Risk Factors for Supraspinatus Tears

A Meta-analysis of Observational Studies

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Background: The pathogenesis of rotator cuff tears remains unclear, and there is a lack of high-quality evidence-based research on the risk factors for supraspinatus tears.

Purpose: To explore 10 potential risk factors for supraspinatus muscle tears.

Study Design: Systematic review; Level of evidence, 3.

Methods: This review was conducted according to the MOOSE (Meta-analysis Of Observational Studies in Epidemiology) guidelines. PubMed, Embase, and Web of Science were searched for cohort, case-control and cross-sectional studies published before January 2021 on supraspinatus tears. The following potential risk factors were analyzed: age, body mass index, male sex, female sex, arm dominance, diabetes mellitus, smoking, hypertension, thyroid disease, and the critical shoulder angle (CSA). Risk ratios (RRs) or weighted mean differences (WMDs) of related risk were calculated. The Egger test was used to evaluate publication bias.

Results: A total of 9 articles from 8 countries were included; among the 3240 patients, 687 were included in the supraspinatus tear group, and 2553 were included in the nonsupraspinatus tear group. The meta-analysis showed that older age (WMD, 3.36 [95% confidence interval (CI), 0.53-6.20]; $P = .02$), male sex (RR, 0.87 [95% CI, 0.78-0.97]; $P = .01$), smoking (RR, 2.21 [95% CI, 1.56-3.14]; $P < .00001$), diabetes (RR, 1.67 [95% CI, 1.03-2.70]; $P = .04$), hypertension (RR, 1.51 [95% CI, 1.16-1.97]; $P = .002$), and the CSA (WMD, 2.25 [95% CI, 1.39-3.12]; $P < .00001$) were risk factors for supraspinatus tears.

Conclusion: Older age, male sex, smoking, diabetes, hypertension, and a higher CSA were found to be risk factors for supraspinatus tears in this meta-analysis review. Identifying risk factors for supraspinatus tears early can help clinicians identify these high-risk patients and choose appropriate treatments.

Keywords: risk factors; meta-analysis; rotator cuff; supraspinatus tears

The rotator cuff comprises the supraspinatus, infraspinatus, teres minor, and subscapularis muscles as well as a sleeve-like structure that includes tendons wrapped around the humeral head.[15] The tendons of these 4 muscles connect with the shoulder capsule when passing through the upper, back, and front of the shoulder joint; they form a similar sleeve like structure around the shoulder joint, which plays an important role in the shoulder joint's stability.[26] Epidemiology studies[22,35] have shown that rotator cuff tears are one of the most common causes of shoulder pain and limited movement, and rotator cuff tears account for pain in 30% to 70% of all patients with shoulder pain. The prevalence of rotator cuff tears increases with age.[23] Some patients with symptomatic rotator cuff tears may have shoulder dysfunction in which the affected limb cannot be lifted or abducted because of secondary weakness caused by pain. Supraspinatus muscle tears are the most common rotator cuff injuries, with a prevalence of 61.9% in men and 38.1% in women.[36] Supraspinatus tears are very common in people >60 years of age; furthermore, 70% of people >80 years develop these tears.[30] Identifying medium to large tears over-the-rotator cuff early and treating them surgically can significantly shorten the lesion repair time and reduce the occurrence of postoperative retears.[40]

The pathogenesis of rotator cuff tears remains unclear. At present, age, trauma, smoking, hypercholesterolemia, and family genetic factors have been confirmed to be associated with rotator cuff injuries.[1,6,18,38] However, a lack of high-quality evidence-based research on the risk factors for supraspinatus tears remains, which makes it very difficult for clinicians and patients to identify tears early and treat them

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in a timely manner. Therefore, the purpose of this study was to conduct a meta-analysis to quantitatively analyze 10 potential risk factors for supraspinatus muscle tears. We hypothesized that the literature has reported some risk factors that identify supraspinatus tears and that this meta-analysis may be helpful in developing better strategies to identify patients who are prone to supraspinatus tears.

METHODS

This meta-analysis was performed in accordance with the relevant requirements of the MOOSE (Meta-analysis Of Observational Studies in Epidemiology) statement.[42] We analyzed the influence of the following 10 potential risk factors on supraspinatus tears: age, body mass index (BMI), male sex, female sex, arm dominance, diabetes mellitus, smoking, hypertension, thyroid disease, and the critical shoulder angle (CSA).

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (1) the case group included patients with a supraspinatus tear, while the control group included patients without rotator cuff tears; (2) the case group and control group were identified using imaging tools, such as magnetic resonance imaging or ultrasound; (3) the study type was a cohort study, case-control study, or cross-sectional study; and (4) the study included at least 1 evaluation index. No language restrictions were implemented.

The exclusion criteria were as follows: (1) duplicate studies; (2) studies with data that could not be converted and merged; and (3) low-quality studies (Newcastle-Ottawa Scale [NOS] score, <4; US Agency for Healthcare Research and Quality [AHRQ] score, <4).

Search Strategy

A computer was used to search PubMed, Embase, and Web of Science databases. Combinations of MeSH words and free words were used in the search. Articles published between each database's inception and January 2021 were considered eligible. Keywords included "risk factor," "supraspinatus tears," "rotator cuff injury," "rotator cuff tears," and "rotator cuff tendinitis." The search strategies used for individual databases are shown in Table A1.

Literature Screening and Data Extraction

Two researchers (J.P. and G.L.) independently screened the literature, extracted data, and cross-checked the data. Disagreements were settled through discussion or negotiation with the senior author (J.L.). After duplicate data were removed from the data retrieved, the abstracts and full texts were read to determine whether a study should be included. If necessary, the original study author was contacted by email or telephone to obtain information important for this study. The extracted information included (1) basic study information, including the first author, publication time, and study design; (2) baseline characteristics of the patients, including sampling and imaging methods; (3) key elements of the risk of bias assessment; and (4) relevant outcome indicators and measurement data.

