introduction of the delto-fulcral triangle model by Naidoo et al. (2017). The delto-fulcral triangle presents as a window to the orthopaedician for the evaluation of pathology in and around the subacromial region (Naidoo et al., 2017). While the superior aspect of the anterior acromial region presents as the origin site for the anterior deltoid segment, the delto-fulcral triangle model (static stabilizer), which was designed to depict the deltoid muscle trajectory and the deltoid moment arm, incorporates the osseous lateral acromial point (static stabilizer) as opposed to the anterior acromial point (Naidoo et al., 2017). Subsequently, in the present study there was no difference in the deltoid muscle height (dynamic stabilizer) across the region of the coraco-acromial ligament (i.e. anterior deltoid segment), thus suggesting that the exclusion of the anterior acromial point would have negligible effects on the design of the new delto-fulcral triangle model.

Geometrically, the deltoid muscle appears triangular and has three distinct portions arising from the antero-superior lateral one-third of the clavicle, the supero-lateral acromion and the inferior border of the scapular spine to insert infero-laterally at the radial tuberosity of the humerus (Williams and Warwick, 1980; Lorne et al., 2001; Leijnse et al., 2008; Audenaert et al., 2009; Sakoma et al., 2011; Meyer et al., 2013; Moser et al., 2013; Rosso et al., 2014; Standring et al., 2016).

Upon consultation with the biostatistician, it was deduced that moderate to small effects, based upon a 95% confidence level, may be detected between the range of n = 34 and n = 56. Since this was a prospective voluntary study, only 17 female volunteers (n = 34) responded to the call for participation in the study. Therefore, this may present as a limitation to the study as there were no voluntary male participants. Given that the present study was conducted as a complementary component to the introduction of the delto-fulcral triangle model (Naidoo et al., 2017), demographic data (*viz*. age, ethnicity) was not recorded as the authors did not wish to investigate these parameters. While the exclusion of such data is not an accurate representation of the population, it is recommended that future studies include the relevant patient demographics, as well as comparisons between sexes and the normal and pathological groups. Furthermore, additional studies may be required to prove the reliability of the data recorded as the intra-observer correlation index was not obtained in the present study.

Table 3. Length of the coraco-acromial ligament as reported in the literature.

Author (Year)	Mean (mm)	Minimum (mm)	Maximum (mm)
Fealy et al. (2005)	31.0±4.7	17.3	41.0
Wang et al. (2009)	31.2±3.0	24.8	37.8
Wu et al. (2010)	31.5±2.4	-	-
Present Study	24.8±7.6	15.2	56.6

CONCLUSION

The present study investigated the specific height of the deltoid muscle in the region of the CAL, a parameter which was not previously documented. Although, statistically significant values were found in certain regions, this did not affect the overall height significantly.

REFERENCES

AUDENAERT E, BARBAIX E (2008) Separate segments within the deltoid muscle: Anatomical variants or wishful thinking? *Int J Shoulder Surg*, 2(3): 69-70.

AUDENAERT EA, DE ROO PJ, MAHIEU P, COOLS A, BAELDE N, D'HERDE K, VERDONK R (2009) Deltoid muscle volume estimated from ultrasonography: in vitro validation and correlation with isokinetic abduction strength of the shoulder. *Medical & biological engineering & computing*, 47(5): 557-563.

CIOCHON RL, CORRUCCINI RS (1977) The coracoacromial ligament and projection index in man and other anthropoid primates. *J Anat*, 124(3): 627-632.

EDELSON JG, TAITZ C (1992) Anatomy of the coracoacromial arch: Relation to degeneration of the acromion. *J Bone Joint Surg*, 74B(4): 589-594.

EDELSON JG, LUCHS J (1995) Aspects of the CAL anatomy of interest to the arthroscopic surgeon. *Arthroscopy*, 11: 715-719.

FEALY S, APRIL EW, KHAZZAM M (2005) The coracoacromial ligament: Morphology and study of acromial enthesopathy. *J Shoulder Elbow Surg*, 14: 542-548.

FICK R (1911) Handbuch der Anatomie und Mekanik der Gelenke. Gustav Fischer, Jena.

FINNI T (2006) Structural and functional features of human muscle-tendon unit. *Scand J Med Sci Sports*, 16: 147-158.

HARRIS JE, BLACKNEY MC (1993) The anatomy and function of the coracoacromial ligament. *J Shoulder Elbow Surg*, 2S: 6-9.

HOLZBAUR KR, MURRAY WM, GOLD GE, DELP SL (2007) Upper limb muscle volumes in adult subjects. *J Biomech,* 40(4): 742-749.

