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Subscapularis repair in reverse total shoulder arthroplasty: a systematic review and descriptive synthesis of cadaveric biomechanical strength outcomes

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A R T I C L E I N F O

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Hypothesis/Background: There is no consensus on whether to repair the subscapularis in the setting of reverse total shoulder arthroplasty (rTSA). There have been an assortment of studies showing mixed results regarding shoulder stability and postoperative strength outcomes when looking at subscapularis repair in rTSA. The purpose of this systematic review was to investigate differences in biomechanical strength outcomes of cadaveric subscapularis repair vs. no repair in rTSA.Increased force will be required to move the shoulder through normal range of motion (ROM) in cadaveric rTSA shoulders with the subscapularis repaired when compared with no subscapularis repair.

Methods: A comprehensive literature review was conducted in accordance with the 2009 Preferred Reporting Items for Systematic Review and Meta-Analysis statement. The databases used to search the keywords used for the concepts of subscapularis, reverse total shoulder arthroplasty, and muscle strength were PubMed (includes MEDLINE), Embase, Web of Science, Cochrane Reviews and Trials, and Scopus. Original, English-language cadaveric studies evaluating rTSA and subscapularis management were included, with subscapularis repair surgical techniques and strength outcomes being evaluated for each article meeting inclusion criteria.

Results: The search yielded 4113 articles that were screened for inclusion criteria by 4 authors. Two articles met inclusion criteria and were subsequently included in the final full-text review. A total of 11 shoulders were represented between these 2 studies. Heterogeneity of the data across the 2 studies did not allow for meta-analysis. Hansen et al found that repair of the subscapularis with rTSA significantly increased the mean joint reaction force and the force required by the posterior deltoid, total deltoid, infraspinatus, teres minor, total posterior rotator cuff, and pectoralis major muscles. Giles et al found that rotator cuff repair and glenosphere lateralization both increased total joint load.

Conclusion: The present review of biomechanical literature shows that repair of the subscapularis in the setting of rTSA can effectively restore shoulder strength by increasing joint reactive forces and ROM force requirements of other rotator cuff muscles and of the deltoid muscle. Available biomechanical evidence is limited, and further biomechanical studies evaluating the strength of various subscapularis repair techniques are needed to evaluate the effects of these techniques on joint reactive forces and muscle forces required for ROM.

Reverse total shoulder arthroplasty (rTSA) is increasingly used to maintain shoulder function and alleviate shoulder pain in patients with severe rotator cuff deficiency. Currently, there is no consensus on whether to repair the subscapularis tendon following placement

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of the rTSA prosthesis. Some studies find a significantly increased risk of shoulder instability if the tendon is left unrepaired in rTSA prostheses, and other studies show no difference in dislocation rates regardless of repair status.[4,10,15,16,33,39] Subscapularis repair has been found to be critical to stability when the surgeon uses an implant with medialized humeral and glenoid components, whereas a lateralized prosthesis does not require subscapularis repair because of increased stability from deltoid wrapping compression.[22,24,36]

Clinically, postoperative strength outcomes have been evaluated in a limited number of studies, comparing subscapularis repair vs. no repair during total shoulder arthroplasty (TSA) or rTSA, with no significant differences found.[3,7,15,17,38] Studies evaluating various subscapularis surgical management techniques—subscapularis peel, lesser tuberosity osteotomy, subscapularis tenotomy and subsequent repair, no repair—have had mixed results, with some studies finding significant differences in shoulder function and others finding no outcome differences between techniques.[6,19,32]

As summarized by Hansen et al,[24] the native subscapularis muscle operates in a biphasic manner, with the superior and inferior portions of the subscapularis having different innervation.[24,25,31] The superior portion inserts on the lesser tuberosity proximal to the shoulder center of rotation causing abduction, and the inferior portion inserts distal to the center of rotation causing adduction.[11,24,27,30] When the humerus shifts to an inferior-medial position in rTSA, the proximal subscapularis moves below the center of rotation, converting it into an adductor for most of the range of motion (ROM). This potentially counteracts the deltoid during shoulder abduction, increasing the force required for arm abduction as well as the joint reaction force.[24]

Cadaveric studies have examined the effect of subscapularis repair after rTSA on joint reactive forces, as well as forces required to move through normal shoulder ROM associated with activities of daily living.[22,24] The purpose of this systematic review is to investigate differences in biomechanical strength outcomes of cadaveric subscapularis repair vs. no repair in rTSA. We hypothesized that higher forces would be required to move the shoulder through ROM in cadaveric rTSA shoulders with the subscapularis repaired when compared with no subscapularis repair.