Assessment of Study Quality

This review included cohort studies, case-control studies, and cross-sectional studies. The NOS was used to evaluate the risk of bias for the case-control and cohort studies.[41] The following 3 aspects are assessed: the research patient selection process, level of intergroup comparability, and data measurement process. The total possible score is 9 points, with higher scores indicating better quality. For cross-sectional studies, risk of bias was assessed according to standards recommended by the AHRQ,[9] containing 11 items. The response options for each item are *yes*, *no*, or *not clear*, and higher scores indicate better study quality.

Quantitative Analysis

The weighted mean difference (WMD) was used to determine the effect size of the measurement data, and the risk ratio (RR) was used to determine the effect size for the categorical variables. The 95% confidence interval (CI) for

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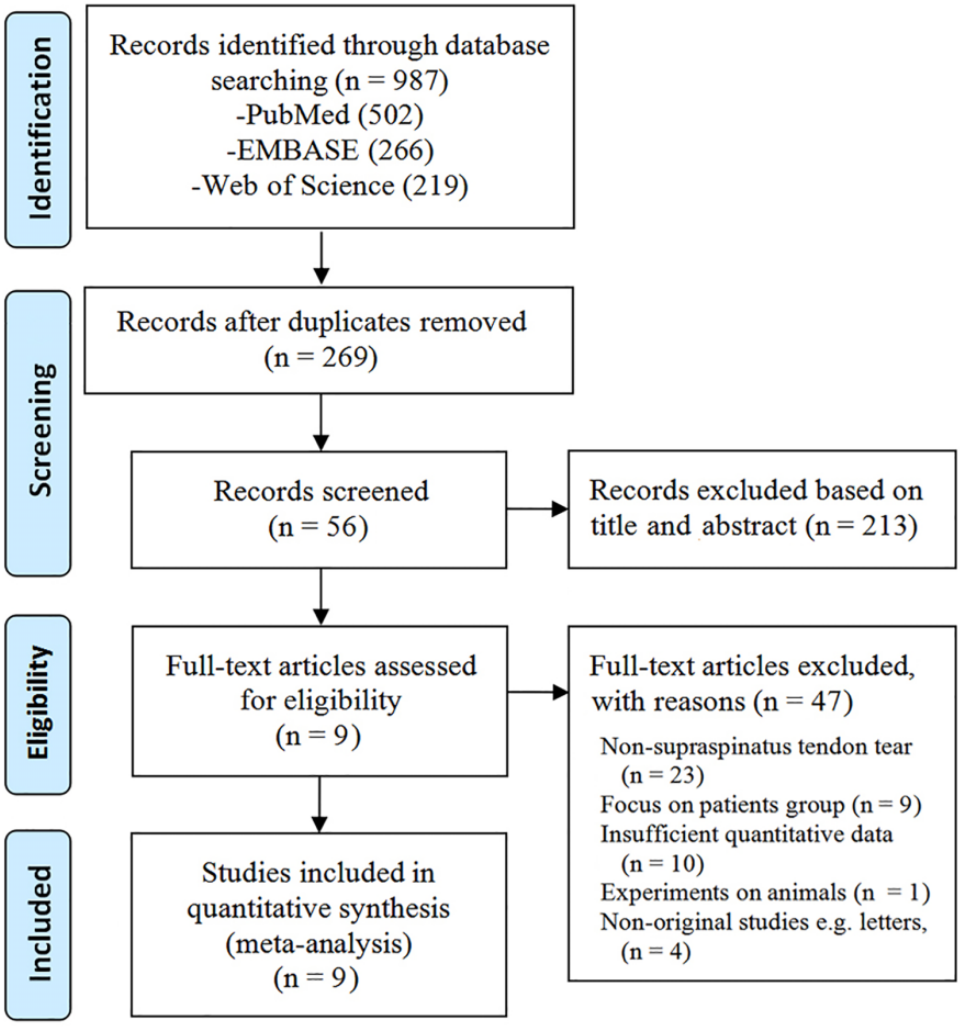

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart.

each effect size was calculated. A heterogeneity test was used to evaluate the heterogeneity of the included studies. If no heterogeneity ($I^2 \leq 50\%$) was found, a fixed-effects model was used to determine the overall effect size; if heterogeneity ($I^2 > 50\%$) was present, a random-effects model was used to merge the effect values. RevMan 5.3 software (Cochrane) was used to conduct the meta-analysis, and Stata 15.1 software (StataCorp) was used to conduct the Begg test to evaluate publication bias and $P < 0.05$ was considered statistically significant.

RESULTS

Study Selection

A total of 987 articles were identified in the search. A total of 269 articles remained after duplicates were removed. After the titles and abstracts were read, 56 articles remained. After full texts were reread, 47 articles that did not meet the inclusion criteria were excluded, and 9 articles were ultimately included. The article screening process is shown in Figure 1.

Characteristics of Included Articles

A total of 9 articles[4,5,7,11,12,20,23,29,43] from 8 countries were included, all of which passed the ethical review. A total of 3240 patients were included in this study, including 687 in the case group and 2553 in the control group. Ten risk factors were involved. In terms of level of evidence, 2 cross-sectional studies were grade 3, and the other 7 cohort studies were grade 2. The basic characteristics of the included studies are shown in Table 1.

Qualitative Assessment

A total of 9 articles were included in this study, including 7 cohort studies[4,5,7,11,12,29,43] and 2 cross-sectional studies.[20,23] The overall quality scores are shown in Table 1.

