A systematic review of proposed rehabilitation guidelines following anatomic and reverse shoulder arthroplasty

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Study Design: Systematic review.

Objectives: To describe the literature on rehabilitation protocols post anatomic total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RTSA).

Background: Total shoulder arthroplasty is indicated for patients with glenohumeral arthritis. In this procedure, the humeral head and glenoid surface are replaced with prosthetic components. Reverse shoulder arthroplasty is indicated for patients with glenohumeral arthritis and a poor functioning rotator cuff. In this procedure, a glenosphere articulates with a humerosocket. While those surgeries are commonly performed, a thorough review of the literature is required to determine the areas of agreement and variations in post-operative rehabilitation.

Methods: A computerized search was conducted in medical databases from inception to May 21, 2018 for relevant descriptive studies on TSA and RTSA rehabilitation protocols. Methodologic index for non-randomized Studies (MINORS) tool and the modified Downs and Black tool for randomized controlled trials were used for assessment of the individual studies.

Results: Sixteen studies met the search criteria. One study was Level I, 1 Level III, 2 Level IV, and 12 Level V evidence. Ten studies described TSA and 6 RTSA rehabilitation guidelines. Following TSA, the use of a sling was recommended for a duration varying from 3 to 8 weeks and 4 of 10 published protocols included resisted exercise during the initial stage of healing (0-6 weeks). Seven of 10 published protocol recommended limiting shoulder external rotation to 30 degrees and that passive range of motion (PROM) can be fully restored by 12 weeks post-surgery. Suggested use of a sling post RTSA varied from "for comfort only" to 6 weeks, motion parameters varied from no PROM to precautionary range limits, and all protocols agreed on performing deltoid isometric exercises early post-surgery.

There was a high level of heterogeneity for the rehabilitation guidelines and associated precautions for both TSA and RTSA.

Conclusions: The majority of published protocols were descriptive in nature. Published rehabilitation strategies following TSA and RTSA are based on biomechanical principles, healing timeframes, and exercise loading principles, with little consistency among protocols. There is a need to determine optimal rehabilitation approaches post TSA and RTSA based on clinical outcomes.

Level of evidence: Therapy, level 5

Key Words: Arthroplasty, Protocol, Rehabilitation, Replacement, Shoulder

Shoulder arthroplasty procedures have more than doubled in the last decade with as many as 70 000 surgeries performed each year in the United States alone.[17, 36, 47] Anatomic total shoulder arthroplasty (TSA) is indicated for end-stage arthritic shoulder conditions in individuals with an intact rotator cuff and sufficient glenoid bone stock to allow for stable glenoid component implantation.[32] This includes primary glenohumeral osteoarthritis,[33] avascular necrosis with glenoid chondral wear,[49, 50] inflammatory arthritis with an intact rotator cuff,[31] and arthritis after instability or post-capsulorrhaphy.[12] The TSA procedure involves replacing the humeral head and glenoid with similarly shaped prosthetic components.[12 33] A reverse total shoulder arthroplasty (RTSA) is indicated for patients with massive rotator cuff tears.[7, 15] The fixed-fulcrum kinematics of the RTSA, with the glenoid as the convex articular surface, allows the deltoid to be the dominant musculature for arm elevation or abduction.[2, 6] Though the RTSA was initially designed to manage arthritis in the rotator cuff deficient shoulder,[6] the indications have expanded to include management of massive irreparable rotator cuff tears without osteoarthritis,[51] primary osteoarthritis with excessive posterior glenoid erosion,[26] and proximal humerus fractures.[6] This expanded list of pathologies to be treated by the RTSA has led to an increase in shoulder arthroplasty, with approximately one-third of all shoulder arthroplasty in the United States being RTSA, and greater than 90% in some European countries.[17, 47] Due to the increasing frequency of both TSA and RTSA, there is a need for evidence based post-surgical rehabilitation guidelines.

