Clinical Approach to Inconclusive Subscapularis Tear Diagnosis: a Meta-analysis

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ABSTRACT

To identify factors associated with subscapularis (SSC) tears and provide a theoretical basis for clinical diagnosis, we included studies related to subscapularis tears published before February 1, 2023. We screened for six predictors across previous studies for the meta-analysis. The predictors included age, sex, coracoid overlap (CO), coracohumeral distance (CHD), impairment of the long head of the biceps tendon (LHB), and dominant arm. The Newcastle-Ottawa Scale (NOS) was used to evaluate the quality of the studies. The risk ratios (RRs) and the weighted mean differences (WMDs) were used to evaluate the effect size of categorical variables and continuous variables, respectively. The Egger test was used to assess the publication bias of the studies. Ten studies were included from seven countries. A total of 2 126 patients were enrolled, of whom 1 041 had subscapularis tears and 1 085 did not. The study showed that age (WMD, 4.23 [95 % CI, 2.32–6.15]; P < .00001), coracoid overlap (WMD, 1.98 [95 % CI, 1.55–2.41]; P < .00001), coracohumeral distance(WMD, −1.03 [95 % CI, −1.17– −0.88]; P < .00001), and an injury of the long head of the biceps tendon (RR, 4.98 [95 % CI, 3.75–6.61]; P < .00001) were risk factors for subscapularis tears. These risk factors can help clinicians identify subscapularis tears early and select appropriate interventions. The level of evidence is 3.

Introduction

For males or females of all ages, shoulder pain and dysfunction could be a sign of rotator cuff injury. The subscapularis (SSC) muscle is important for the balance, stability and internal rotation of the shoulder joint. Relevant studies have found that 12 %–50 % of patients present with SSC tendon tears during arthroscopy [1, 2].

Magnetic resonance imaging (MRI) is a noninvasive method of examining rotator cuff injuries [3]. Although MRI has a sensitivity of more than 90 % for both supraspinatus and infraspinatus tears, the use of MRI as a tool for SSC tears is challenging [4]. Furukawa R et al. showed that when the MRI field strength was 3.0 T, the sensitivity of diagnosis of SSC tears was 57.9 % and 60.5 % in the axial and oblique sagittal positions, respectively [3]. If the field strength was 1.5 T, the sensitivity of diagnosis of SSC tears was 45.3 % [5]. A systematic review showed that MRI for the diagnosis of SSC tears had an overall sensitivity of 68 % [6]. Howev-

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er, more than half of the studies used magnetic resonance arthrography (MRA) as a diagnostic tool, which increases the sensitivity of diagnosis. In addition, the thickness and size of SSC tears have a direct influence on the diagnostic accuracy of MRI. The smaller a torn area is, the lower the accuracy of the diagnosis [7, 8]. In addition, some researchers used CT as a preoperative diagnostic criterion for rotator cuff tears. They looked for correlations with rotator cuff tears by taking some anatomical measurements on CT [9]. However, due to regional differences, differences in research designs and research indicators, differences in patients' races, and differences in economic conditions, the indicator has different research effects in different studies [9].

Although the repair of SSC tears with arthroscopy has achieved good clinical results, the sensitivity of diagnosis of SSC tears with MRI is not ideal at present [10]. If an SSC tear is missed, it may cause long-term shoulder pain or dysfunction with muscle atrophy, fat infiltration, and extended tear areas [11]. During arthroscopic rotator cuff repair, it was observed that SSC tears were missed in 43.1 % of patients, and the fatty infiltration of SSC tendons, which was initially overlooked, showed further expansion during revision [12]. SSC tendon injury is easily missed, has a low sensitivity of diagnosis, has a high degree of involvement in important functions, and has great clinical significance. Therefore, it is necessary to improve methods for the early diagnosis of SSC tears. In-depth studies of SSC tendon injury found that the morphological changes of the coracoid process in subcoracoid impingement may result in the pathological injury of SSC tendons [13]. Researchers believe that some imaging signs may be related to SSC tears [14–16]. These findings suggest that the sensitivity and accuracy of the diagnosis of SSC tears may be improved by measuring a number of imaging indicators related to SSC tears.

Relevant studies have shown that age, sex, coracoid overlap (CO), coracohumeral distance (CHD), long head of the biceps tendon (LHB) injury, and the dominant arm may be related to SSC tears [6, 9, 15, 17–20]. The purpose of our study was to summarize previously demonstrated correlations between the above indicators and SSC tears through meta-analysis and to identify the most valuable predictive indicators for SSC tears to help clinicians make early diagnoses and formulate early treatment plans for SSC injuries. To our knowledge, this is the first meta-analysis evaluating risk factors for SSC tears.

Materials and Methods

Search strategy

The MOOSE (Meta-analysis Of Observational Studies in Epidemiology) guidelines were used to guide the meta-analysis [21]. First, PROSPERO (International prospective register of systematic reviews) searches revealed that there was no systematic review or meta-analysis related to risk factors for SSC tears before our research was performed. Second, PROSPERO was used to register the protocol of the meta-analysis online, as recommended by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, and the registration number is CRD42022332681. EMBASE, PubMed, the Cochrane Library and Web of Science were searched from inception up to February 1, 2023. The keywords used were "rotator cuff injury", "rotator cuff tears", "rotator cuff tendinosis", "rotator cuff tendinitis", "subscapularis tears", and "risk factors". The search strategy is shown in ▶ **Table 1**.

Criteria for inclusion and exclusion

The inclusion criteria were as follows: (1) patients in the experimental group had SSC tears, and those in the control group did not have SSC tears; (2) the experimental group and control group were identified with arthroscopy; (3) studies were case-control, cohort, or cross-sectional studies; (4) there was at least one evaluation indicator in the included studies; and (5) there was no language restriction.

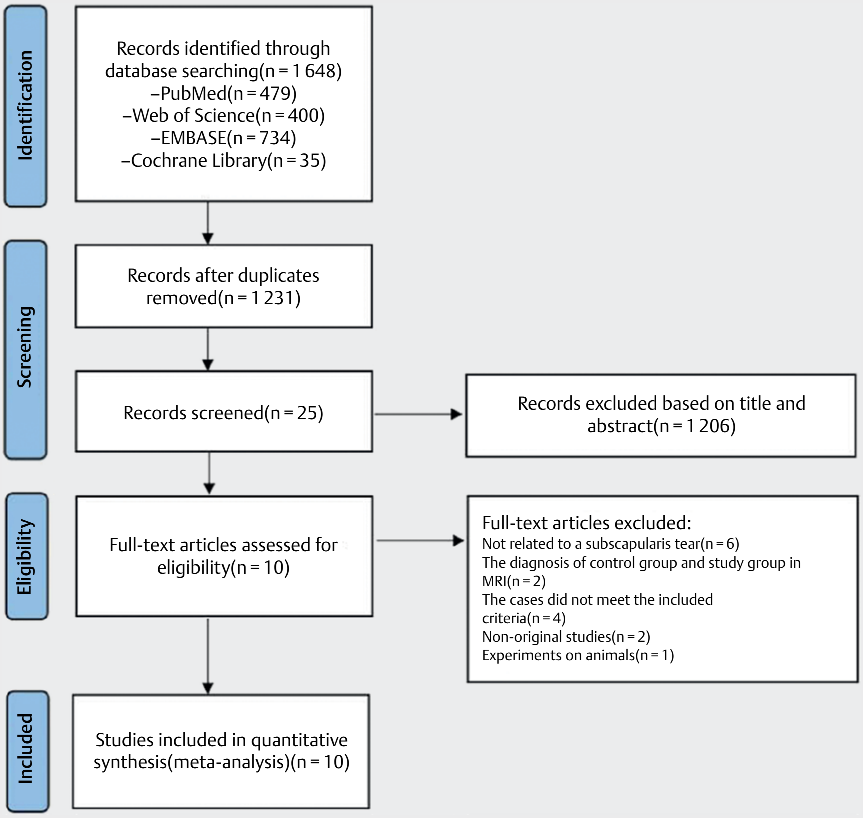
Studies with incomplete data, duplicate studies, and studies with patients who had undergone previous shoulder operations were excluded. Studies that were unpublished or in progress were excluded.