TABLE 1
Characteristics of the Included Studies[a]

Lead Author (Year)	Country	Study Design (LOE)	No. of Patients		Imaging Modality	NOS or AHRQ Score
			ST	Non-ST		
Watanabe (2018)[43]	Japan	Cohort (2)	54	54	MRI	6
Applegate (2017)[4]	USA	Cohort (2)	156	1070	NR	7
Atala (2021)[5]	Argentina	Cohort (2)	52	53	MRI	8
Blonna (2016)[7]	Italy	Cohort (2)	40	80	MRI	8
Cunningham (2018)[11]	Switzerland	Cohort (2)	33	38	MRI	7
Figueiredo (2019)[12]	Brazil	Cohort (2)	211	567	MRI	6
Haveri (2020)[20]	India	Cross-sectional (3)	69	31	MRI	8
Jeong (2017)[23]	Korea	Cross-sectional (3)	23	355	US	6
Mehta (2020)[29]	USA	Cohort (2)	49	305	US	9

[a]All included studies received ethics approval. AHRQ, Agency for Healthcare Research and Quality; LOE, level of evidence; MRI, magnetic resonance imaging; NOS, Newcastle-Ottawa Scale; NR, not reported; ST, supraspinatus tear; US, ultrasound.

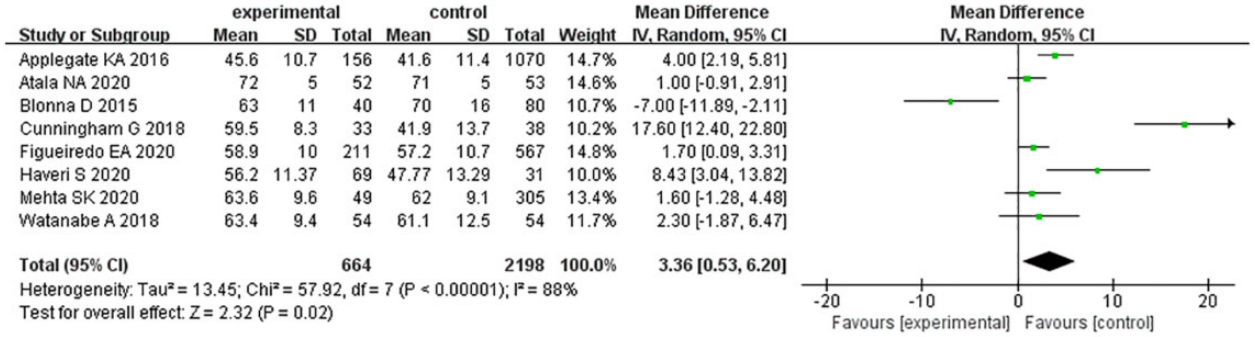

Figure 2. Meta-analysis forest plot for age. IV, inverse variance methods.

The specific quality evaluation results for each study are shown in Tables A2 and A3. The 7 cohort studies had scores ranging from 6 to 9. The quality scores of the 2 cross-sectional studies were 6[23] and 8[20]. These results suggested that the included studies had a low risk of bias and high methodological quality.

Meta-analysis Results

Age. A total of 2862 patients were included in the 8 studies[4,5,7,11,12,20,29,43] that assessed age, including 664 patients in the case group and 2198 patients in the control group. Heterogeneity was present among the studies, and a random-effects model was used for the meta-analysis. The results showed that age was a risk factor for supraspinatus tears, and the difference was statistically significant (WMD, 3.36 [95% CI, 0.53-6.20]; $P = .02$) (Figure 2).

Body Mass Index. A total of 4 studies[4,5,7,20] involving 1551 patients were included, and no heterogeneity existed among the studies assessing BMI ($P = .50$; $I^2 = 0\%$), so a fixed-effects model was used for the meta-analysis. The results showed that BMI was not a risk factor for supraspinatus tears, and the difference was not statistically significant (WMD, 0.39 [95% CI, –0.25 to 1.04]; $P = .23$) (Figure 3).

Male Sex. A total of 8 studies[4,5,7,11,12,20,29,43] assessing male sex were included, and no heterogeneity was present among the studies ($P = .43$; $I^2 = 0\%$). According to the fixed-effects model, male sex was a risk factor for supraspinatus tears, and the difference was statistically significant (RR, 0.87 [95% CI, 0.78-0.97]; $P = .01$) (Figure 4).

Female Sex. A total of 8 studies[5,7,11,12,20,23,29,43] assessing female sex were included, and the heterogeneity among the studies was low ($P = .11$; $I^2 = 40\%$). According to the fixed-effects model, female sex was not a risk factor for supraspinatus tears (RR, 1.06 [95% CI, 0.97-1.17]; $P = .21$) (Figure 5).

Dominant Arm Affected. A total of 4 studies[5,7,11,29] assessing arm dominance were included, and no heterogeneity was present among the studies ($P = .44$; $I^2 = 0\%$). According to the fixed-effects model, arm dominance was not a risk factor for supraspinatus tears (RR, 1.11 [95% CI, 0.95-1.29]; $P = .20$) (Figure 6).

Smoking. A total of 4 studies[5,7,20,23] assessing smoking were included, and no heterogeneity was present among the studies ($P = .97$; $I^2 = 0\%$). According to the fixed-effects model, smoking was a risk factor for supraspinatus tears (RR, 2.21 [95% CI, 1.56-3.14]; $P < .00001$) (Figure 7).

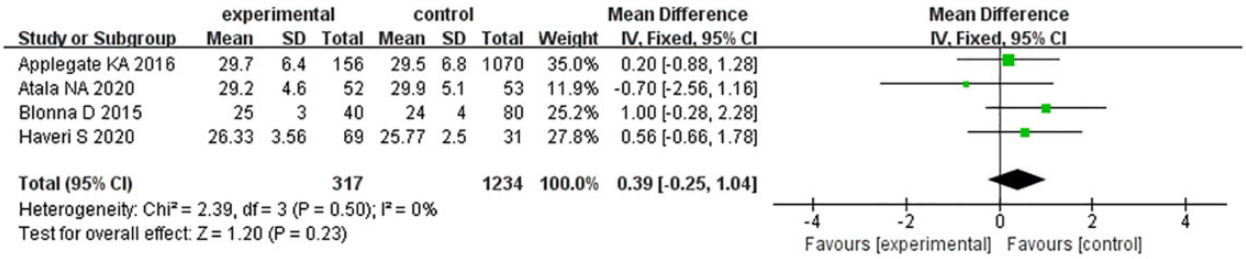

Figure 3. Meta-analysis forest plot for body mass index. IV, inverse variance methods.