Dating back to the work of Hughes and Neer,[33] rehabilitation post TSA included the principle of early range of motion (ROM) in a protected and graduated manner to avoid stiffness and minimize muscle atrophy while protecting healing tissues and minimizing risks of instability or stress fractures.[7, 33, 59, 60] Since publication of this initial TSA rehabilitation protocol,[33] the surgical procedure and related rehabilitation principles have progressed, specifically with respect to the management of the subscapularis takedown,[19, 38, 41] which is

needed for humeral head exposure to initiate dislocation during surgery.[14] Surgical options, based on surgeon preference and training, include detaching the subscapularis at its bony insertion on the humerus,[39] performing a tenotomy approximately 1 centimeter proximal to its insertion, or performing a lesser tuberosity osteotomy.[14, 41] The authors of a narrative review,[52] based on lower quality studies, concluded that all surgical methods resulted in similar tendon integrity and functional outcomes.[52] In a prospective comparison of lesser tuberosity osteotomy to subscapularis tenotomy, there was no difference in tendon healing rates, American Shoulder and Elbow Surgery patient reported outcome scores, or strength.[39] In a systematic review by Levy et al,[40] the weighted mean subscapularis re-tear rate was 3.0 ±13.6% following TSA. Subscapularis failure following TSA is associated with anterior shoulder instability, pain, lower patient reported outcomes, and weakness in shoulder internal rotation.[40, 52] Differences in subscapularis surgical methods complicate comparison amongst rehabilitation protocols following TSA.[35] However, the majority of TSA rehabilitation protocols are still based on Hughes and Neer's original work, with no specificity regarding subscapularis management and a paucity of clinical data to support a preferred rehabilitative strategy.[59]

While TSA and RTSA have some similarities, there are key differences in surgical indications and post-operative precautions.[10, 33, 37, 60] Unlike TSA which is critically dependent on the function of the subscapularis,[10, 19, 38, 41] post-operative subscapularis integrity is not as critical to successful outcomes post RTSA.[27] This lesser need for protection of healing tissues post RTSA has been used as a justification for a faster, more aggressive rehabilitation protocol.[60] However, the complication rate post RTSA is significantly higher than for TSA, including dislocation and acromial stress fracture, which may create a rationale for a slower rehabilitation approach.[58] There is therefore substantial disagreement about RTSA rehabilitation guidelines.[37]

While there are multiple published rehabilitation protocols, including some based on thorough biomechanical rationales, for both TSA and RTSA,[7, 33, 60] there is no consensus for the types and timeline of physical therapy interventions following shoulder arthroplasty. [17, 36, 48] Given the prevalence of both surgical procedures within the healthcare setting, there is a need to perform a systematic review of the literature to determine the extent of consensus and level of evidence for post-surgical rehabilitation.

METHODS

Study Design

A systematic review was performed on the published rehabilitation protocols, precautions, and clinical outcomes post TSA and RTSA. The *Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)* guidelines were followed.[43] This review was prospectively registered with Prospero CRD42018095551.

Search Strategy

A comprehensive computerized search was performed with the assistance of a medical librarian (LL). Six online databases were searched: MEDLINE, CINAHL, Cochrane, Embase, PsycINFO, and Clinicaltrials.gov, from inception to May 21, 2018. Controlled vocabulary (such as MeSH-Medical Subject headings in PubMed) and keywords were incorporated for *"anatomic total shoulder arthroplasty," "reverse total shoulder arthroplasty," "rehabilitation,"* and *"rehabilitation precautions."* See the **APPENDIX** for the full search strategy. References were tracked in Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia).

Eligibility Criteria

Inclusion criteria consisted of: (1) patients treated with TSA or RTSA; (2) description of rehabilitation protocols following TSA or RTSA; (3) comparison between home based therapy versus physical therapy provided in clinical settings; (4) studies that analyzed

biomechanical and tissue physiology rehabilitation precautions and protocols; (5) publication in a peer review journal; (6) full-text articles written in English. Exclusion criteria consisted of: (1) case reports or cadaveric studies; (2) surgical revision of TSA or RTSA; (3) patients that incurred a fracture or osteonecrosis; (4) studies that reported on management of hemiarthroplasty; (5) articles that included individuals with chronic dislocation or rheumatoid arthritis; (6) studies that did not thoroughly report rehabilitation protocols; (7) surgical technical reports; (8) articles that reported only surgical complications; (9) studies that reported only non-shoulder related comorbidities; (10) papers written in a language other than English.