HUIJING PA (2003) Muscular force transmission necessitates a multilevel integrative approach to the analysis of function of skeletal muscle. *Exercise Sport Sci Rev*, 31: 167-175.

HUNT JL, MOORE RJ, KRISHNAN J (2000) The fate of the coracoacromial ligament in arthroscopic acromioplasty: An anatomical study. *J Shoulder Elbow Surg*, 9: 491-494.

JUUL-KRISTENSEN B, BOJSEN-MØLLER F, HOLST E, EKDAHL C (2000) Comparison of muscle sizes and moment arms of two rotator cuff muscles measured by ultrasonography and magnetic resonance imaging. *Eur J Ultrasound,* 11(3): 161-173.

LANG TF (2011) The bone-muscle relationship in men and women. *J Osteoporos*, 2011: 702735. doi: 10.4061/2011/702735.

LEE TQ, BLACK AD, TIBONE JE, MCMAHON PJ (2001) Release of the coracoacromial ligament can lead to glenohumeral laxity: A biomechanical study. *J Shoulder Elbow Surg*, 10: 68-72.

LEIJNSE JN, HAN SH, KWON YH (2008) Morphology of deltoid origin and end tendons – a generic model. *J Anat*, 213: 733-742.

LIEBER RL, FRIDEN J (2001) Clinical significance of skeletal muscle architecture. *Clin Orthop Rel Res,* 383: 140-151.

LORNE E, GAGEY O, QUILLARD J, HUE E, GAGEY N (2001) The fibrous frame of the deltoid muscle: Its functional and surgical relevance. *Clin Orthop Rel Res*, 386: 222-225.

MEYER DC, RAHM S, FARSHAD M, LAJTAI G, WIESER K (2013) Deltoid muscle shape analysis with magnetic resonance imaging in patients with chronic rotator cuff tears. *BMC Musculoskeletal Disorders*, 14 (247): 1-7.

MOORMAN CT, WARREN RF, DENG HX, WICKIEWICZ TL, TORZILLI PA (2012) Role of coracoacromial ligament and related structures in glenohumeral stability: a cadaveric study. *J Surg Orthop Adv*, 21(4): 210-217.

MOSER T, LECOURS J, MICHAUD J, BUREAU NJ, GUILLIN R, CARDINAL E (2013) The deltoid, a forgotten muscle of the shoulder. *Skeletal Radiol*, 42: 1361-1375.

NEER CS (1972) Anterior acromioplasty for the chronic impingement syndrome in the shoulder: A preliminary report. *J Bone Joint Surg Amer*, 54(1): 41-50.

NAIDOO N, LAZARUS L, DE MUYNCK M, SATYAPAL KS, VAN TONGEL A, DE WILDE L (2017) The morphometric anatomy of the delto-fulcral triangle: A 3D CT-based reconstruction study. *J Orthop*, 14: 62-67.

ROCKWOOD CA, LYONS FR (1993) Shoulder impingement syndrome: diagnosis, radiographic evaluation, and treatment with a modified Neer acromioplasty. *J Bone Joint Surg*, 75A: 409-424.

ROSSO C, MUELLER AM, MCKENZIE B, ENTEZARI V, CEREATTI A, CROCE UD, RAMAPPA AJ, NAZARIAN A, DEANGELIS JP (2014) Bulk effect of the deltoid muscle on the glenohumeral joint. *J Exp Orthop*, 1(14): 1-9.

SAKOMA Y, SANO H, SHINOZAKI N, ITOIGAWA Y, YAMAMOTO N, OZAKI T, ITOI E (2010) Anatomical and functional segments of the deltoid muscle. *J Anat*, 218: 185-190.

STANDRING S (2016) *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. Elsevier Ltd, Spain.

VIOSIN J-L, RPARS M, THOMAZEAU H (2014) The human acromion viewed from an evolutionary perspective. *Orthop Traumatol: Surgery and Research,* 100S: S355-S360.

WANG YC, WANG HK, CHEN WS, WANG TG (2009) Dynamic visualization of the coracoacromial ligament by ultrasound. *Ultrasound in Medicine & Biology,* 35 (8): 1242-1248.

WILLIAMS P, WARWICK L (1980) *Gray's Anatomy*. Churchill Livingstone, Edinburgh.

WU CH, WANG YC, WANG HK, CHEN WS, WANG TG (2010) Evaluating displacement of the coracoacromial ligament in painful shoulders of overhead athletes through dynamic ultrasonographic examination. *Arch Physic Med Rehab*, 91(2): 278-282.