Methods

Search strategy

This study was conducted in accordance with the 2009 Preferred Reporting Items for Systematic Review and Meta-Analysis statement. Registration of this systematic review was performed in November 2021 using the PROSPERO International prospective register of systematic reviews (registration number CRD42021291800).

The search strategies were developed by a health sciences librarian who translated the search concepts using each database platform's search fields and field tags. The following databases were searched using the aforementioned strategies: PubMed (includes MEDLINE), Embase, Web of Science, Cochrane Reviews and Trials, and Scopus.

For the search terms, MeSH, Emtree, and keywords were used for the concepts of subscapularis, rTSA, and muscle strength. All 3 concepts were combined with the "AND" Boolean operator (see Supplementary Appendix S1 for detailed search strategies). A date limit was applied to each search strategy to obtain articles published beginning January 2000 to March 2021. Final searches were completed on March 5, 2021, and references downloaded for deduplication.

Deduplication was conducted using Bramer's instructions for deduplication of search results in EndNote.[5] The total number of results downloaded from all databases searched totaled 7551 with 4253 unique articles. After the final removal of duplicates (n = 140), the final number of unique results was 4113. The deduplicated results were exported to an Excel file for final review and appraisal.

Article selection

A total of 4113 articles were screened by 4 authors (F.R.P., B.W.F., A.M.P., and S.K.E.) to exclude articles not related to the topic of interest. A second independent review was performed (A.M.P.) to resolve any existing conflicts. Articles were reviewed in full, and references checked to ensure no further relevant articles were missing from the present review. Articles were excluded if they included case studies, clinical trials, anatomic total shoulder arthroplasty, fracture repair, revision surgery, or animal studies. Cadaveric English-language studies evaluating rTSA and subscapularis management were included, and subscapularis repair surgical techniques and strength outcomes were evaluated for each article meeting inclusion criteria.

Results

Search results

Following title, abstract, and full-text review and application of exclusion criteria, 2 studies (Hansen et al[24]; Giles et al[22]) were included for final data analysis. Heterogeneity of the data across the 2 studies did not allow for meta-analysis. A Preferred Reporting Items for Systematic Review and Meta-Analysis flowchart summarizing the literature search is presented in Figure 1.

Demographics

A total of 11 shoulders were represented across the 2 included studies. Demographic information for each study is presented in Table I.

Strength outcomes

Hansen et al[24] tested 5 conditions (native shoulder, native with supraspinatus tear, 42 mm Equinoxe rTSA with subscapularis repair, 42 mm Equinoxe rTSA without subscapularis repair, and 42 mm Delta III Grammont rTSA without subscapularis repair) over 5° ROM increments between 20° and 70° degrees of scapular plane abduction, with the elbow flexed at 90° to simulate the passive internal rotation gravitational torque experienced by the shoulder during activities of daily living.[22] The mean force requirements for the following muscles were measured: mid deltoid, posterior deltoid, anterior deltoid, total deltoid, infraspinatus, teres minor, total posterior rotator cuff, pectoralis major. Total joint reaction forces were also measured. When comparing shoulders that underwent Equinoxe rTSA with and without subscapularis repair, the subscapularis repair was found to increase force requirements for posterior deltoid (percent change 31.7%; P=.0139), total deltoid (13.9%; P=.0008), infraspinatus (34.5%; P=.0017), teres minor (34.2%; P=.0015), total posterior rotator cuff (34.4%; P=.0016), and pectoralis major (36.2%; P=.0075), as well as joint reaction force (28.1%; P=.0003). Repair of the subscapularis with rTSA significantly increased the force required by the posterior deltoid, total deltoid, infraspinatus, teres minor, total posterior rotator cuff, and pectoralis major muscles and also significantly increased the mean joint reaction force.

Giles et al[22] evaluated the effect of 0 and 10 mm of humeral lateralization and glenosphere lateralization on total deltoid force and joint load, with and without rotator cuff repair.[20]