Study Selection

Two authors (JK and GB) independently assessed studies identified by the search criteria. Title and abstracts were initially screened. Following title and abstract screening, full-text review was performed independently by the 2 authors. If any conflicts arose, and agreement could not be reached for full-text inclusion, the third author (GG) was utilized as arbiter for final study eligibility. Following full-text screening, a hand search was performed by 2 authors (JK and GS) for any additional manuscripts.

Data Extraction

Two authors (JK and GS) collected and recorded data in a customized database using Microsoft Excel (Version 2013, Microsoft, Redmond, WA, USA). Data regarding study design, sample size, age, sex, follow up time, surgical procedure, rehabilitation timing, rehabilitation precautions, rehabilitation venue, and complications (ROM, strength, patient reported outcomes, etc.) were recorded.

Risk of Bias Assessment

All methodological risk of bias was assessed by the 2 authors (JK and GS) independently. If consensus could not be reached, the third author (GG) was used as arbiter for the final decision. The Oxford Centre for Evidence-Based Medicine (OCEBM), levels of

evidence (Level I to V)[24] was utilized to ascertain study design. The methodological index for non-randomized studies (MINORS) checklist was used as well to assess the risk of bias of the included studies.[53] With the MINORS checklist, comparative studies are rated on a maximum score of 24 whereas non-comparative studies are rated on a maximum score of 16.

The modified Downs and Black tool was used to assess the risk of bias for randomized controlled studies.[22] The modified Downs and Black uses a scale ranging from 0 to 15, with studies scoring 12 to 15 being regarded as high quality, studies scoring 10 or 11 regarded as of moderate quality, and those scoring 9 or lower regarded as low quality.[44]

Statistical Analyses

Due to the heterogeneity and non-uniformity of the data in the included studies, the results are summarized in a descriptive manner. Descriptive statistics, including means and ranges were calculated in Microsoft Excel (Version 2013, Microsoft, Redmond, WA, USA).

RESULTS

Search Results

A total of 3317 references were imported for screening. After duplicates were removed (n=3), 3314 publications underwent title and abstract screening. After 3273 publications were excluded, 41 underwent full-text review. An additional 2 papers were added through hand search of included manuscripts. Therefore, 16 papers were included in quality assessment and analysis (**TABLE 1** and **FIGURE 1**).[3, 4, 7-9, 11, 12, 20, 23, 28, 37, 45, 46, 54, 59, 60]

Risk of Bias

A total of 15 publications were assessed using the MINORS tool (**TABLE 2**), with 1 rated level III,[45] 2 rated level IV,[4, 46] and 12 rated level V evidence.[3, 7-9, 11, 12, 23, 28, 37, 54, 59, 60] The median MINORS score for the 14 non-comparative studies was 2 of 16.[3, 4, 7-9, 11, 12, 23, 28, 37, 54, 59, 60] The median MINORS score for the 2 comparative studies were 14 of 24.[45, 46] No

studies performed a prospective collection of data nor had an unbiased evaluation of endpoints. Three studies had an appropriate follow up time.[4, 45, 46]

The single randomized control trial (Level 1)[20] scored 11 of 15 on the modified Downs and Black scale (**TABLE 2**). The study did not adequately control for potential confounders.

