

Critical shoulder angle is intrinsically associated with the development of degenerative shoulder diseases: A systematic review

Dimitrios Stamiris, Stavros Stamiris, Kyriakos Papavasiliou, Michail Potoupnis, Eleftherios Tsiridis, Ioannis Sarris

Academic Orthopedic Department, Aristotle University of Thessaloniki Medical School, Thessaloniki; CORE - Center of Orthopedic Research, Center for Interdisciplinary Research and Innovation, Thessaloniki, Greece

Abstract

Aim of this study was to investigate the potential influence of Critical Shoulder Angle (CSA) as a predisposing factor for the development of degenerative full-thickness rotator cuff tears (DRCT) or primary glenohumeral osteoarthritis (PGOA). A systematic review of the Pubmed, Scopus, Mendeley, ScienceDirect and the Cochrane Central Register of Controlled Trials online databases was performed for literature regarding CSA and its association with DRCT and PGOA. In order to evaluate solely the relationship between CSA as a predisposing factor for the development of the aforementioned degenerative shoulder diseases (DSDs), we precluded any study in which traumatic cases were not clearly excluded. Our search strategy identified 289 studies in total, nine of which were eligible for inclusion based on our pre-established criteria. Quality assessment contacted using the Newcastle Ottawa Scale for case-control studies. There were a total of 998 patients with DRCT and 285 patients with PGOA. The control groups consisted of a total of 538 patients. The mean CSA ranged from 33.9° to 41.01° for the DRCT group, from 27.3° to 29.8° for the PGOA group and from 30.2° to 37.28° for the control group. All studies reported statistically significant differences between the DRCT and PGOA groups and the respective control groups.

Our study results showed that there is moderate evidence in the literature supporting an intrinsic role of CSA in the development of DSDs. Level of evidence: IV. Systematic review of diagnostic studies, Level II-IV.

Introduction

The etiopathogenesis of rotator cuff tears (RCT) and shoulder osteoarthritis (OA) is complex and multifactorial. Apart from age, sex and trauma, other predisposing factors such as humeral head avascular necrosis, inflammatory arthritis and smoking have also been associated with the development of the aforementioned shoulder disorders.^{1,2} Conversely, the atraumatic degenerative rotator cuff tears (DRCT) and the primary glenohumeral osteoarthritis (PGOA) are less well studied and understood conditions. Both genetic and acquired predisposing factors have been associated with these degenerative shoulder diseases (DSDs), including increased body mass index, diabetes, hypo-high-density lipoproteinemia and kyphosis.^{3,4}

Moreover, individual scapular anatomic variations have been directly linked with the development of shoulder degenerative conditions.⁵ These variations concern either the acromion or the glenoid and can be assessed with the implementation of several radiologic markers. Acromial side variations include acromial type,⁶ acromial slope⁷ and acromial index,⁸ while glenoid side variations include glenoid inclination and version.^{9,10} Moor *et al.*¹¹ introduced the critical shoulder angle (CSA), a radiologic parameter which combines glenoid inclination and lateral extension of the acromion. CSA is defined as the angle which is formed by a line drawn from the inferior to the superior border of the glenoid fossa and another line connecting the inferior border of the glenoid with the most infero-lateral point of the acromion (Figure 1). The authors reported in the same study, an increased incidence of DRCT in subjects with higher CSA values and higher incidence of PGOA in subjects with lower CSA values. Gerber *et al.*¹² tested the aforementioned hypothesis on a shoulder simulator and reported that higher CSA stimulates increased shear forces, thus leading to supraspinatus tendon overload, in order to preserve joint stability. Using the same simulator, Viehofer *et al.*¹³ reported increased joint reaction forces with lower CSA values, suggesting that lower CSA leads to joint overload and eventually development of osteoarthritis (OA).

Since the publication of these pivotal studies, considerable research has been made regarding the CSA and its relationship with the development of degenerative shoulder conditions, with conflicting results.^{11,14-16} Even though most of the published studies acknowledge the association between CSA values and the prevalence of

Correspondence: Dimitrios Stamiris, Papageorgiou General Hospital, Ring Road West 56403 Nea Efkarpia, Thessaloniki, Greece.
Tel.: +306998347012 - Fax: +302310614795
E-mail: dimitris.stamiris@hotmail.com

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DSDs, there are studies decline this relationship or attribute it to the presence of heel type acromial osteophytes or individual differences in acromial roof morphology.^{14,15,17,18} Furthermore, an increasing number of systematic reviews and meta-analyses evaluating the predictive value of the CSA, have been published recently. To the best of our knowledge, none of these studies precludes patients with history of a previous trauma, thus providing a less sophisticated view of the association between CSA and the prevalence of DSDs.