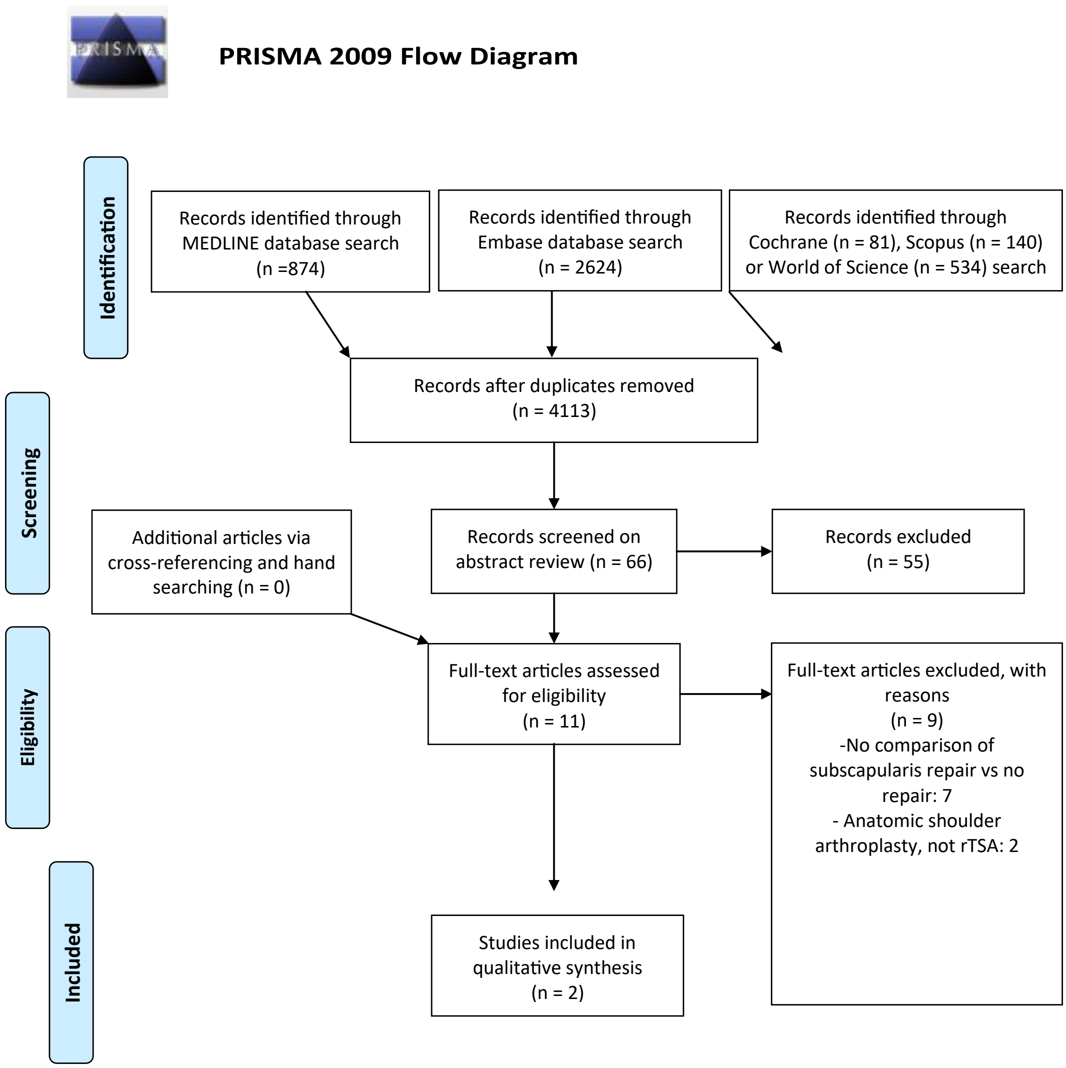

Figure 1 Flowchart of systematic review screening process. *rTSA*, reverse total shoulder arthroplasty.

Table I
Demographic information of reviews literature.

Study	Study population (N)	% Male vs. female	Average age
Hansen et al. 2015[24]	5 shoulders	100% male	65.6 ± SD 6.3 years
Giles et al. 2016[22]	6 shoulders	N/A	60 ± SD 21 years

Motion was assessed with subscapularis and infraspinatus/teres minor loading to assess the effect of repairing the rotator cuff. The study found that rotator cuff repair (+11.9% ± 5.1% BW; *P*=.002) and glenosphere lateralization (+13.3% ± 3.7% BW; *P*<.001) both increased total joint load.

Discussion

The present review includes 2 studies, which evaluate the effect of subscapularis repair on joint forces following rTSA.[22,24] Hansen et al[24] found that subscapularis repair resulted in significantly increased joint force requirements of the rotator cuff and deltoid during scapular abduction.[24] Similarly, Giles et al[22] reported that rotator cuff repair and glenosphere lateralization resulted in significantly increased total joint load.[22] Although the paucity of literature on this topic limits definitive conclusions, the findings by both Hansen et al[24] and Giles et al[22] suggest that repair of the subscapularis increases both joint load and ROM force requirements of the rotator cuff and deltoid. A total of 11 cadaveric shoulders were represented across these studies, which limits conclusions and suggests that further research is needed to evaluate the biomechanical effects of subscapularis repair in rTSA.