Rehabilitation

Ten manuscripts reported on rehabilitation post TSA,[4, 8, 9, 11, 12, 20, 23, 28, 45, 59] with 9 delineating rehabilitation strategies by phases of recovery (**TABLE 3**). Five papers[4, 8, 12, 23, 28] include 3 rehabilitation phases (Time frame: 10+ weeks to 3+ months), 4 papers[9, 11, 20, 45] 4 rehabilitation phases (Time frame: 12+ weeks to 6 months), and 1 paper reported rehabilitation for different shoulder pathologies without delineation of phases of recovery.[59] Seven of 10 studies utilized a shoulder sling for a duration ranging from 2 to 8 weeks post-surgery.[4, 9, 11, 12, 20, 28, 45] Three studies allowed resisted exercise in the first 3 weeks,[8, 23, 28] with 2 of 3 initiating deltoid isometrics,[8, 23] and 1 aquatic exercise.[28] Seven of 10 studies progress to full shoulder ROM by week 8.[4, 8, 9, 12, 20, 23, 28] Only 1 study did not recommend shoulder strengthening by the second rehabilitation phase,[20] with the other 9 studies[4, 8, 9, 11, 12, 23, 28, 45, 59] including deltoid isometrics, 3 starting closed chain exercises at 4-6 weeks,[11, 23, 45] and 2 specifically beginning scapular strengthening exercises in that phase.[9, 11] All 10 studies recommended full shoulder ROM and begining shoulder strengthening by week 12,[4, 8, 9, 11, 12, 20, 23, 28, 45, 59] and only 2 studies recommended specific lifelong activity modification.[20, 45]

Six publications reported on rehabilitation post RTSA (**TABLE 4**).[3, 7, 37, 46, 54, 60] Five publications[3, 7, 46, 54, 60] described the rehabilitation protocol post RTSA and 1 used a questionnaire to gather expert opinions.[37] One study had 4 rehabilitation phases (Time frame: 4+ months),[7] 2 studies had 3 rehabilitation phases (Time frame: 12 to 16 weeks),[3, 54] and 2 had 2 rehabilitation phases (Time frame: 6 to 12 weeks).[46, 60] Four of 6 studies[7, 46, 54, 60] required sling use after surgery, with timeframe ranging from 2 to 6 weeks. Two studies[3, 60] did not

allow passive ROM (PROM) in the first 6 weeks, while the other 4 studies did. [7, 37, 46, 54] Three studies[7, 46, 54] recommended resisted exercise within the first 6 weeks post-surgery, focusing on deltoid and scapular isometrics. All 6 studies[3, 7, 37, 46, 54, 60] initiated shoulder PROM and resisted exercise by week 6. Resisted exercise consisted of deltoid and scapular strengthening,[3, 7, 37, 46, 54, 60] push ups and rows,[54] and 1 study recommended exercise when supine active shoulder flexion is well controlled.[3] All 6 studies[3, 7, 37, 46, 54, 60] recommended full passive and active ROM by week 12. Two studies[7, 60] prescribed lifelong activity modification of lifting no more than 6.8 kilograms.

Precautions

Seven studies[8, 11, 12, 20, 23, 28, 45] provided precautions for the first 6 weeks post TSA (**TABLE 3**). In 5 studies[8, 11, 12, 23, 45] shoulder flexion or scapular abduction was limited to values ranging from 90° to 130°. In 7 studies[8, 11, 12, 20, 23, 28, 45] shoulder ER was limited to values ranging from 15° to 30°, while in 1 study[8] shoulder internal rotation was limited to 45°. For the period 6 to 12 weeks post-surgery, only 2 studies[11, 45] still required ROM precautions with shoulder flexion or scapular abduction limited to 135° to 150° and shoulder ER limited to 35° to 45°. Two studies recommended lifelong precautions,[20, 45] with Denard et al[20] limiting patients to lift no more than 11.3 kilograms with the surgical arm and Mulieri et al[45] limiting patient's shoulder ROM to 55° ER and 30° extension.

For RTSA, 4 studies[3, 7, 46, 60] provided precautions for the first 6 weeks post-surgery with 3[3, 7, 60] recommending to avoid shoulder IR, adduction, and extension and Romano et al[46] requiring that individuals with a subscapularis repair limit shoulder ER for 4 weeks and perform no active shoulder IR for 8 weeks. For weeks 6 through 12 post-surgery, 2 studies[7, 60] required precautions with both continuing to limit shoulder IR, shoulder adduction, and extension. Past week 12, only Boudreau et al[7] stipulated any precautions, with patients not

allowed to lift more than 1.4 kilograms. Two studies had lifelong precautions, [7] [60] limiting patients to lift no more than 6.8 kilograms with the surgical arm.