Aim of this systematic review was to investigate the available published literature and critically evaluate the potential influence of Critical Shoulder Angle (CSA) as a predisposing factor for the later development of degenerative full-thickness rotator cuff tears (DRCT) or primary glenohumeral osteoarthritis (PGOA).

Materials and Methods

This systematic review was conducted following the guidelines of the Preferred Reporting Items for a Systematic Review and Meta-analysis (PRISMA) statement,¹⁹ and did not necessitate institutional committee approval for the use of publicly available data.

A comprehensive search of PubMed, Scopus, Mendeley, ScienceDirect and the Cochrane Central Register of Controlled Trials online databases was performed on 20 July 2019, for literature regarding the association between CSA and the development of DRCT or PGOA. For the PubMed online database, we used the following search string: (“Rotator Cuff Injuries”[Mesh]) OR “Osteoarthritis” [Mesh] AND (“Critical Shoulder Angle” OR “CSA”). Beside English language, no other filters were applied.

The aforementioned literature research was independently performed by two authors (D.S. and S.S.). After removing all duplicates, the titles and abstracts were then screened for coherence. Consequently, we reviewed the full texts of the remaining articles for eligibility. Reference lists of all included studies were also screened for additional studies that may have been relevant but were not detectable by our initial search design. Any inconsistencies were resolved after discussion between the two authors. A flowchart of our search strategy is demonstrated in Figure 2.

We included case-control studies investigating the association of the CSA with the development of DRCT or PGOA. The included studies should implement radiographs in order to measure CSA in both case and control groups using the method described by Moor *et al.*¹¹ The primary outcome measure was the incidence of DRCT or PGOA with regard to CSA values.

Our aim was to investigate the potential association between solely CSA as a predisposing factor for the development of DSDs. Beside age, trauma is the most significant risk factor of rotator cuff tears (RCT) or “secondary” shoulder osteoarthritis (OA).^{1,20} To be able to accurately examine

the relationship between CSA and the development of DSDs and in order to reduce possible bias generated by post-traumatic cases of either RCT or OA, we precluded any study in which post-traumatic cases were not clearly excluded. We also excluded a specific type of shoulder arthritis, called rotator cuff tear arthropathy (CTA). Although RCT is the leading cause of CTA, this condition is often associated with superior humeral head migration and increased incidence of superior glenoid erosion, which could lead to a “secondary” increase of CSA,²¹ thus compromising interpretation of the results. Other exclusion criteria were studies using other methods than x-rays for CSA measurement, studies investigating CSA in patients with partial rotator cuff tears, anatomic and biomechanical studies. A complete summary of our eligibility criteria is presented in Table 1.

Quality assessment of the included studies was performed independently by the same two authors, using the Newcastle-Ottawa Scale (NOS) for case control-studies. NOS is a tool designed to evaluate the quality of nonrandomized studies. For that purpose, it uses a star awarding system. Each study can receive a maximum of 4 stars in the selection category, 2 stars in the

comparability category, and 3 stars in the exposure category. A higher number of stars per category corresponds to a higher quality study design and execution.



Figure 1. Critical shoulder angle (CSA) measurement, as proposed by Moor *et al.*, is determined as the angle formed by the line connecting the superior to the inferior most aspect of the glenoid (-) and a second line extending from the inferior glenoid to the most inferolateral aspect of the acromion (B-C).