Study screening and data extraction

Two researchers independently checked the studies and extracted the data. The third participant resolved any discrepancies through discussion or negotiation. After duplicates were removed, the abstracts and full texts were read to determine which studies could be included. The extracted information included the basic characteristics of the studies, such as the first author, country, study design,

▶ **Table 1** Search strategy.

PubMed: 479 results (up to 1 January 2023)
(("rotator cuff injury"[Title/Abstract] OR "subscapularis tears"[Title/Abstract] OR "rotator cuff tears"[Title/Abstract] OR "rotator cuff tear"[Title/Abstract] OR "rotator cuff tendinosis"[Title/Abstract] OR "rotator cuff tendinitis"[Title/Abstract] OR "Rotator Cuff Injuries"[MeSH Terms]) AND ("Risk Factors"[MeSH Terms] OR ("Risk Factors"[Title/Abstract] OR "risk factor"[Title/Abstract])))
Embase: 734 results (up to 1 January 2023)
#1 'risk factor'/exp
#2 'risk factor':ab,ti
#3 #1 OR #2
#4 'rotator cuff injury'/exp
#5 ('rotator cuff injury':ab,ti OR 'rotator cuff tears':ab,ti OR 'rotator cuff tear':ab,ti OR 'rotator cuff tendinosis':ab,ti OR 'rotator cuff tendinitis':ab,ti OR 'subscapularis tears':ab,ti)
#6 #4 OR #5
#7 #3 AND #6
Cochrane library: 35 results (up to 1 January 2023)
#1 MeSH descriptor: [Rotator Cuff Injuries] explode all trees
#2 (Rotator Cuff Injury):ti,ab,kw OR (subscapularis Tears):ti,ab,kw OR (Rotator Cuff Tears):ti,ab,kw OR (Rotator Cuff Tear):ti,ab,kw OR (Rotator Cuff Tendinosis):ti,ab,kw
#3 #1 OR #2
#4 MeSH descriptor: [Risk Factors] explode all trees
#5 (risk factor):ti,ab,kw OR (risk factors):ti,ab,kw
#6 #4 OR #5
#7 #3 AND #6
Web of science: 400 results (up to 1 January 2023)
#1 AB = (Rotator Cuff Injury OR Rotator Cuff Tears OR Rotator Cuff Tear OR Rotator Cuff Tendinosis OR Rotator Cuff Tendinitis OR subscapularis tears)
#2 AB = (risk factors OR risk factor)
#3 #2 AND #1



▶ **Fig. 1** Flow diagram showing the study screening process.

publication dates, sex of the patients, level of evidence, method of diagnosis, preoperative evaluation method, and blinding procedures. In addition to the above, for some studies, if there was some unmentioned but important information that we needed, we contacted the corresponding author of the original study by email.

After the initial screening, a total of 1 648 records were identified. After title, abstract and full text filtering, 417 duplicates were deleted, and 1 206 records that did not meet the criteria were excluded. Finally, there were ten eligible studies that were included in the qualitative and quantitative analysis. ▶ **Fig. 1** provides a PRISMA flowchart for the screening of studies conducted through this meta-analysis.

Assessment of study quality

Our meta-analysis included cohort studies, cross-sectional studies, and case–control studies. The Newcastle–Ottawa Scale (NOS) quality scoring system was used to assess the risk of bias in case-control studies and cohort studies [22]. The scale was evaluated in three aspects: study population selection, comparability between groups, and measurement of exposure factors. The maximal possible score is 9: 0–3 is low quality, 4–6 is medium quality, and 7–9 is high quality. Two researchers met to complete the work.

Statistical analysis

RevMan 5.3 software (Cochrane, London, UK) and Stata 15.1 software (StataCorp College Station, Texas, USA) were used for our meta-analysis. The risk ratios (RRs) and the weighted mean differences (WMDs) were used to evaluate the effect size of categorical variables and continuous variables, respectively. The 95 % confidence interval (95 % CI) was calculated for each effect size. Heterogeneity tests were used to assess heterogeneity among the included studies. If there was no heterogeneity ($I^2 < = 50\%$), the overall effect size was evaluated by a fixed effects model. If there was heterogeneity ($I^2 > 50\%$), the overall effect size was evaluated by a random effects model. The Egger test was performed with Stata 15.1 software to assess publication bias. $P < 0.05$ was considered to be statistically significant.

Results

Characteristics of included articles

Ten studies from seven countries were included [6, 9, 15, 17–20, 23–25]. A total of 2 126 patients and six predictors were included. A total of seven articles had a level of evidence of "3", one article had a level of evidence of "1", one article had a level of evidence of "2", and two articles had a level of evidence of "4". Among the 10 references, all arthroscopy was used for the diagnosis in all articles. MRI was used as the evaluation standard in eight studies, while computed tomography (CT) was used as the evaluation standard in two studies. Six studies were single-blinded, and four studies were not blinded. The basic characteristics of the included studies are shown in ▶ **Table 2**.

▶ **Table 2** The Characteristics of Included Studies.

Studies(first author)	Year	Country	Experimental group(n)	Control group(n)	Sex (E: F/M) (C: F/M)	Age (y) (E/C)	Study design	Level of evidence	Diagnosis	Method of evaluation	Blind
Adam C. Watson	2017	Australia	53	23	–	–	case-control design	III	arthroscopy	MRI	no-blinded
Eduardo A. Malavolta	2016	Brazil	50	43	30/20	58.54 ± 6.929/	case-control design	III	arthroscopy	MRI	single-blinded
					29/14	53.49 ± 8.143					
Joong-Bae Seo	2019	Korea	114	57	39/75	60.3 ± 10.7/	case-control design	III	arthroscopy	MRI	single-blinded
					16/41	51.3 ± 9.8					
Jun Kawamata	2022	Japan	53	77	25/28	68.4 ± 10/	case-control design	III	arthroscopy	CT	single-blinded
					28/49	61.5 ± 11.8					
Mehmet Çetinkaya	2016	Turkey	141	78	93/48	57.85 ± 10.44/	case-control design	III	arthroscopy	MRI	no-blinded
					56/22	55.46 ± 11.73					
Mehmet Çetinkaya	2018	Turkey	28	28	22/6	48.71 ± 9.66/	case-control design	III	arthroscopy	MRI	no-blinded
					21/7	64.85 ± 6.1					
Siddhant K. Mehta	2020	USA	49	305	20/29	63.6 ± 9.6/	cohort design	I	arthroscopy	MRI	no-blinded
					131/174	62 ± 9.1					
Sizheng Zhu	2021	China	72	141	38/34	64.1 ± 8.7/	case-control design	II	arthroscopy	CT	single-blinded
					73/68	63.3 ± 9.5					
Sung-Hyun Yoon	2020	Korea	297	57	97/200	57.8 ± 8.4/	case-control design	IV	arthroscopy	MRI	single-blinded
					16/41	51.3 ± 9.8					
Wennan Xu	2022	China	184	276	126/58	62.55 ± 9.03/	case-control design	III	arthroscopy	MRI	single-blinded
					184/92	59.76 ± 9.42					

Experimental group: subscapularis tears; Control group: non-subscapularis tears; E: experimental group; C: control group; F: female; M: male.

▶ **Table 3** The Newcastle-Ottawa Scale(NOS)for risk of bias assessment of cohort studies and case-control studies included in the meta-analysis.