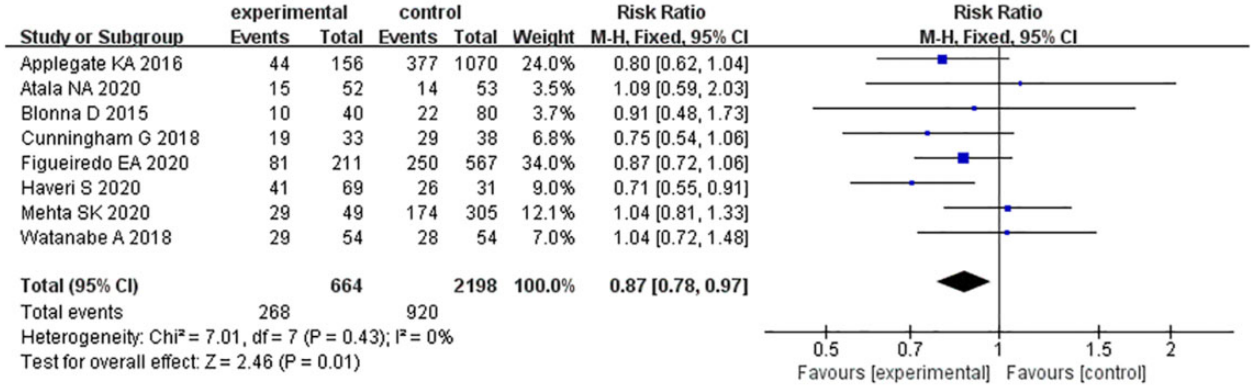

Figure 4. Meta-analysis forest plot of male sex. M-H, Mantel-Haenszel.

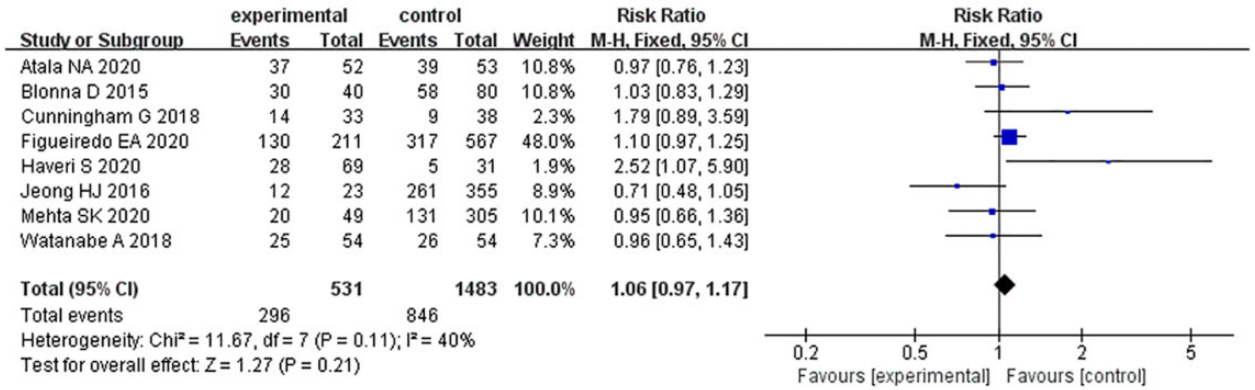

Figure 5. Meta-analysis forest plot of female sex. M-H, Mantel-Haenszel.

Diabetes Mellitus. A total of 3 studies[4,5,23] assessing diabetes mellitus were included, and no heterogeneity was present among the studies ($P = .81$; $I^2 = 0\%$). According to the fixed-effects model, diabetes was a risk factor for supraspinatus tears (RR, 1.67 [95% CI, 1.03-2.70]; $P = .04$) (Figure 8).

Hypertension. A total of 2 studies[4,7] assessing hypertension were included, and the heterogeneity among the studies was low ($P = .18$; $I^2 = 45\%$). According to the fixed-effects model, hypertension was a risk factor for supraspinatus tears (RR, 1.51 [95% CI, 1.16-1.97]; $P = .002$) (Figure 9).

Thyroid Disease. A total of 2 studies[5,23] assessing thyroid disease were included, and no heterogeneity was present among the studies ($P = .75$; $I^2 = 0\%$). According to the fixed-effects model, thyroid disease was not a risk factor for supraspinatus tears (RR, 0.77 [95% CI, 0.34-1.74]; $P = .53$) (Figure 10).

Critical Shoulder Angle. A total of 2 studies[7,43] assessing CSA were included, and no heterogeneity was present among the studies ($P = .50$; $I^2 = 0\%$). According to the fixed-effects model, CSA was a risk factor for supraspinatus tears (WMD, 2.25 [95% CI, 1.39-3.12]; $P < .00001$) (Figure 11).

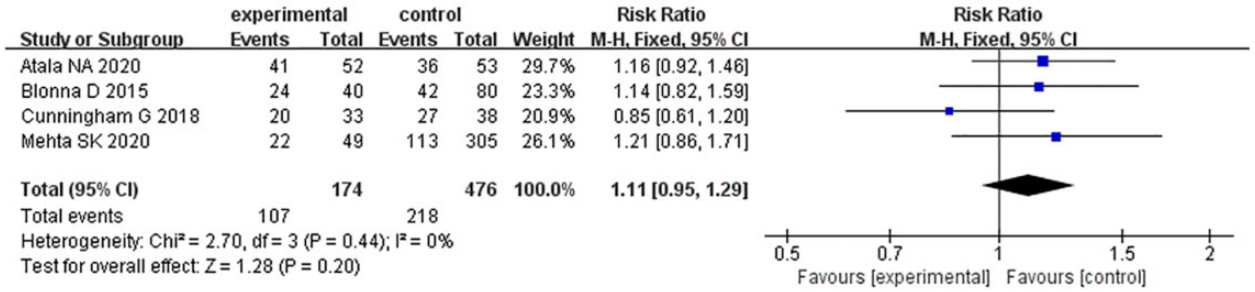

Figure 6. Meta-analysis forest plot of dominant arm. M-H, Mantel-Haenszel.