DISCUSSION

Rehabilitation following TSA and RTSA is important for patients to have the best possible outcomes with minimal complications.[3, 7, 20, 33] Currently there is significant diversity in post-surgical rehabilitation programs, specifically regarding when exercises are initiated, the amount of allowed shoulder motion, the timing and extent of resisted exercises, and short and long term precautions.[14, 20, 37, 45] Current rehabilitation guidelines post TSA and RTSA are based on low quality evidence, with only one[20] of 16 studies being a randomized control trial and 12 studies being based on expert opinion.[3, 7-9, 11, 12, 23, 28, 37, 54, 59, 60] Thus, there is a need to for further high-quality randomized control trials investigating rehabilitation protocols post TSA and RTSA. Currently, even well-done case control trials and other retrospective designs could add substantially to this arena.

Anatomic Total Shoulder Arthroplasty

Preventing stiffness during the early recovery phase, while protecting healing tissue impacted by surgery, mandates a balance of rest and exercise.[33] Following TSA, regardless of subscapularis tendon take down procedure, the subscapularis repair requires the most protection.[10, 13, 42] Subscapularis failure after TSA can result in anterior shoulder instability, pain, weakness in internal rotation, early glenoid loosening, and lower patient reported outcome scores.[5, 10, 13] Overall, there was no consensus in subscapularis protection post-surgery. Denard et al[20] published the only TSA rehabilitation randomized control trial contrasting immediate versus 4 weeks delayed physical therapy. They found a greater subscapularis healing rate in the delayed group (96% versus 81%) which was associated with improved patient reported outcomes and shoulder flexion ROM. Some studies[4, 20] recommended utilizing pulleys for active assisted ROM immediately after surgery. Cadaveric studies suggest that

shoulder elevation can be unrestricted following subscapularis repair.[61] However, electromyographic studies have shown that seated pulley exercises are not truly passive, therefore potentially placed increased stress on the subscapularis.[21, 29]

In contrast, there was good agreement that the amount of shoulder ER ROM following subscapularis takedown should be limited to prevent passive tension on the repaired tendon, and active and resisted internal rotation exercises should be limited to prevent active tension across the repair.[8, 11, 20] Some authors[13, 30] have suggested limiting shoulder ER to neutral when performed with arm along the trunk, observing better subscapularis function with this approach. This is in contrast to other post-operative initial ER precautions of 30° to 40°, which have shown higher rates of subscapularis complications.[42] Multiple studies[4, 9, 28] in this review did not have ER ROM precautions in the first rehabilitation phase. Furthermore, 3 studies[11, 23, 45] initiated subscapularis isometrics and quadruped closed kinetic chain exercises beginning at 4 weeks. These guidelines incur increased subscapularis injury risk.[8, 11, 20, 23, 45] Early postoperative rehabilitation precautions are critical in allowing tendon healing and preventing subscapularis failure following TSA.[13, 30] There is a great need to carefully study the role of formal physical therapy following this surgical procedure, with specific attention given to the different subscapularis take-down methods and how exercise selection and progression impacts subscapularis healing. Specifically, investigations need to focus on the impact of early passive ER, resisted IR. [5, 30, 40] Recent research has found that immobilization following rotator cuff surgery can increase rotator cuff tendon healing,[57] while other studies recommend conservative ROM and loading following rotator cuff surgery.[14, 56] There is a need to determine the best time table and strategies to protect the subscapularis while improving shoulder ROM and function post TSA.

Reverse Total Shoulder Arthroplasty

There were 6 reports[3, 7, 37, 46, 54, 60] on rehabilitation guidelines following RTSA. All of these publications were written by experts and guidelines based on knowledge of anatomy,[3, 7, 46, 60] biomechanics,[7, 60] and surgical procedures.[3, 7, 46, 54, 60] However, none systematically and prospectively evaluated patient reported and clinical outcomes, and complications incidence. Additionally, the results of a survey of 30 surgeons with publications on RTSA indicated great variability on duration of use of a sling and the timing to begin shoulder motion post-surgery[37]