Study	Selection				Comparability	Outcome			Quality score
	1	2	3	4		5	6	7	
Adam C. Watson	★	★	★	★	★	★	★	★	8
Eduardo A. Malavolta	★	★	★	★	★	★	★	★	8
Joong-Bae Seo	★	★	☆	★	★	★	★	★	7
Jun Kawamata	★	★	★	★	★	★	★	★	8
Mehmet Çetinkaya2016	★	★	★	★	★	★	★	★	8
Mehmet Çetinkaya2018	★	★	☆	★	★	★	★	★	7
Siddhant K. Mehta	★	★	★	☆	★★	★	★	★	8
Sizheng Zhu	★	★	★	★	★	★	★	★	8
Sung-Hyun Yoon	★	★	☆	★	★	★	★	★	7
Wennan Xu	★	★	★	★	★	★	★	★	8

★ = score of 1; ★★ = score of 2; ☆ = score of 0. Key to items: 1 = representativeness of exposed cohort; 2 = selection of nonexposed; 3 = ascertainment of exposure; 4 = outcome not present at start; 5 = assessment of outcome; 6 = adequate follow-up length; 7 = adequacy of follow-up.

▶ **Table 4** Assessment of publication bias.

Analyzed factor	Number of studies	Egger test	
		T	p value
Age in years	9	−0.92	0.389
CHD	7	−1.14	0.305
CO	3	−0.51	0.701
Female sex	9	1.19	0.273
Male sex	9	0.83	0.433
Dominant arm	4	1.19	0.355
LHB injury	3	−0.25	0.842

CHD: coracohumeral distance; CO: coracoid overlap; LHB: long head of the biceps tendon.

Qualitative assessment

Ten studies were included in this meta-analysis, including nine case-control studies and one cohort study. All ten studies were evaluated by the NOS. Seven studies received eight points, and three studies received seven points. The quality of each study is shown in ▶ **Table 3**.

Assessment of publication bias

Publication bias was evaluated by Egger's test. There was no publication bias in any of the seven outcome measures (P > 0.05) (▶ **Table 4**).

Meta-analysis results

Age

Age was reported in nine studies [6, 9, 15, 17–19, 23, 25]. There were 1 994 patients included, the experimental group had 960 patients, and the control group had 1 034 patients. There was moderate heterogeneity ($I^2 = 74\%$, P = 0.0004). Therefore, the random effects model was selected for meta-analysis, and the results suggested that the effect size was significantly larger in the experimental group than in the control group (WMD, 4.23 [95 % CI, 2.32–6.15]; P < 0.00001). This suggested that age may be a risk factor for SSC tears: the older the patient was, the more likely an SSC tendon injury would occur. The forest plot for age is shown in ▶ **Fig. 2**.

Female sex

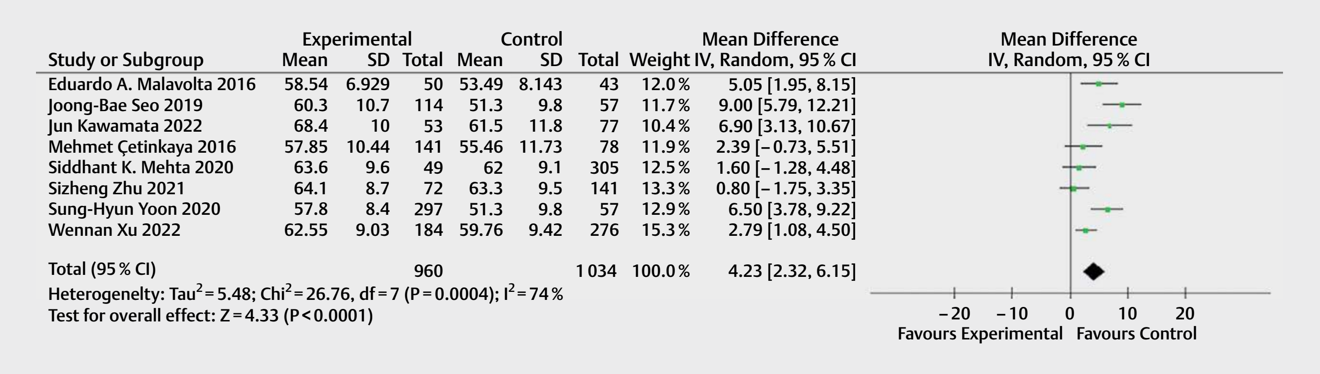
Female sex was evaluated in nine studies [6, 9, 15, 17–19, 23–25]. There were 2 050 patients included, with 988 patients in the experimental group and 1 062 patients in the control group. There was no heterogeneity ($I^2 = 0\%$, P = 0.81). Therefore, the fixed effects model was selected for meta-analysis, and the results suggested that there were no statistically significant differences in the effect size between the experimental and control groups (RR, 1.02 [95 % CI, 0.94–1.12]; P = 0.58). This suggested that female sex may not be a risk factor for SSC tears. The forest plot of age is shown in ▶ **Fig. 3**.

Male sex

Male sex was evaluated in nine studies [6, 9, 15, 17–19, 23–25]. There were 2 050 patients included, and the experimental group had 988 patients, while the control group had 1 062 patients. There was no heterogeneity ($I^2 = 0\%$, P = 0.89). Therefore, the fixed effects model was selected for meta-analysis, and the results suggested that there were no statistically significant differences in effect size between the experimental group and the control group (RR, 0.97 [95 % CI, 0.88–1.07]; P = 0.57). This suggested that male sex may not be a risk factor for SSC tears. The forest plot for the male sex is shown in ▶ **Fig. 4**.

Coracohumeral distance (CHD)

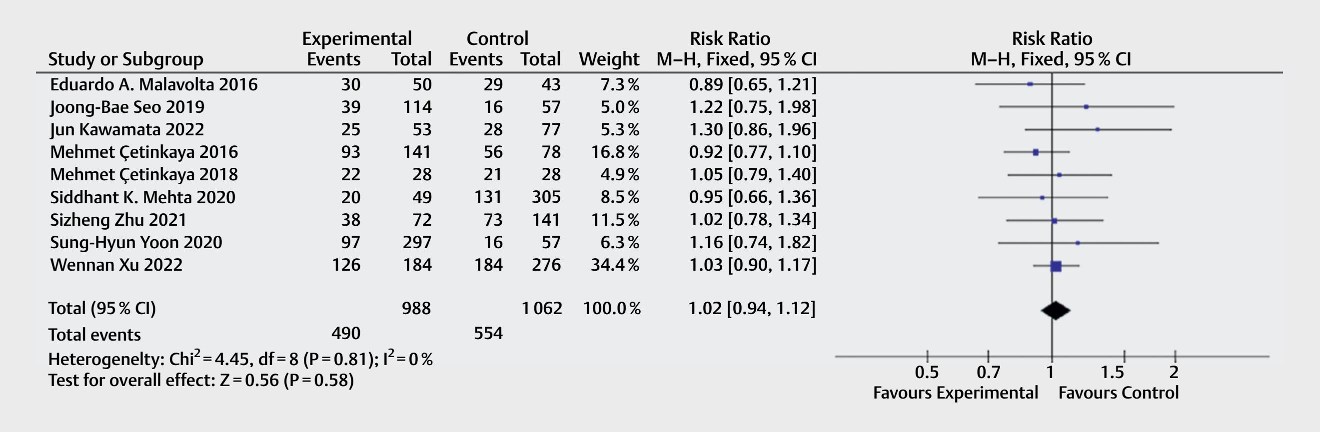
A total of 1 586 patients were included in seven studies [6, 9, 17, 19, 20, 23, 25]; the experimental group had 911 patients, and the control group had 675 patients. There was moderate heterogeneity ($I^2 = 55\%$, P = 0.04). The results suggested that the effect size was significantly lower in the experimental group than in the control group (WMD, −1.03 [95 % CI, −1.17 – −0.88]; P < .00001). We reviewed all studies and found that five studies used single blinding, and two studies did not. Therefore, we conducted a subgroup analysis of this factor based on the presence or absence of blinding. The results were as follows: there was low heterogeneity among the five single-blinded studies ($I^2 = 34\%$, P = 0.19); the experimental group had 717 patients, and the control group had 574 patients. The effect size was smaller in the experimental group than in the control group. There was also low heterogeneity between the two studies without blinding ($I^2 = 36\%$, P = 0.21); the experimental group had



Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95 % CI
Eduardo A. Malavolta 2016	58.54	6.929	50	53.49	8.143	43	12.0 %	5.05 [1.95, 8.15]
Joong-Bae Seo 2019	60.3	10.7	114	51.3	9.8	57	11.7 %	9.00 [5.79, 12.21]
Jun Kawamata 2022	68.4	10	53	61.5	11.8	77	10.4 %	6.90 [3.13, 10.67]
Mehmet Çetinkaya 2016	57.85	10.44	141	55.46	11.73	78	11.9 %	2.39 [−0.73, 5.51]
Siddhant K. Mehta 2020	63.6	9.6	49	62	9.1	305	12.5 %	1.60 [−1.28, 4.48]
Sizheng Zhu 2021	64.1	8.7	72	63.3	9.5	141	13.3 %	0.80 [−1.75, 3.35]
Sung-Hyun Yoon 2020	57.8	8.4	297	51.3	9.8	57	12.9 %	6.50 [3.78, 9.22]
Wennan Xu 2022	62.55	9.03	184	59.76	9.42	276	15.3 %	2.79 [1.08, 4.50]
Total (95 % CI)			960			1 034	100.0 %	4.23 [2.32, 6.15]

Heterogenelty: $Tau^2 = 5.48$; $Chi^2 = 26.76$, df = 7 (P = 0.0004); $I^2 = 74\,\%$
Test for overall effect: Z = 4.33 (P < 0.0001)

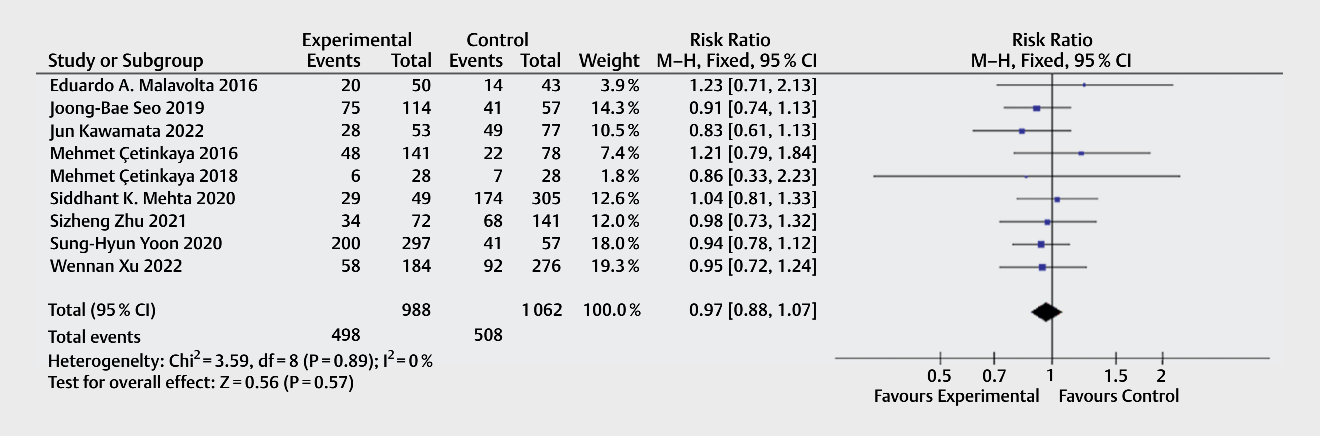
▶ **Fig. 2** Meta-analysis forest plot for age. IV, inverse variance methods.



Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio M–H, Fixed, 95 % CI
Eduardo A. Malavolta 2016	30	50	29	43	7.3 %	0.89 [0.65, 1.21]
Joong-Bae Seo 2019	39	114	16	57	5.0 %	1.22 [0.75, 1.98]
Jun Kawamata 2022	25	53	28	77	5.3 %	1.30 [0.86, 1.96]
Mehmet Çetinkaya 2016	93	141	56	78	16.8 %	0.92 [0.77, 1.10]
Mehmet Çetinkaya 2018	22	28	21	28	4.9 %	1.05 [0.79, 1.40]
Siddhant K. Mehta 2020	20	49	131	305	8.5 %	0.95 [0.66, 1.36]
Sizheng Zhu 2021	38	72	73	141	11.5 %	1.02 [0.78, 1.34]
Sung-Hyun Yoon 2020	97	297	16	57	6.3 %	1.16 [0.74, 1.82]
Wennan Xu 2022	126	184	184	276	34.4 %	1.03 [0.90, 1.17]
Total (95 % CI)		988		1 062	100.0 %	1.02 [0.94, 1.12]
Total events	490		554			

Heterogenelty: $Chi^2 = 4.45$, df = 8 (P = 0.81); $I^2 = 0\,\%$
Test for overall effect: Z = 0.56 (P = 0.58)

▶ **Fig 3** Meta-analysis forest plot of Sex-female. M-H, Mantel-Haenszel.



Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio M–H, Fixed, 95 % CI
Eduardo A. Malavolta 2016	20	50	14	43	3.9 %	1.23 [0.71, 2.13]
Joong-Bae Seo 2019	75	114	41	57	14.3 %	0.91 [0.74, 1.13]
Jun Kawamata 2022	28	53	49	77	10.5 %	0.83 [0.61, 1.13]
Mehmet Çetinkaya 2016	48	141	22	78	7.4 %	1.21 [0.79, 1.84]
Mehmet Çetinkaya 2018	6	28	7	28	1.8 %	0.86 [0.33, 2.23]
Siddhant K. Mehta 2020	29	49	174	305	12.6 %	1.04 [0.81, 1.33]
Sizheng Zhu 2021	34	72	68	141	12.0 %	0.98 [0.73, 1.32]
Sung-Hyun Yoon 2020	200	297	41	57	18.0 %	0.94 [0.78, 1.12]
Wennan Xu 2022	58	184	92	276	19.3 %	0.95 [0.72, 1.24]
Total (95 % CI)		988		1 062	100.0 %	0.97 [0.88, 1.07]
Total events	498		508			