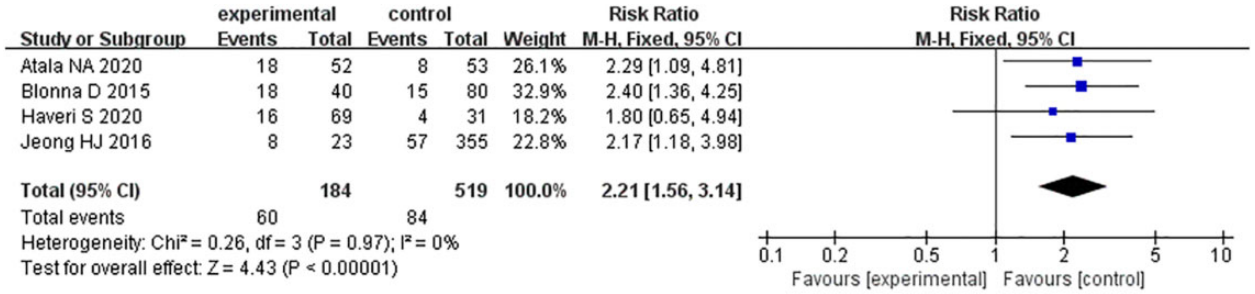

Figure 7. Meta-analysis forest plot of smoking. M-H, Mantel-Haenszel.

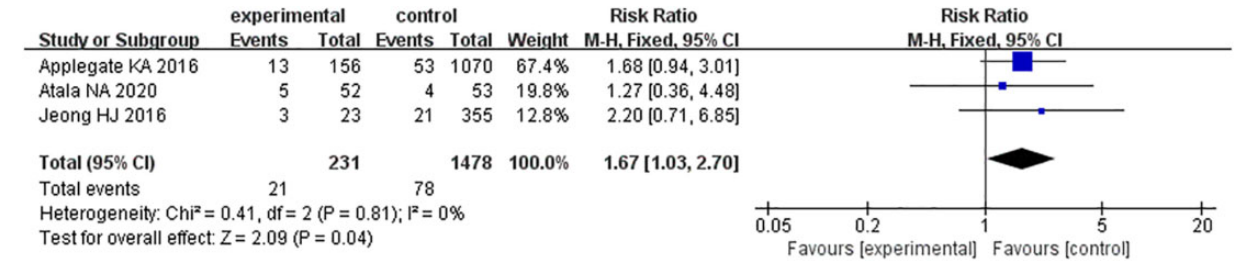

Figure 8. Meta-analysis forest plot of diabetes mellitus. M-H, Mantel-Haenszel.

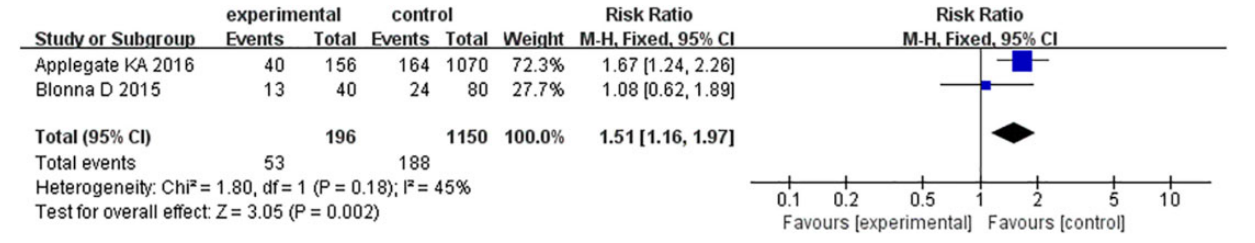

Figure 9. Meta-analysis forest plot of hypertension. M-H, Mantel-Haenszel.

Assessment of Publication Bias

The Begg test was the method used to evaluate publication bias, as only 2 studies each were included in the analysis for hypertension, thyroid disease, and CSA. Results showed that none of the 10 outcome indicators were associated with publication bias ($P > .05$) (Table A4).

DISCUSSION

Our results indicated that age, male sex, smoking, diabetes, hypertension, and the CSA are risk factors for supraspinatus tears and that BMI, female sex, arm dominance, and thyroid disease do not directly relate to supraspinatus tears. Rotator cuff tears account for approximately 60%

Figure 10. Meta-analysis forest plot of thyroid disease. M-H, Mantel-Haenszel.

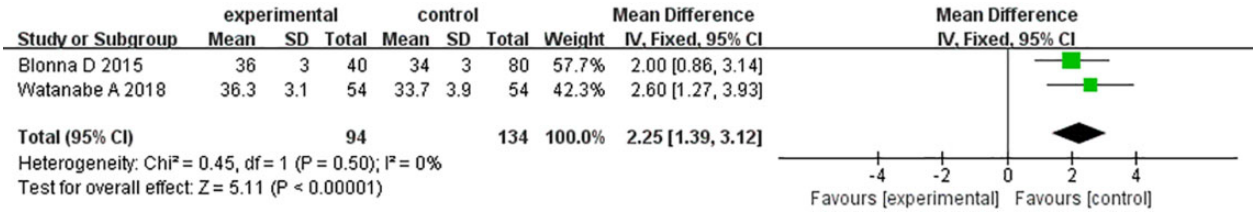

Figure 11. Meta-analysis forest plot of the critical shoulder angle. IV, inverse variance methods.

of shoulder joint lesions, and the self-healing rate is close to zero.[24,28] Rotator cuff tears easily progress without intervention, and secondary steatosis, muscle atrophy, and traumatic arthritis easily occur over time; the opportunity for surgery can be missed.[25] Supraspinatus tears are the most common type of rotator cuff tears.[13] Therefore, it is critical to explore the risk factors for supraspinatus tears to identify supraspinatus lesions early. To our knowledge, this is the first meta-analysis of risk factors for supraspinatus tears.