Reverse shoulder arthroplasty is often a recommended end-stage procedure for pain reduction and to improve functional elevation in patients with massive rotator cuff tear with or without arthritis.[7] Blacknall et al[3] and St. Pierre & Frankle[54] both stress the benefit of a prehabilitation session with a physical therapist to review expectations and practice exercises prior to surgery.[3, 54] If these expectations for recovery can be clearly explained to patients prior to the operation, outcomes may be more favorable as patient expectation has been linked to successful outcomes following shoulder arthroplasty.[55] All of the rehabilitation progressions post RTSA emphasized protection from combined movement of shoulder extension, adduction, and internal rotation (hand behind the back posture) due to risk for instability and allow scar formation around the reverse articulation, however each protocol differed regarding when to integrate this motion into recovery.[3, 7, 37, 46, 54, 60] While some authors promote rehabilitation differentiation based on other concomitant procedures such as rotator cuff repair or tendon transfers,[7, 46, 60] others do not highlight this as an important consideration.[8,39]

Previous authors[16, 18] have reported that patients with or without repair of the subscapularis had no difference in complication rates or outcomes postoperatively, however an intact subscapularis may provide improved shoulder internal rotation range of motion.[18] Therefore, if repaired, consideration should be given to protecting the healing tendon. Post-surgery, immediate concerns for rehabilitation include prosthesis protection from dislocation and acromial overload from deltoid tension, which can increase risk for stress reaction or stress

fracture.[1, 16, 25] Despite these known concerns, there was substantial disagreement between authors on proper protection time frames and progression of rehabilitation and activity. Boudreau et al[7] published rehabilitation guidelines dividing recovery into 4 phases that emphasized initial joint protection followed by gradual tissue loading. These authors promote sling use for 3-4 weeks following surgery, early deltoid and scapular isometric exercises, and a gradual restoration of PROM in the first 6 weeks of recovery. When PROM is restored, active assisted, then active motion progression, as described by Jackins, was recommended to provide gradual deltoid load to the acromion.[34] Similarly Romano et al[46] employed sling use for 2 to 4 weeks, with immediate deltoid and scapular isometrics. In contrast, Blacknall et al[3] proposed a less restrictive criterion based rehabilitation progression.[3] These authors did not promote use of a sling, and allowed rehabilitation progression based on demonstration of good deltoid and pain control and no instability signs.[3] A final rehabilitation method proposed by St. Pierre & Frankle,[54] promoted surgeon directed rehabilitation for patients with exercises performed at home using web-based videos. A sling was worn for 4 weeks, during which time deltoid and scapular isometrics were performed. Supported elevation was allowed without motion limitation at 3 weeks, and strengthening with elastic band exercises, and shoulder extension ensued at 5 to 7 weeks. Pain was used as the main criterion to advance exercise, and a unique feature of this rehabilitation plan was the integration of core stability exercises. Referral for formal physical therapy was reserved for patients who were not progressing well, or who had higher level rehabilitation goals.[54] Other authors[60] suggested a more conservative approach, promoting 2 to 6 weeks of full immobilization, depending on patient factors, deferral of deltoid and scapular strengthening for 6 weeks, with formal rehabilitation continuing for 4 to 6 months. Even with reported stress fracture and deltoid overload risk,[1, 16, 25] healing and protective time frames did not have expert agreement.[3, 7, 37, 46, 54, 60]

Limitations

This systematic review limited the search to articles with full text published in the English language which may have resulted in a loss of literature and a potential bias. The body of evidence was primarily based off of Level V evidence, which had low methodological quality. The MINORS tool is specifically designed for non-randomized observational studies.[53] Therefore, with the majority of studies being clinical commentaries or expert opinions, there is an inherent bias in this study's quality assessment.

CONCLUSION

Currently there is low consensus amongst published rehabilitation guidelines post TSA and RTSA, precluding specific clinical best practice suggestions. The only consensus is that therapy is believed to play an important role in optimizing patient outcomes, and that there is a need for high quality prospective research.[3, 20, 54, 60] Objective scientifically based information is essential in determining best-practice to optimize outcomes for patients post TSA or RTSA surgery.