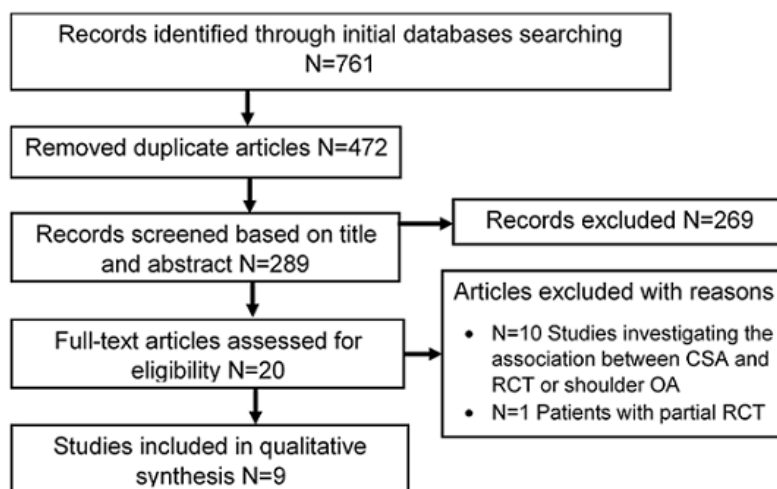


Figure 2. PRISMA flow diagram depicting the application of the study algorithm and screening process at each stage based upon eligibility criteria.

Table 1. Eligibility criteria.

Inclusion criteria	Exclusion criteria
- Studies investigating the association between CSA and full-thickness degenerative rotator cuff tears	- Studies where CSA was measured using other methods than x-ray
- Studies investigating the association between CSA and primary glenohumeral osteoarthritis	- Patients with traumatic RCT tears or studies not reporting
- CSA measured, using x-rays	- Patients with post-traumatic shoulder OA or studies not reporting
- Studies published in the English language	- Patients with Partial RCT
	- Patients with CTA
	- Anatomic/Biomechanical studies

The following data were extracted from the included studies using a systematic form: (1) Study origin and design, (2) Number of cases and controls, (3) CSA values for cases and controls (mean and Standard Deviation), (4) Cases and controls demographics (age - mean and Standard Deviation), Age-match between case and control groups and (6) Control groups characteristics.

Results

Our search strategy identified 289 potentially relevant studies. Nine of these

studies were eventually eligible for inclusion based on our pre-established criteria. Eight studies were retrospective, while only one was prospective. Five studies evaluated the association between full-thickness DRCT and CSA, and four reported on the association between CSA and either full-thickness DRCT or PGOA. Most of the included studies were of low evidence (level IV), one study was level II²² and one was level III.²³ The high heterogeneity of the included studies, impeded the conduction of a meta-analysis.

The quality assessment, using the NOS scale for case-control studies resulted in two studies being awarded with five stars, three studies awarded with six stars and

four studies awarded with seven stars. Overall, no studies revealed to have serious methodological weaknesses. Most studies^{11,16,23-27} (No=7) achieved an overall score ≥ 6 and therefore are considered of high methodological quality, while few^{22,28} (No=2) achieved an overall score of 5 and are of adequate quality.

Regarding the patient selection domain, one study was considered to have potential risk of bias because there was no independent validation of the pathology in the case subjects,²² three^{23,27,28} because the design was a non-consecutive case-control study and seven^{11,16,22,23,25,27,28} because the control group consisted of subjects that had been hospital patients, instead of community sub-

Table 2. Quality assessment of the included studies using NOS.

Study	Selection	Comparability	Exposure	Total
Chalmers 2017 ²²	**	*	**	5
Rhee 2019 ²⁴	****	*	**	7
Watanabe 2018 ²⁵	***	**	**	7
Gomide 2017 ²⁸	**	*	**	5
Heuberer 2017 ²⁶	****	*	**	7
Spiegel 2016 ²⁷	**	**	**	6
Pandey 2016 ²³	**	**	**	6
Moor 2014 ¹⁶	***	**	**	7
Moor 2013 ¹¹	***	*	**	6

Table 3. Summary of included studies characteristics.