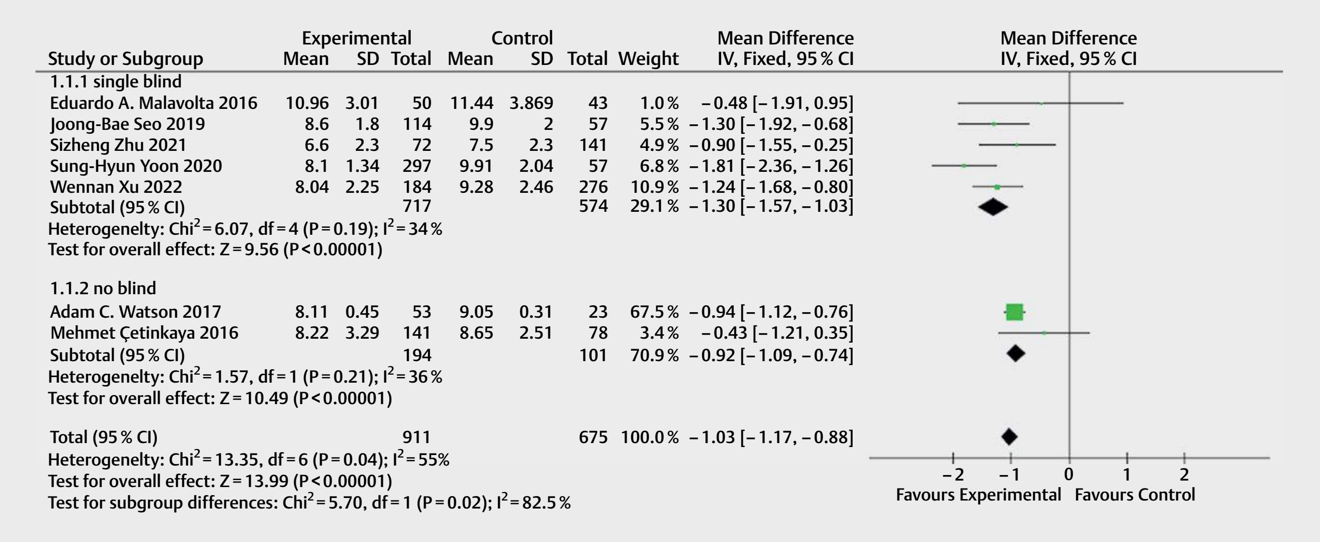
Heterogenelty: $Chi^2 = 3.59$, df = 8 (P = 0.89); $I^2 = 0\,\%$
Test for overall effect: Z = 0.56 (P = 0.57)

▶ **Fig. 4** Meta-analysis forest plot of Sex-male. M-H, Mantel-Haenszel.

194 patients, and the control group had 101 patients. The effect size was smaller in the experimental group than in the control group. Therefore, the overall effect size in the experimental group was smaller than that in the control group in the fixed effects model meta-analysis. The forest plot for CHD is shown in ▶ **Fig. 5**.

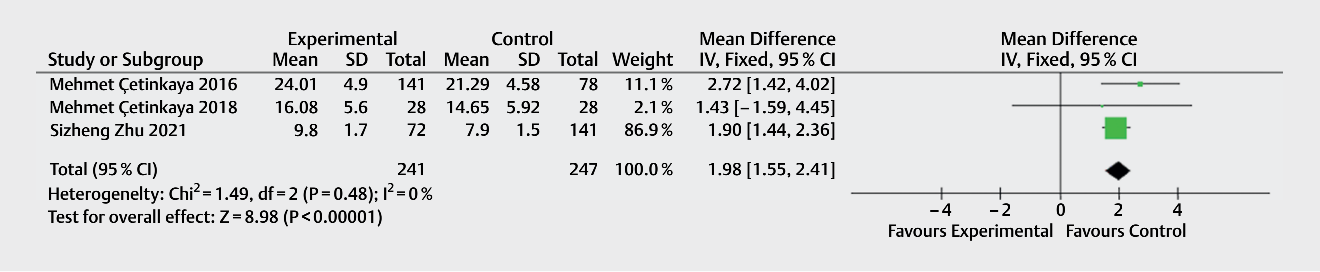
Coracoid overlap (CO)

A total of 488 patients were included in three studies [9, 23, 24]; the experimental group had 241 patients, and the control group had 247 patients. There was no heterogeneity ($I^2 = 0\,\%$, P = 0.48). Therefore, the fixed effects model was selected for meta-analysis, and the results suggested that the effect size in the experimental group was significantly larger than that in the control group (WMD,



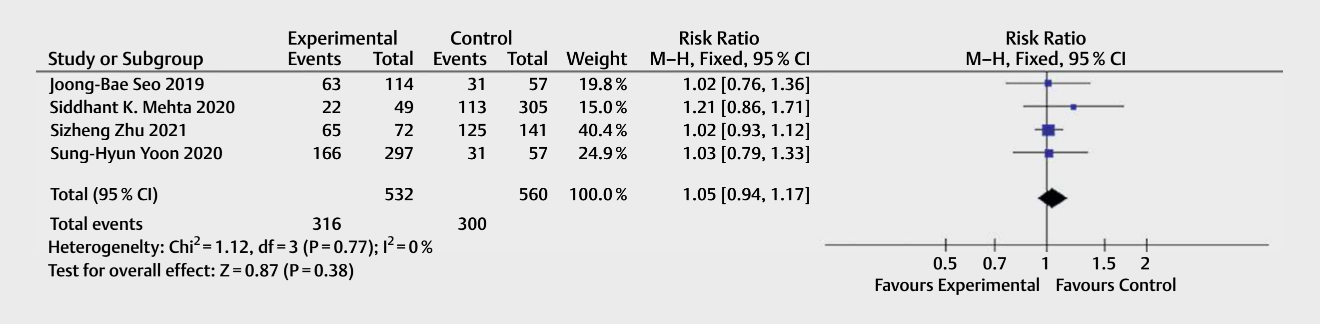
Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95 % CI
1.1.1 single blind								
Eduardo A. Malavolta 2016	10.96	3.01	50	11.44	3.869	43	1.0 %	− 0.48 [− 1.91, 0.95]
Joong-Bae Seo 2019	8.6	1.8	114	9.9	2	57	5.5 %	− 1.30 [− 1.92, − 0.68]
Sizheng Zhu 2021	6.6	2.3	72	7.5	2.3	141	4.9 %	− 0.90 [− 1.55, − 0.25]
Sung-Hyun Yoon 2020	8.1	1.34	297	9.91	2.04	57	6.8 %	− 1.81 [− 2.36, − 1.26]
Wennan Xu 2022	8.04	2.25	184	9.28	2.46	276	10.9 %	− 1.24 [− 1.68, − 0.80]
Subtotal (95 % CI)			717			574	29.1 %	− 1.30 [− 1.57, − 1.03]
Heterogenelty: Chi² = 6.07, df = 4 (P = 0.19); I² = 34 %								
Test for overall effect: Z = 9.56 (P < 0.00001)								
1.1.2 no blind								
Adam C. Watson 2017	8.11	0.45	53	9.05	0.31	23	67.5 %	− 0.94 [− 1.12, − 0.76]
Mehmet Çetinkaya 2016	8.22	3.29	141	8.65	2.51	78	3.4 %	− 0.43 [− 1.21, 0.35]
Subtotal (95 % CI)			194			101	70.9 %	− 0.92 [− 1.09, − 0.74]
Heterogenelty: Chi² = 1.57, df = 1 (P = 0.21); I² = 36 %								
Test for overall effect: Z = 10.49 (P < 0.00001)								
Total (95 % CI)			911			675	100.0 %	− 1.03 [− 1.17, − 0.88]
Heterogenelty: Chi² = 13.35, df = 6 (P = 0.04); I² = 55%								
Test for overall effect: Z = 13.99 (P < 0.00001)								
Test for subgroup differences: Chi² = 5.70, df = 1 (P = 0.02); I² = 82.5 %								

▶ **Fig. 5** Meta-analysis forest plot for CHD. IV, inverse variance methods.



Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95 % CI
Mehmet Çetinkaya 2016	24.01	4.9	141	21.29	4.58	78	11.1 %	2.72 [1.42, 4.02]
Mehmet Çetinkaya 2018	16.08	5.6	28	14.65	5.92	28	2.1 %	1.43 [− 1.59, 4.45]
Sizheng Zhu 2021	9.8	1.7	72	7.9	1.5	141	86.9 %	1.90 [1.44, 2.36]
Total (95 % CI)			241			247	100.0 %	1.98 [1.55, 2.41]
Heterogenelty: Chi² = 1.49, df = 2 (P = 0.48); I² = 0 %								
Test for overall effect: Z = 8.98 (P < 0.00001)								

▶ **Fig. 6** Meta-analysis forest plot for CO. IV, inverse variance methods.



Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio M–H, Fixed, 95 % CI
Joong-Bae Seo 2019	63	114	31	57	19.8 %	1.02 [0.76, 1.36]
Siddhant K. Mehta 2020	22	49	113	305	15.0 %	1.21 [0.86, 1.71]
Sizheng Zhu 2021	65	72	125	141	40.4 %	1.02 [0.93, 1.12]
Sung-Hyun Yoon 2020	166	297	31	57	24.9 %	1.03 [0.79, 1.33]
Total (95 % CI)		532		560	100.0 %	1.05 [0.94, 1.17]
Total events	316		300			
Heterogenelty: Chi² = 1.12, df = 3 (P = 0.77); I² = 0 %						
Test for overall effect: Z = 0.87 (P = 0.38)						

▶ **Fig. 7** Meta-analysis forest plot of Dominant arm. M-H, Mantel-Haenszel.

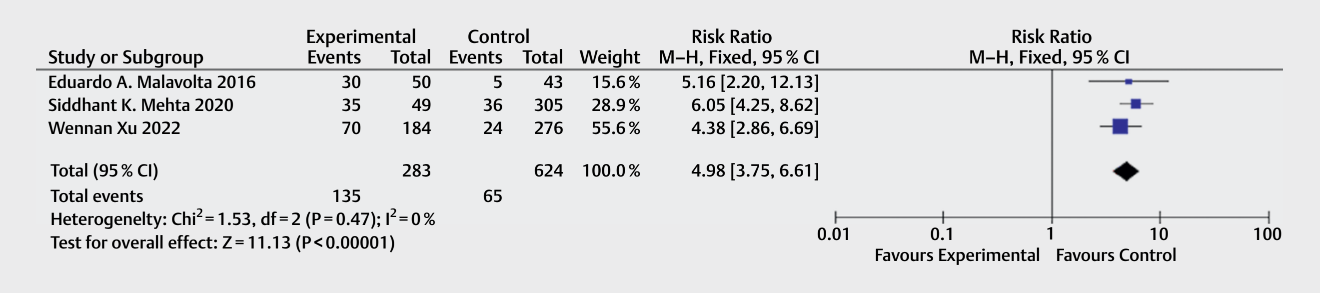
1.98 [95 % CI, 1.55–2.41]; P < .00001). This suggested that CO may be a risk factor for SSC tears. The forest plot for CO is shown in ▶ **Fig. 6**.

Dominant arm

There were 1 092 patients included in the four studies [9, 15, 19, 25]; the experimental group had 532 patients, and the control group had 560 patients. There was no heterogeneity ($I^2 = 0\%$, P = 0.77). Therefore, the fixed effects model was selected for meta-analysis, and the results suggested that there were no statistically significant differences between the effect size in the experimental group and the effect size in the control group (RR, 1.05 [95 % CI, 0.94–1.17]; P = 0.38). This suggested that the dominant arm may not be a risk factor for SSC tears. The forest plot for dominant arm is shown in ▶ **Fig. 7**.

Injury of long head of the biceps (LHB) tendon

LHB injury was reported in three studies [6, 15, 17]. There were 907 patients included, with 283 patients in the experimental group and 624 patients in the control group. There was no heterogeneity ($I^2 = 0\%$, P = 0.47). Therefore, the fixed effects model was selected for meta-analysis, and the results suggested that the effect size of



Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio M–H, Fixed, 95 % CI
Eduardo A. Malavolta 2016	30	50	5	43	15.6 %	5.16 [2.20, 12.13]
Siddhant K. Mehta 2020	35	49	36	305	28.9 %	6.05 [4.25, 8.62]
Wennan Xu 2022	70	184	24	276	55.6 %	4.38 [2.86, 6.69]
Total (95 % CI)		283		624	100.0 %	4.98 [3.75, 6.61]
Total events	135		65			

Heterogenelty: $Chi^2 = 1.53$, df = 2 (P = 0.47); $I^2 = 0\,\%$

Test for overall effect: Z = 11.13 (P < 0.00001)

▶ **Fig. 8** Meta-analysis forest plot of LHB injury. M-H, Mantel-Haenszel.

the experimental group was larger than that of the control group, and it was statistically significant (RR, 4.98 [95 % CI, 3.75–6.61]; P < .00001). This suggested that LHB injury may be a risk factor for SSC tears. The forest plot of LHB injury is shown in ▶ **Fig. 8**.

Discussion

Rotator cuff tears are common, significantly reduce people's quality of life, and increase the economic burden on people, which increases the pressure on the social medical insurance system [26]. Rotator cuff tears are most common in the supraspinatus muscle, followed by the SSC muscle [27]. Many studies have shown that the incidence of SSC tears is 27.4 %–69.1 % in rotator cuff tear cases repaired under arthroscopy [28–31]. Studies have shown that most SSC tears are associated with degenerative changes [15]. The diagnosis of SSC tears is still difficult and there is a risk of missed diagnosis. At present, MRI remains the gold standard for the preoperative diagnosis of rotator cuff tears, and many researchers have been committed to finding anatomic risk factors for SSC tears on MRI in an attempt to increase the sensitivity of the diagnosis of SSC tears by measuring these anatomical indicators on MRI.

Many studies have shown that the incidence of rotator cuff tears increases with age [32, 33]. In older adults, the amount of microvasculature in the tendon is significantly reduced, making rotator cuff tissues more prone to fibroangiogenesis, adipose deposition, atrophy, and calcification, which may contribute to rotator cuff tears [32, 34]. Studies have shown that the incidence of rotator cuff tears in patients over 60 years old is 5.07 times higher than in patients under 60 years old [35]. In this study, patients with SSC tears were older than those without SSC tears. However, there was heterogeneity in the studies included with this indicator ($I^2 = 74\,\%$, P < .0001). This may have been related to the patient's country, economic status, study design and other factors, so the random effects model was selected for meta-analysis.

A systematic study showed that males were more prone to supraspinatus tears than females. Maria J. Leite et al. suggested that males were more prone to SSC injuries [13]. However, there were no significant differences in CHD and CO between men and women. Previous studies have shown no relationship between sex and SSC tears [15, 36]. In our study, there was no significant difference in the probability of SSC tears between men and women.

The CHD is a measurement of the shortest distance from the coracoid process cortex to the humeral cortex, and there are transverse positions and oblique sagittal positions. Relevant studies have shown that the normal value of the CHD on MRI is 8.7–11 mm [23, 37, 38]. Leite et al., suggested that the optimal sensitivity and specificity for predicting SSC tears was a CHD of 7.95 mm [13]. Xu et al., and Seo et al. showed that a decreased CHD was closely related to SSC tears and had high predictive value and diagnostic sensitivity [17, 25]. According to Zhu et al., there was a significant difference between affected and contralateral CHD in patients with SSC tears, and the bilateral discrepancy (ΔCHD) was closely related to SSC tears and subcoracoid impingement [9]. Other researchers believe that CHD is not significantly associated with SSC tears [23, 39]. There are many factors that impact the measurement of the CHD. For example, there is a difference between the measurement value when in the neutral position and the internal rotation position of the upper limb. Some studies have suggested that CHD values should be measured when the upper limb is in a neutral position [9, 17, 19]. Some studies have suggested that the value of the CHD should be measured when the upper limb is in an internal rotation position [8]. In addition, magnetic field strength, scan thickness, and other factors related to the MRI procedure will also affect the CHD measurement, thus affecting the diagnosis of SSC tears [3, 5, 6]. In our study, there were seven studies related to CHD, which were all measured in transverse positions with the patient's upper limb in a standard neutral position. There was heterogeneity among the seven studies ($I^2 = 55\,\%$, P < .00001). We performed a subgroup analysis depending on whether blinding procedures were used, and this significantly reduced heterogeneity. We concluded that the CHD was significantly associated with SSC tears: in particular, the lower the CHD was, the more likely an SSC tear.