KEY POINTS:

Findings: The majority of published rehabilitation guidelines post TSA and RTSA are clinical commentaries, with little consensus on timeline for initiation and progression of exercises.

Implications: There is a need for prospective randomized controlled trials comparing rehabilitation methodology after TSA and RTSA to determine best practice.

Caution: Due to the heterogeneous findings, and the paucity of substantial data, there is not enough evidence to create specific clinical best practice suggestions regarding TSA and RTSA rehabilitation.

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TABLE 1. Inclusion and exclusion criteria

Key Concept	Inclusion Criteria	Exclusion Criteria
Population	• GHJ osteoarthritis • Rotator cuff arthropathy • Rotator cuff deficiency	• Humeral fracture • Osteonecrosis • Rheumatoid arthritis • Chronic dislocation
Exposure	• Primary TSA • Primary RTSA	• TSA revision • RTSA revision • Shoulder hemiarthroplasty
Outcomes	• Thoroughly reported rehabilitation protocols • Home based therapy versus physical therapy • Biomechanical and tissue physiology rehabilitation concepts	• In situ or cadaveric studies • Biomechanical studies • Reported only complication • Reported only outcomes

Abbreviations: TSA, anatomical total shoulder arthroplasty; RTSA, reverse total shoulder arthroplasty

TABLE 2. Descriptors of manuscripts included in the review

Manuscript	Design (Level of Evidence)	Risk of Bias*	Surgical Procedure
Blacknall et al.[3] 2017	5 (Expert Opinion)	2/16	RTSA
Boardman et al.[4] 2001	4 (Case Series)	7/16	TSA
Boudreau et al.[7] 2007	5 (Expert Opinion)	2/16	RTSA
Brander et al.[8] 1995	5 (Expert Opinion)	2/16	TSA
Brown et al.[9] 1998	5 (Expert Opinion)	2/16	TSA
Cahill et al.[11] 2014	5 (Expert Opinion)	2/16	TSA
Cameron et al.[12] 2001	5 (Expert Opinion)	2/16	TSA
Denard et al.[20] 2016	1 (Randomized Control Trial)	11/15**	TSA
Etier et al.[23] 2016	5 (Expert Opinion)	2/16	TSA
Fusaro et al.[28] 2013	5 (Expert Opinion)	2/16	TSA
Kwaees et al.[37] 2014	5 (Expert Opinion)	4/16	RTSA
Mulieri et al.[45] 2010	3 (Case Control)	16/24	TSA
Romano et al.[46] 2017	4 (Case Series)	12/24	RTSA
St. Pierre &Frankle[54]	5 (Expert Opinion)	2/16	RTSA
Wilcox et al.[59] 2005	5 (Expert Opinion)	2/16	TSA
Wolff et al.[60] 2017	5 (Expert Opinion)	2/16	RTSA

Abbreviations: TSA, anatomical total shoulder arthroplasty; RTSA, reverse total shoulder arthroplasty

* Rated using MINORS (0-16 and 0-24 point scales) for non-comparative and comparative studies, respectively

** Rated using Downs and Black (0-15 point scale)

TABLE 3: Rehabilitation guidelines following Anatomic Total Shoulder Arthroplasty