Author	Study design	Country	DRCT* group			PGOA ^o group			Control group			Control group characteristics	Age matched groups
			No of patients	Mean CSA (SD) [#]	Mean age (SD) [#]	No of patients	Mean CSA (SD) [#]	Mean age (SD) [#]	No of patients	Mean CSA (SD) [#]	Mean age (SD) [#]		
Chalmers 2017 ²²	Retrospective	USA	90	33,9(4,2)	NR [§]	-	-	-	50	31,7(4,3)	NR [§]	Adhesive capsulitis	NR [§]
Rhee 2019 ²⁴	Retrospective	Korea	493	34,2(3,7)	61,1(8,6)	73	29,8(5,6)	72,3(9,7)	84	32,1(4,5)	52,4(10,3)	Adhesive capsulitis	No
Watanabe 2018 ²⁵	Retrospective	Japan	54	36,3(3,1)	NR [§]	-	-	-	54	33,7(3,9)	NR [§]	Patients with shoulder pain but normal MRI [#]	NR [§]
Gomide 2017 ²⁸	Retrospective	Brazil	44	39,75(5,34)	59,75	-	-	-	34	33,58(3,36)	59,97	Patients with a non-shoulder orthopedic problem	Yes
Heuberer 2017 ²⁶	Retrospective	Austria	100	36,3(2,7)	NR [§]	100	27,3(3,5)	NR [§]	100	30,2(2,9)	NR [§]	TC [^]	No
Spiegel 2016 ²⁷	Retrospective	USA	10	37,3(2,6)	53,3	10	28,7(2,2)	53,9	10	32,7(2,5)	52,7	Bankart-SLAP [§] -LHBT** tendonitis	Yes
Pandey 2016 ²³	Prospective	India	54	41,01(3,1)	57,8(8,83)	-	-	-	61	37,28(4,89)	53,4(7,88)	Isolated AC arthritis or adhesive capsulitis	Yes
Moor 2014 ¹⁶	Retrospective	Switzerland	51	38,2(3,2)	58,2(8,0)	-	-	-	51	32,9(3,4)	58,1(8,4)	Isolated AC ^{oo} arthritis or adhesive capsulitis	Yes
Moor 2013 ¹¹	Retrospective	Switzerland	102	38,0(2,8)	58,1(8,5)	102	28,1(3,3)	68,7(8,9)	94	33,1(2,1)	65,9(3,2)	Patients with a non-shoulder orthopedic problem	NR [§]

*DRCT = Degenerative rotator cuff tears; ^oPGOA = Primary glenohumeral osteoarthritis; [§]SD = Standard deviation; [§]NR = Not reporting; [^]TC = Tendonitis calcarea; [§]SLAP = Superior labrum anterior to posterior; ^{**}LHBT = Long head of biceps tendon; ^{oo}AC = Acromioclavicular; [#]MRI = Magnetic resonance imaging

jects. Regarding the comparability domain all studies achieved at least one point, as they took under consideration in the study design one or more confounding factors thus achieving a low risk of bias. Specifically, in all studies, subjects with post-traumatic etiology were excluded, while in four studies^{16,23,25,27}, case and control subjects were comparable in terms of age. Lastly, in the exposure domain, all studies achieved a low risk of bias, as they used the same method of ascertainment for both cases and controls. Quality assessment of the included studies is portrayed in Table 2.^{11,16,22-28} Authors in all the included studies used the method described by Moor *et al.*¹¹ to measure CSA. The most frequently used radiographic view for measurement of CSA was the true anteroposterior (AP) shoulder or Grashey view, as initially proposed by Moor *et al.*¹¹ One study²² included only patients with a preoperative radiograph of either type A1 or C1 according to the Suter-Henninger scale.²⁹ In eight studies diagnosis of RCT was confirmed intraoperatively, while in one study²² authors used ultrasonography findings. In all four studies investigating OA, diagnosis was confirmed intraoperatively. For the control groups three studies^{22,24,26} confirmed the absence of either RCT or OA intraoperatively. Four studies used MRI^{16,25,27,28} to investigate the integrity of rotator cuff in the control group, while the remaining two^{11,23} used ultrasonography. Respectively, two studies used radiographs to preclude the presence of shoulder OA.^{11,27}

Three of the included studies were conducted in Europe, two were from USA, three from Asia and one from Brazil. Among the nine included studies, there were a total of 998 patients with a full thickness DRCT and 285 patients with PGOA. Control group characteristics varied between the included studies and consisted of a total of 538 subjects. The mean CSA values ranged from 33,9° to 41,01° for the DRCT group, from 27,3° to 29,8° for the PGOA group and from 30,2° to 37,28° for the control group respectively. Likewise, the mean age varied from 53,3 to 61,1 for the DRCT group, from 53,9 to 72,3 for the PGOA group and from 52,4 to 65,9 for the control group. It is noteworthy that in four out of the nine included studies the case and control groups were age matched. All the included studies reported statistically significant difference between the DRCT group and control group (P-value<0,05), with regard to the CSA values. Likewise, four studies reported statistically significant difference between the PGOA group and control group (P-value<0,05). The study characteristics are summarized in Table 3.^{11,16,22-28}