The distance between the glenoid and the tip of the coracoid process was defined as the CO, which was measured on the axial plane. Leite et al. showed that the CO had a strong predictive value for SSC tears, and when the CO value was 16.6 mm, the sensitivity and specificity for the prediction of SSC muscle tears reached the optimal value [13]. However, Zhu et al. found that a CO value of 10 mm had the most appropriate sensitivity and specificity for the prediction of SSC tears, and the predictive value was higher than that of CHD [9]. Cetinkaya et al. identified the CO as the most valuable predictor of SSC tears [23]. In our study, there were three studies related to CO, which were all measured in transverse positions, and the upper limbs were in the standard neutral position. There was no heterogeneity among the three studies. We concluded that CO was significantly associated with SSC tears: in particular, the higher the CO was, the more likely SSC tears were to occur.

The dominant arm, usually the right one, is the side that is preferred for most tasks. For example, most people use the right arm, so the right arm is the dominant arm. Relevant studies have shown that rotator cuff tears of the dominant arm are more likely to have symptoms [40]. In a study of 20 overhead athletes with no shoulder symptoms, Connor et al. found that 40 % of dominant arms had partial or full-thickness rotator cuff tears [41]. Some studies suggest that rotator cuff tears are more likely to occur in the dominant arm [42]; however, other studies have found that there is no significant difference in the chance of supraspinatus tears between the dominant arm and the nondominant arm [27]. Our study included four studies involving the dominant arm, and there was no heterogeneity among these four studies. We concluded that there was no significant difference in the dominant arm with regard to SSC tears.

The LHB originates from supraglenoid tubercle of the scapula and passes through a skeletal fiber canal formed by the intertubercular sulcus of the humerus and the transverse ligament. It has anatomical proximity to the SSC and supraspinatus tendons. The stability of the LHB in the groove is conferred by the sling-like confluence of fibrous tissue originating from the coracohumeral ligament, superior glenohumeral ligament, articular capsule, supraspinal muscle, and SSC tendons [43, 44]. Upper SSC tears usually cause LHB instability and shoulder pain [45, 46]. Subluxation and dislocation of the LHB can cause damage to the SSC muscle [15, 16]. Studies have found that when the CHD is 7.7 mm and the CO is 18.9 mm, the prediction of LHB injury has good sensitivity and specificity [13, 17]. Our study included three studies involving LHB injury, and there was no heterogeneity among these three studies. We concluded that LHB injury was significantly associated with SSC tears.

Certainly, there are other risk factors related to SSC tears, such as coracoid distal length (CLD), coracoid proximal length (CLP), and coracoid angle (CA) [18, 36]. However, there are few studies evaluating these indicators. The different study designs, different evaluation methods, different imaging machine types, different measurement methods, and other factors caused differences in the measured results for these indicators among studies. Therefore, the combined meta-analysis could not be carried out, and the forced merging of data would have produced greater heterogeneity and lost analytical significance. Therefore, it is expected that an increasing number of high-quality studies will involve these indicators, which will be evaluated in a subsequent systematic review.

There are also some limitations in this study: (1) the included studies were conducted in different social and economic environments, different medical systems, different countries, and different ethnic groups, which may have led to heterogeneity among some outcome indicators. However, the results of these systematic reviews of studies from different countries and ethnic groups have a universality that might be considered beneficial. (2) This study considered only SSC tears, not the size or other features of the tears. (3) The number of included studies for some indicators was small, which may have affected the credibility of the results. Future studies should include studies with larger sample sizes. (4) The included studies lacked high-quality research evidence, which may have affected the credibility of this study. The shortcomings of this study provide an important direction for future research.

Conclusion

Our study suggested that age, CHD, LHB injury, and CO can be used as predictors of SSC tears. It is helpful for surgeons to detect SSC tears and implement intervention measures in the early stages.

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Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Lee JH, Yoon YC, Jee S et al. Comparison of three-dimensional isotropic and two-dimensional conventional indirect MR arthrography for the diagnosis of rotator cuff tears. Korean J Radiol 2014; 15: 771–780. DOI: 10.3348/kjr.2014.15.6.771

[2] Waldt S, Bruegel M, Mueller D et al. Rotator cuff tears: assessment with MR arthrography in 275 patients with arthroscopic correlation. Eur Radiol 2007; 17: 491–498. DOI: 10.1007/s00330-006-0370-7

[3] Furukawa R, Morihara T, Arai Y et al. Diagnostic accuracy of magnetic resonance imaging for subscapularis tendon tears using radial-slice magnetic resonance images. J Shoulder Elbow Surg 2014; 23: e283–e290. DOI: 10.1016/j.jse.2014.03.011

[4] Lin L, Yan H, Xiao J et al. The diagnostic value of magnetic resonance imaging for different types of subscapularis lesions. Knee Surg Sports Traumatol Arthrosc 2016; 24: 2252–2258. DOI: 10.1007/s00167-014-3335-4

[5] Matsushita R, Yokoya S, Negi H et al. Evaluation of subscapularis tendon tears of the anterosuperior aspect using radial-sequence magnetic resonance imaging. JSES Int 2022; 6: 97–103. DOI: 10.1016/j.jseint.2021.08.005

[6] Malavolta EA, Assunção JH, Gracitelli MEC et al. Accuracy of magnetic resonance imaging (MRI) for subscapularis tear: A systematic review and meta-analysis of diagnostic studies. Arch Orthop Trauma Surg 2019; 139: 659–667. DOI: 10.1007/s00402-018-3095-6

[7] Banerjee M, Müller-Hübenthal J, Grimme S et al. Moderate value of non-contrast magnetic resonance imaging after non-dislocating shoulder trauma. Knee Surg Sports Traumatol Arthrosc 2016; 24: 1888–1895. DOI: 10.1007/s00167-014-3102-6

[8] Naimark M, Zhang AL, Leon I et al. Clinical, radiographic, and surgical presentation of subscapularis tendon tears: A retrospective analysis of 139 patients. Arthroscopy 2016; 32: 747–752. DOI: 10.1016/j.arthro.2015.11.019

[9] Zhu S, Tan J, Wu D et al. Bilateral coracohumeral distance discrepancy is associated with subscapularis tear in rotator cuff rupture patients. Knee Surg Sports Traumatol Arthrosc 2021; 29: 3936–3942. DOI: 10.1007/s00167-021-06597-6

[10] Cigolotti A, Biz C, Lerjefors E et al. Medium- to long-term clinical and functional outcomes of isolated and combined subscapularis tears repaired arthroscopically. Arch Med Sci 2021; 17: 1351–1364. DOI: 10.5114/aoms.2020.97714

[11] Hasler A, Ker A, Passon T et al. Nonoperatively managed small- to medium-sized subscapularis tendon tears: magnetic resonance imaging evaluation with a minimum of 5 years of follow-up. JSES Int 2022; 6: 84–90. DOI: 10.1016/j.jseint.2021.09.002

[12] Yoon T-H, Kim S-J, Choi Y-R et al. Arthroscopic revision rotator cuff repair: The Role of previously neglected subscapularis tears. Am J Sports Med 2021; 49: 3952–3958. DOI: 10.1177/03635465211047485

[13] Leite MJ, Sa MC, Lopes MJ et al. Coracohumeral distance and coracoid overlap as predictors of subscapularis and long head of the biceps injuries. J Shoulder Elbow Surg 2019; 28: 1723–1727. DOI: 10.1016/j.jse.2019.01.012

[14] Cetinkaya M, Öner AY, Ataoglu MB et al. Lesser tuberosity cysts and their relationship with subscapularis tears and subcoracoid impingement. J Orthop Sci 2017; 22: 63–68. DOI: 10.1016/j.jos.2016.09.018