The incidence of rotator cuff tears increases with age, as studies have confirmed.[32,39] As people age, they experience a decline in muscle strength, degeneration of the shoulder muscles and tendons, and strain over long periods, which can easily lead to rotator cuff tears.[37] In elderly people, the number of microvessels in the tendon is significantly lower than that in young people, which makes the rotator cuff tissue more prone to fibrovascular hyperplasia, fat formation, atrophy, and calcification, which all increase the risk for rotator cuff tears.[27,33] However, the specific causes of rotator cuff tear transformation and degeneration remain unclear. This study showed that patients with supraspinatus tears were older than those without rotator cuff tears (WMD, 3.36 [95% CI, 0.53-6.20]). Therefore, evidence shows that the older the patient is, the easier it is for him or her to develop supraspinatus tears.

Our study showed that people who smoke are more likely to develop supraspinatus tears (RR, 2.21 [95% CI, 1.56-3.14]). Hatta et al[19] hypothesized that nicotine in cigarettes is a risk factor for rotator cuff tears and studied nicotine's effect on tendon cells under cyclic stretching. The authors used porcine tendon cells, which are very similar to human tendon cells, and cultured them in the presence of nicotine for 24 hours. Then, the authors observed the morphological changes in the cells and the expression of matrix metalloproteinase–9 enzyme genes. They found that the nicotine-exposed tendons showed significantly less gene expression and enzyme activity in a dose-dependent manner. A decrease in matrix metalloproteinase expression may directly worsen tendons' metabolism, which in turn affects the mechanical properties of the extracellular matrix of rotator cuff tendons.[19] The above study's[19] results show that some components of cigarettes can produce negative stimulating effects on the generation, apoptosis, and metabolism of muscle cells in vitro. Although these results cannot fully explain why patients who smoke are prone to rotator cuff tears, they can be used to study the relationship between smoking and supraspinatus tears in the future.

This study showed that diabetes is a risk factor for supraspinatus tears (RR, 1.67 [95% CI, 1.03-2.70]). Previous studies[3,21] have shown that diabetes is a risk factor for rotator cuff tears. An experimental study[2] has also suggested that diabetes can accelerate steatosis after supraspinatus tears occur. Nichols et al's study[34] showed that compared with patients without diabetes, patients with type 2 diabetes have 4 times the risk of tendon disease and 5 times the risk of tendon tears or rupture. Another study has shown that focal collagen degeneration occurs in the tendons of patients with diabetes but inflammatory cell infiltration does not occur in the tendons of patients without diabetes.[17] The change in collagen structure affects the mechanical function of tendons, resulting in a decrease in tendon length.[10] Therefore, diabetes may change the supraspinatus muscle's collagen structure, reduce its mechanical strength, and easily cause supraspinatus muscle tears.

Our results showed that hypertension was more likely to cause supraspinatus tears than non-rotator cuff injuries (RR, 1.51 [95% CI, 1.16-1.97]). To determine whether hypertension increases the risk of rotator cuff tears and affects their size, Gumina et al[16] divided 408 patients into a hypertension group and a nonhypertension group; they

then used a logistic regression model to evaluate hypertension's effect on the risk of rotator cuff tears. The authors found that high blood pressure is associated with a high risk of tears, with a 2-fold higher risk of large tears and a 4-fold higher risk of small tears. Their research showed that the risk of rotator cuff tears is higher in people with high blood pressure. Our research also supports this conclusion. However, the mechanism by which hypertension leads to supraspinatus tears requires further study.

Studies[14,31] have shown that the CSA is related to rotator cuff tears and is much higher in people with than in those without rotator cuff tears. This study's results showed that CSA is a risk factor for supraspinatus tears (WMD, 2.25 [95% CI, 1.39-3.12]). Differences in CSA actually led to significant differences in joint force. The compression force and shear force of the joint depend on the CSA. With increasing CSA, the shear force of the joint increases, resulting in shoulder joint instability. The supraspinatus muscle must generate more force to maintain the joint's stability.[13] In patients with a small active abduction range of motion, too high of a CSA will overload the supraspinatus muscle and lead to rotator cuff tears, especially supraspinatus tears, which affect biomechanical properties.[13] Considering the results of these relevant biomechanical studies and this study, this research confirmed that the CSA is a risk factor for supraspinatus tears.

This study found that men were prone to supraspinatus tears (RR, 0.87 [95% CI, 0.78-0.97]). However, no research has addressed the mechanism by which this phenomenon occurs, which may be an area of future research. BMI, female sex, arm dominance, and thyroid disease were not associated with supraspinatus tears.

Limitations

While the aforementioned findings are promising, some limitations exist in this: (1) The included studies were conducted in different countries containing various socioeconomic environments and medical systems, which may have caused heterogeneity in some of the outcome indicators. (2) This study considered only supraspinatus tears and did not consider the size of the tears or other combinations of tears of the rotator cuff. (3) Some risk factors were assessed in only 2 included studies, and this small sample size may have affected the results' credibility. Therefore, interpreting the results of these risk factors requires caution. (4) No level 1 research evidence exists, such as clinical randomized controlled trials; additionally, the included literature mainly comprised level 2 or 3 cohort studies and cross-sectional studies, which may affect this study's credibility. This study's shortcomings provide important directions for future research.