Discussion

This systematic review investigates the possible etiopathogenic correlation between CSA and the development of DSDs. The main finding of our study was that there is a statistically significant difference for the mean CSA values between the full-thickness DRCT, the PGOA and the respective control groups in all the included studies. Even though most of the included studies were of low evidence, this finding suggests that there is evidence for an interconnection between the CSA and the development of these degenerative shoulder conditions.

Another interesting finding is that although in all studies higher CSA values correlate with DRCT, in two studies^{22,24} the mean CSA for the DRCT group, albeit being significantly higher compared to the control group, it is nonetheless below the 35° threshold, as proposed by Moot *et al.*¹¹ Moreover, in one study,²³ the CSA in the control group is higher than the respective 35° threshold.

The aforementioned observation may be the result of morphologic variability of the shoulder joint among different populations.³⁰ A further explanation for this finding could be provided by the implementation of different radiographic protocols for the evaluation of shoulder pathology in different hospitals. Moor *et al.*¹¹ initially proposed a true AP shoulder radiograph for the measurement of CSA with up to 20° of rotational or flexion/extension error. More recently Suter *et al.*²⁹ reported that views exceeding 5° of anteversion, 8° of retroversion, 15° of flexion, and 26° of extension resulted in >2° deviation of the CSA compared with the true AP view and proposed a new classification system. Bouaicha *et al.*³¹ found significantly deviated values on measurements of shoulder AP radiographs in cases with malrotation exceeding 9° and acknowledged the need for standardized protocols in shoulder imaging.

The cardinal objective of this systematic review was to investigate the relationship between the CSA and DSDs. Since trauma is a well recognized cause for RCT and secondary shoulder OA, we adapted our search strategy accordingly to reduce possible bias generated by post-traumatic cases of either RCT or OA. Our study results suggest the existence of a strong correlation between an increased CSA and the development of DRCT and between a lower CSA and the development of PGOA.

Alongside trauma, age is another well-known risk factor for the development of DSDs. Four of our included studies investigated age matched groups.^{16,23,27,28} In all of

them, CSA was a statistically significant factor for the development of both DRCT and PGOA. The intrinsic etiopathogenic connection of CSA with DRCT is also portrayed by the positive correlation between increased CSA and re-tears following rotator cuff repair.^{5,32}

This may not be the case though, for post-traumatic RCTs. Balke *et al.*³³ compared seventy-two patients with DRCT with a group of sixty-four patients with a traumatic RCT. They reported statistically significant difference in various radiographic parameters including CSA. Furthermore, Moor *et al.*²⁰ found less evident differences regarding age and CSA between traumatic tears and patients with a normal rotator cuff compared to non-traumatic DRCT.

Major strengths of our study were the systematic and comprehensive search of the English literature for studies investigating the association between CSA and DRCT or PGOA, in patients without previous trauma.

Despite our best attempts to perform a well-designed systematic review, this study presents some intrinsic limitations as well. First, even though the studies which were included in this systematic review report on populations from multiple countries, there are still races and ethnicities which are not included. As a result, there may be a selection bias, since there is evidence supporting that CSA normal values may vary between different populations.³⁰

Another limitation is the fact that several technical errors may have occurred during CSA measurement. Even though literature suggests that CSA appears to have a high interobserver and intraobserver reliability,²⁰ there are still studies supporting the occurrence of potentially clinically significant errors during measurement.²² Finally, eight out of the nine included studies use the true AP shoulder view to measure CSA, while there is one study²² using the Suter-Henninger A1 and C1 types, which could lead to comparability bias.

Despite these limitations, the clinical message of this systematic review is the inherent association of CSA with the development of DRCT and PGOA, in patients without previous trauma.

Conclusions

Our systematic review of studies evaluating the association between CSA and the development of DRCT and PGOA showed that there is moderate evidence supporting an intrinsic role of CSA in the development of shoulder DSDs.

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