The rTSA procedure treats patients with rotator cuff deficiencies and anterior instability of the glenohumeral joint.[23] rTSA has continued to increase in popularity, and rTSAs made up 46% of all shoulder arthroplasties in 2014.[26,34] However, this procedure is not without limitations, and several studies note high complication rates in rTSA.[28,37,41,42] Complications include intraoperative glenoid and acromial fractures, scapular notching (most common), postoperative scapular fractures, glenohumeral instability, and glenoid or humeral component loosening.[8,13,18,29,43,44] Postoperative complications such as these necessitate rTSA intraoperative techniques that optimize shoulder strength and stability.

Although techniques continue to evolve in efforts to optimize rTSA outcomes, there remains a lack of consensus about the impact of subscapularis repair on the biomechanics of the shoulder. Some published studies have demonstrated that subscapularis repair reduces the risk of dislocation.[1,9,16,36] Oh et al published a study comparing the forces needed for anterior dislocation for different humeral neck-shaft angles, rotation, and subscapularis repair in rTSA. They reported that the loaded (repaired) subscapularis resulted in significantly higher anterior dislocation forces for all tested humeral neck-shaft angles and humeral rotation when compared with unloaded subscapularis states.[33] However, other studies have found that this repair does not significantly improve stability and actually antagonizes the posterior cuff during external rotation.[10,20] Subscapularis repair can increase the workload of the residual posterior rotator cuff and deltoid, resulting in reduced postoperative external rotation and negative consequences on overall function.[36] In addition, studies evaluating patient postoperative strength outcomes found no significant difference when comparing subscapularis repair vs. no repair.[3,7,15,17,38] Heterogenous outcomes reported in the current literature indicate that further investigation is necessary to better understand potential biomechanical and clinical benefits of subscapularis repair during rTSA.

Indications for repairing the subscapularis also relate to glenosphere positioning.[2] Subscapularis repair increases stability when using humeral and glenoid components that are medialized.[36] When the glenosphere is lateralized, there is increased stability from horizontal deltoid compression, and subscapularis repair may not be required.[36] Functional outcome results vary when the subscapularis is repaired over lateralized rTSA components. Friedman et al reported increased internal rotation and functional outcomes with a lateralized humeral design. Following subscapularis repair in this study, they found decreased passive external rotation and active abduction.[21] Roberson et al reported no differences in functional outcomes between repair and no repair in lateralized rTSA,[35] whereas Werner et al reported that subscapularis repair in lateralized rTSA has a negative effect on functional outcomes.[40] Future biomechanical evaluation of different repair techniques, with both medialized and lateralized rTSA components, are needed to further elucidate their survivability and effects on shoulder stability and will improve the understanding of forces experienced by and required of the shoulder after rTSA.

The variability of results in the biomechanical literature is also seen in the clinical literature evaluating subscapularis repair outcomes. Two recent meta-analyses of clinical studies report conflicting results. Corona et al[12] evaluated 4 comparative studies, including 978 rTSA patients. It is suggested that repair can reasonably be used whenever the subscapularis is in good condition and with no evidence of fatty degeneration. In contrast, De Fine et al[14] evaluated 6 studies including 1085 rTSA patients, finding that subscapularis repair produced no clinical benefit with regard to stability, ROM, or clinical outcomes, particularly with utilization of lateralized prostheses. Studies of clinical outcomes after subscapularis repair are confounded by a number of factors, including prosthetic design, technique used for repair, and preoperative state of the rotator cuff.

There are limitations to this study inherent in all systematic reviews. Relevant articles may not have been identified with our search criteria, despite taking multiple steps to limit this possibility. In addition, there was heterogeneity in measurement techniques and reporting of objective force outcomes in our cadaveric studies, which did not allow for true cross-comparison between the included studies. The generalizability of the findings in this systematic review and descriptive synthesis are limited by heterogeneity of outcome measurements. Finally, the inclusion of only 11 cadaveric specimens in the 2 studies in the final review limits the conclusions that can be made.

Conclusion

The present review of biomechanical literature shows that biomechanical evidence is limited, but that repair of the subscapularis in the setting of rTSA can effectively restore shoulder strength by increasing joint reactive forces and ROM force requirements of other rotator cuff muscles and deltoid. Future biomechanical studies evaluating the strength of various subscapularis repair techniques are needed to better understand the effect these techniques have on joint reactive forces and muscle forces required for ROM.

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Supplementary data

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