CONCLUSION

This meta-analysis showed that older age, male sex, smoking, diabetes, hypertension, and higher CSA are risk factors for supraspinatus tears, which lends important information to clinical medical staff seeking to accurately identify rotator cuff disease in the early stages to formulate treatment plans. In addition, because of the small sample sizes for some risk factors, more multicenter and large sample-size studies are still necessary to further verify the results.

REFERENCES

1. Abboud JA, Kim JS. The effect of hypercholesterolemia on rotator cuff disease. *Clin Orthop Relat Res*. 2010;468(6):1493-1497.
2. 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(3):176-183.
3. Ahmed AS. Does diabetes mellitus affect tendon healing? *Adv Exp Med Biol*. 2016;920:179-184.
4. Applegate KA, Thiese MS, Merryweather AS, et al. Association between cardiovascular disease risk factors and rotator cuff tendinopathy: a cross-sectional study. *J Occup Environ Med*. 2017;9(2):154-160.
5. Atala NA, Bongiovanni SL, Galich AM, et al. Is sarcopenia a risk factor for rotator cuff tears? *J Shoulder Elbow Surg*. 2021;30(8):1851-1855. doi:10.1016/j.jse.2020.10.001
6. Baumgarten KM, Baumgarten KM, Gerlach D, et al. Cigarette smoking increases the risk for rotator cuff tears. *Clin Orthop Relat Res*. 2010;468(6):1534-1541.
7. Blonna D, Giani A, Bellato E, et al. Predominance of the critical shoulder angle in the pathogenesis of degenerative diseases of the shoulder. *J Shoulder Elbow Surg*. 2016;25(8):1328-1336.
8. 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(1):56-60.
9. 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;98:98-104.
10. Cronin NJ, Peltonen J, Ishikawa M, et al. Achilles tendon length changes during walking in long-term diabetes patients. *Clin Biomech*. 2010;25(5):476-482.
11. Cunningham G, Nicodème-Paulin E, Smith MM, et al. The greater tuberosity angle: a new predictor for rotator cuff tear. *J Shoulder Elbow Surg*. 2018;27(8):1415-1421.
12. Figueiredo EA, Loyola LC, Belangero PS, et al. Rotator cuff tear susceptibility is associated with variants in genes involved in tendon extracellular matrix homeostasis. *J Orthop Res*. 2019;38(1):192-201.
13. Gerber C, Snedeker JG, Baumgartner D, et al. Supraspinatus tendon load during abduction is dependent on the size of the critical shoulder angle: a biomechanical analysis. *J Orthop Res*. 2014;32(7):952-957.
14. Gomide LC, Carmo T, Bergo G, et al. Relationship between the critical shoulder angle and the development of rotator cuff lesions: a retrospective epidemiological study. *Rev Bras Ortop*. 2017;52(4):423-427.
15. Guevara JA, Entezari V, Ho JC, et al. An update on surgical management of the repairable large-to-massive rotator cuff tear. *J Bone Joint Surg Am*. 2020;102(19):1742-1754.
16. Gumina S, Arceri V, Carbone S, et al. The association between arterial hypertension and rotator cuff tear: the influence on rotator cuff tear sizes. *J Shoulder Elbow Surg*. 2013;22(1):229-232.
17. Guney A, Vatansever F, Karaman I, et al. Biomechanical properties of Achilles tendon in diabetic vs. non-diabetic patients. *Exp Clin Endocrinol Diabetes*. 2015;123(7):428.
18. Harvie P, Ostlere SJ, Teh J, et al. Genetic influences in the aetiology of tears of the rotator cuff: sibling risk of a full-thickness tear. *J Bone Joint Surg Br*. 2004;86(5):696.
19. Hatta T, Sano H, Sakamoto N, et al. Nicotine reduced MMP-9 expression in the primary porcine tenocytes exposed to cyclic stretch. *J Orthop Res*. 2013;31(4):645-650.
20. Haveri S, Patil KS, Uppin RB, et al. A cross-sectional study on novel-risk factors associated with supraspinatus tendon tear. *Indian J Orthop*. 2020;55(2):457-463. doi:10.1007/s43465-020-00222-3