[15] Mehta SK, Teefey SA, Middleton W et al. Prevalence and risk factors for development of subscapularis and biceps pathology in shoulders with degenerative rotator cuff disease: A prospective cohort evaluation. J Shoulder Elbow Surg 2020; 29: 451–458. DOI: 10.1016/j.jse.2019.11.012

[16] Yoon J-S, Kim S-J, Choi Y-R et al. Medial subluxation or dislocation of the biceps on magnetic resonance arthrography is reliably correlated with concurrent subscapularis full-thickness tears confirmed arthroscopically. BioMed Res Int 2018; 2018: 2674061. DOI: 10.1155/2018/2674061

[17] Xu W, Wang F, Xue Q. Identifying key factors associated with subscapularis tendon tears and developing a risk prediction model to assist diagnosis. BMC Musculoskelet Disord 2022; 23: 393. DOI: 10.1186/s12891-022-05351-4

[18] Kawamata J, Suenaga N, Oizumi N et al. Morphology of the coracoid process as a predictor of articular side tear at the upper border of the subscapularis. J Shoulder Elbow Surg 2022; 31: 1442–1450. DOI: 10.1016/j.jse.2021.12.035

[19] Yoon SH, Seo JB, Kim MG et al. The anterior translation of the humeral head leads to a decrease in the coracohumeral distance in subscapularis tear. J Orthop 2020; 22: 535–538. DOI: 10.1016/j.jor.2020.11.005

[20] Watson AC, Jamieson RP, Mattin AC et al. Magnetic resonance imaging based coracoid morphology and its associations with subscapularis tears: A new index. Shoulder Elbow 2019; 11: 52–58. DOI: 10.1177/1758573217744170

[21] Stroup DF, Berlin JA, Morton SC et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA 2000; 283: 2008–2012

[22] Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol 2010; 25: 603–605. DOI: 10.1007/s10654-010-9491-z

[23] Cetinkaya M, Ataoglu MB, Ozer M et al. Subscapularis tendon slip number and coracoid overlap are more related parameters for subcoracoid impingement in subscapularis tears: A magnetic resonance imaging comparison study. Arthroscopy 2017; 33: 734–742. DOI: 10.1016/j.arthro.2016.09.003

[24] Cetinkaya M, Ataoglu MB, Ozer M et al. Relationship between coracoid overlap and subscapularis tears. Çukurova Med J 2018; 43: 1008–1014. DOI: 10.17826/cumj.349391

[25] Seo JB, Kim SJ, Ham HJ et al. New predictors for subscapularis tear: Coraco-lesser tuberosity angle, lesser tuberosity angle, and lesser tuberosity height. Orthop Traumatol Surg Res 2020; 106: 45–51. DOI: 10.1016/j.otsr.2019.10.017

[26] Mitterer M, Matis N, Steiner G et al. Muscle volume imbalance may be associated with static posterior humeral head subluxation. BMC Musculoskelet Disord 2021; 22: 279. DOI: 10.1186/s12891-021-04146-3

[27] Zhao J, Luo M, Liang G et al. Risk factors for supraspinatus tears: A meta-analysis of observational studies. Orthop J Sports Med 2021; 9:. DOI: 10.1177/23259671211042826

[28] Acar B, Köse Ö, Aytaç G et al. Diabetes mellitus accelerates fatty degeneration of the supraspinatus muscle after tendon tear: An experimental study in rats. Eklem Hastalik Cerrahisi 2018; 29: 176–183. DOI: 10.5606/ehc.2018.62388

[29] Atala NA, Bongiovanni SL, Galich AM et al. Is sarcopenia a risk factor for rotator cuff tears? J Shoulder Elbow Surg 2021; 30: 1851–1855. DOI: 10.1016/j.jse.2020.10.001

[30] Carbone S, Gumina S, Arceri V et al. The impact of preoperative smoking habit on rotator cuff tear: Cigarette smoking influences rotator cuff tear sizes. J Shoulder Elbow Surg 2012; 21: 56–60. DOI: 10.1016/j.jse.2011.01.039

[31] Chou R, Baker WL, Bañez LL et al. Agency for Healthcare Research and Quality Evidence-based Practice Center methods provide guidance on prioritization and selection of harms in systematic reviews. J Clin Epidemiol 2018; 98:. DOI: 10.1016/j.jclinepi.2018.01.007

[32] Motta Gda R, Amaral MV, Rezende E et al. Evidence of genetic variations associated with rotator cuff disease. J Shoulder Elbow Surg 2014; 23: 227–235. DOI: 10.1016/j.jse.2013.07.053

[33] Shim SB, Jeong JY, Yum TH et al. A comparative study to evaluate the risk factors for medium-sized rotator cuff tear in patients younger than 50 years of age. Arthroscopy 2018; 34: 2971–2979. DOI: 10.1016/j.arthro.2018.06.031

[34] Santago AC, Vidt ME, Li X et al. Shoulder strength requirements for upper limb functional tasks: Do age and rotator cuff tear status matter? J Appl Biomech 2017; 33: 446–452. DOI: 10.1123/jab.2016-0116

[35] Sayampanathan AA, Andrew THC. Systematic review on risk factors of rotator cuff tears. J Orthop Surgery (Hong Kong) 2017; 25: 2309499016684318. DOI: 10.1177/2309499016684318

[36] Leite MJ, Pinho AR, Sá MC et al. Coracoid morphology and humeral version as risk factors for subscapularis tears. J Shoulder Elbow Surg 2020; 29: 1804–1810. DOI: 10.1016/j.jse.2020.01.074

[37] Abdrabou AM, Shalaby MH. Narrowed coraco-humeral distance on MRI: Association with subscapularis tendon tear. Egypt J Radiol Nucl Med 2017; 48: 977–981. DOI: 10.1016/j.ejrnm.2017.04.011

[38] Gerber C, Terrier F, Zehnder R et al. The subcoracoid space. An anatomic study. Clin Orthop Relat Res 1987; 132–138

[39] Radas CB, Pieper H-G. The coracoid impingement of the subscapularis tendon: a cadaver study. J Shoulder Elbow Surg 2004; 13: 154–159

[40] Yamamoto A, Takagishi K, Kobayashi T et al. Factors involved in the presence of symptoms associated with rotator cuff tears: a comparison of asymptomatic and symptomatic rotator cuff tears in the general population. J Shoulder Elbow Surg 2011; 20: 1133–1137. DOI: 10.1016/j.jse.2011.01.011

[41] Connor PM, Banks DM, Tyson AB et al. Magnetic resonance imaging of the asymptomatic shoulder of overhead athletes: A 5-year follow-up study. Am J Sports Med 2003; 31: 724–727

[42] Zhao J, Luo M, Liang G et al. What factors are associated with symptomatic rotator cuff tears: A meta-analysis. Clin Orthop Relat Res 2022; 480: 96–105. DOI: 10.1097/CORR.0000000000001949

[43] Gleason PD, Beall DP, Sanders TG et al. The transverse humeral ligament: A separate anatomical structure or a continuation of the osseous attachment of the rotator cuff? Am J Sports Med 2006; 34: 72–77

[44] Werner A, Mueller T, Boehm D et al. The stabilizing sling for the long head of the biceps tendon in the rotator cuff interval. A histoanatomic study. Am J Sports Med 2000; 28: 28–31

[45] Lafosse L, Reiland Y, Baier GP et al. Anterior and posterior instability of the long head of the biceps tendon in rotator cuff tears: a new classification based on arthroscopic observations. Arthroscopy 2007; 23: 73–80

[46] Walch G, Nové-Josserand L, Boileau P et al. Subluxations and dislocations of the tendon of the long head of the biceps. J Shoulder Elbow Surg 1998; 7: 100–108