21. Huang SW, Wang WT, Chou LC, et al. Diabetes mellitus increases the risk of rotator cuff tear repair surgery: a population-based cohort study. *J Diabetes Complications*. 2016;30(8):1473-1477.
22. Jeong J, Park S, Ji J, et al. Trans-tendon suture bridge rotator cuff repair with tenotomized pathologic biceps tendon augmentation in high-grade PASTA lesions. *Arch Orthop Trauma Surg*. 2020;140(1): 67-76.
23. Jeong J, Shin D, Kim T, et al. Prevalence of asymptomatic rotator cuff tear and their related factors in the Korean population. *J Shoulder Elbow Surg*. 2017;26(1):30-35.
24. Kennedy P, Joshi R, Dhawan A. The effect of psychosocial factors on outcomes in patients with rotator cuff tears: a systematic review. *Arthroscopy*. 2019;35(9):2698-2706.
25. Kim HM, Dahiya N, Teefey SA, et al. Relationship of tear size and location to fatty degeneration of the rotator cuff. *J Bone Joint Surg Am*. 2010;92(4):829-839.
26. Liu Y, Fu SC, Leong HT, et al. Evaluation of animal models and methods for assessing shoulder function after rotator cuff tear: a systematic review. *J Orthop Translat*. 2021;26:31-38.
27. Massier JRA, Wolterbeek N, Wessel RN. The normative Western Ontario Rotator Cuff Index values for age and sex. *J Shoulder Elbow Surg*. 2021;30(6):e276-e281. doi:10.1016/j.jse.2020.09.026
28. Matava MJ, Purcell DB, Rudzki JR. Partial-thickness rotator cuff tears. *Am J Sports Med*. 2005;33(9):1405-1417.
29. 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(3):451-458.
30. Minagawa H, Yamamoto N, Abe H, et al. Prevalence of symptomatic and asymptomatic rotator cuff tears in the general population: from mass-screening in one village. *J Orthop*. 2013;10(1):8-12.
31. Miyazaki AN, Itoi E, Sano H, et al. Comparison between the acromion index and rotator cuff tears in the Brazilian and Japanese populations. *J Shoulder Elbow Surg*. 2011;20(7):1082-1086.
32. Motta GDRM, Amaral MVM, Rezende EM, et al. Evidence of genetic variations associated with rotator cuff disease. *J Shoulder Elbow Surg*. 2014;23(2):227-235.
33. Newton JB, Fryhofer GW, Rodriguez AB, et al. Mechanical properties of the different rotator cuff tendons in the rat are similarly and adversely affected by age. *J Biomech*. 2021;117:110249.
34. Nichols AEC, Oh I, Loiselle AE. Effects of type II diabetes mellitus on tendon homeostasis and healing. *J Orthop Res*. 2019;38(1):13-22.
35. Patel S, Gualtieri AP, Lu HH, et al. Advances in biologic augmentation for rotator cuff repair. *Ann N Y Acad Sci*. 2016;1383(1):97-114.
36. Redondo-Alonso L, Chamorro-Moriana G, Jiménez-Rejano JJ, et al. Relationship between chronic pathologies of the supraspinatus tendon and the long head of the biceps tendon: systematic review. *BMC Musculoskelet Disord*. 2014;15:377.
37. 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(6):446-452.
38. Sayampanathan AA, Andrew THC. Systematic review on risk factors of rotator cuff tears. *J Orthop Surg (Hong Kong)*. 2017;25(1):920227919.
39. 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(11):2971-2979.
40. Spargoli G. Supraspinatus tendon pathomechanics: a current concepts review. *Int J Sports Phys Ther*. 2018;13(6):1083-1094.
41. 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(9):603-605.
42. 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(15):2008-2012.
43. Watanabe A, Ono Q, Nishigami T, et al. Association between the critical shoulder angle and rotator cuff tears in Japan. *Acta Med Okayama*. 2018;72(6):547-551.

APPENDIX

TABLE A1
Search Strategy

PubMed (up to January 2021): 502 results
((Risk Factors[MeSH Terms]) OR (risk factor)) AND ((((((Rotator Cuff Injury[Title/Abstract]) OR (supraspinatus tears[Title/Abstract]) OR (Rotator Cuff Tears[Title/Abstract])) OR (Rotator Cuff Tear[Title/Abstract])) OR (Rotator Cuff Tears[MeSH Terms])) OR (Rotator Cuff Tendinosis[Title/Abstract])) OR (Rotator Cuff Tendinitis[Title/Abstract]))
Embase (up to January 2021): 266 results
1. 'risk factors'/exp OR 'risk factors': ab, ti
2. '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 'supraspinatus tears': ab, ti
3. #1 AND #2

Web of Science: 219 results
1. AB = (risk factors OR risk factor)
2. AB = (Rotator Cuff Injury OR Rotator Cuff Tears OR Rotator Cuff Tear OR Rotator Cuff Tendinosis OR Rotator Cuff Tendinitis OR supraspinatus tears)
3. #1 AND #2

TABLE A2
Newcastle-Ottawa Scale (NOS) for Risk of Bias Assessment of the Cohort Studies Included in the Review[a]

	Selection Items[b]					Outcome Items[b]			
Lead Author (Year)	1	2	3	4	Comparability	5	6	7	NOS Score
Watanabe (2018)[43]	☆	★	★	★	★	★	☆	★	6
Applegate (2017)[4]	☆	★	★	★	★	★	★	★	7
Atala (2021)[5]	☆	★	★	★	★★	★	★	★	8
Blonna (2016)[7]	★	★	★	★	★	★	★	★	8
Cunningham (2018)[11]	☆	★	★	★	★	★	★	★	7
Figueiredo (2019)[12]	★	★	★	☆	★	☆	★	★	6
Mehta (2020)[29]	★	★	★	★	★★	★	★	★	9

[a] ★, 1 point; ★★, 2 points; ☆, 0 points.
[b] 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 A3
AHRQ Score Assessing the Quality of the Cross-Sectional Studies Included in the Review[a]

	Item[b]											
Lead Author (Year)	1	2	3	4	4	5	6	7	8	9	10	AHRQ Score
Haveri (2020)[20]	+	+	+	+	NA	+	+	NA	+	+	–	8
Jeong (2017)[23]	+	+	+	NA	NA	+	+	NA	–	+	NA	6

[a]AHRQ, Agency for Healthcare Research and Quality; NA, unclear; +, yes; –, no.

[b]Key to items: 1 = define the source of information (survey, record review); 2 = list inclusion and exclusion criteria for exposed and unexposed patients (cases and controls) or refer to previous publications; 3 = indicate time period used for identifying patients; 4 = indicate whether or not patients were consecutive if not population-based; 5 = indicate if evaluators of subjective components of study were masked to other aspects of the status of the participants; 6 = describe any assessments undertaken for quality assurance purposes (eg, test/retest of primary outcome measurements); 7 = explain any patient exclusions from analysis; 8 = describe how confounding was assessed and/or controlled; 9 = if applicable, explain how missing data were handled in the analysis; 10 = summarize patient response rates and completeness of data collection; 11 = clarify what follow-up, if any, was expected and the percentage of patients for which incomplete data or follow-up was obtained.

TABLE A4
Assessment of Publication Bias

		Begg Test	
Analyzed Factor	No. of Studies	*z*	*P*
Age	8	2.60	.09
Body mass index	4	–0.34	≥.999
Male sex	9	1.15	.251
Female sex	8	0.62	.536
Arm dominance	4	–0.34	≥.999
Smoking	6	0.38	.707
Diabetes mellitus	3	0.0000	≥.999
Hypertension	2	0.0000	≥.999
Thyroid disease	2	0.0000	≥.999
Critical shoulder angle	2	0.0000	≥.999