Study	Sling	PROM	AAROM	AROM	Resisted Exercise	Precautions
Boardman et al.[4] 2001	0-6 wks	0-3 wks: Shoulder stretching at home	3-5 wks: Pulley exercises 5-10 wks: ER and IR at 0° and 90° abduction	0-4 wks: Elbow, wrist, and hand 10+ wks: Gradual return to shoulder function	5-10 wks: Shoulder isometrics 10+ wks: Exercises with elastic bands	None
Brander et al.[8] 1995	0-4 wks	0 -3 wks: 90° flexion and abduction, 45° IR, 15° ER 4-12 wks: Greater than 90° flexion and abduction	3-4 wks: Wall walking 6-12 wks: Greater than 90°	0-6 wks: ADLs with non-surgical side 6-12 wks: Past 90° two handed ADL's 12+ wks: AROM without resistance in all planes and full ROM Body weight exercise in all planes	0-3 wks: Deltoid isometrics 3-6 wks: Deltoid?? vigorous isometrics 6-12 wks: Progress to isotonics as tolerated 12+ wks: Progressive resistance	None
Brown et al.[9] 1998	0-4 wks	0-4 wks: ER, IR, flexion 4-6 wks: continue with ER, IR, flexion	4-6 wks: Horizontal adduction, ER at 90° abduction	4-6 wks: Flexion supine 6-10 wks: Flexion and abduction in sitting	4-6 wks: Shoulder isometrics, scapular and distal arm musculature 6-10 wks: ER and IR 10 wks - 6 months: Add weights to active ROM exercise, wall push ups, functional specificity	None
Cahill et al.[11] 2014	0-6 wks	0-4 wks: 120° flexion, 30° ER, 4-6 wks: Horizontal adduction, 90° ER	0-4 wks: Pendulums 4-10 wks: ER and pulleys	0-4 wks: Elbow, wrist, and hand 4-10 wks: Shoulder, all planes	4-10 wks: Deltoid isometrics closed chain exercises, scapular retraction 10-16 wks: Isometrics, scapular strengthening, resistance exercises 16-22 wks: Functional strength through full ROM, gym program	4- 10 wks: 150° flexion, 45° ER
Cameron et al.[12] 2001	0-4 wks	0-6 wks: 120° flexion, 30° ER 6-10 wks: Full ROM	0-6 wks: Pendulums 6-10 wks: Pendulums	0-6 wks: Elbow, wrist, and hand 6-10 wks: Shoulder flexion and abduction 11+wks: Full activities as tolerated	6-10 wks: ER and IR exercises with elastic bands 11+ wks: Free weight exercises	0-6 wks: Protect subscapularis
					8-12 wks: Strength as tolerated	

Denard et al.[20] 2016 (Immediate)	0-4 wks	Flexion, as tolerated, 30° ER 4-8wks: ER as tolerated	0-4 wks: Pulleys, 4-8 wks: Flexion	0-4 wks: Elbow, wrist, and hand, 4-8 wks: Flexion, 8-12 wks: Full ROM as tolerated	12+ wks: Activity as tolerated	12+ wks: 11.3 kilograms
Denard et al.[20] 2016 (Delayed)	0-4 wks	0-4 wks: None 4-8 wks: Flexion and ER	8-12 wks: Begin AAROM	0-4 wks: Elbow, wrist, and hand 8-12 wks: ROM as tolerated	8-16 wks: Strength as tolerated 16+ wks: Activity as tolerated	16+ wks: 11.3 kilograms
Etier et al.[23] 2016	0-6 wks	0-6 wks: 130° flexion, 25° ER 6-12 wks: Movement as tolerated in all planes	0-6 wks: Pendulum, 6-12 wks: Movement as tolerated in all planes	0-6 wks: Elbow, wrist, and hand 6-12 wks: Flexion 12+wks: Full ROM as tolerated	0-6 wks: Deltoid isometrics 6-12 wks: Closed kinetic chain exercises, light resistance exercises 12+ wks: Isometrics and resistive exercises	None
Fusaro et al.[28] 2013	0-6 wks	0-6 wks: PROM device 6 wks to 3 months: Full ROM	0-6 wks: Pendulums and pulleys, 6 wks-3 months: Full ROM	0-6 wks: Elbow, wrist, and hand 6 wks - 3 months: Non-painful ROM	0-6 wks: Aquatic physical therapy, 6 wks - 3 months: Proprioception isometrics, 3+ months: return to driving and work, 6+ months: moderate sports	None
Mulieri et al.[45] 2010 (PT Group)	0-3 wks	0-3 wks: 20° ER, 120 scapular abduction, sling use except during therapy 4-6 wks: ER to 35°, sling use except during therapy 6-12 wks: 55° ER	4-6 wks: Scapular abduction to 135° with wand	0-3 wks: Elbow, wrist, and hand 4-6 wks: Elbow, wrist, and hand 7-9 wks: Flexion, ER, extension, diagonals	4-6 wks: Closed kinetic chain exercises, isometrics for IR, ER, extension, abduction, and depression 7-9 wks: Isometrics at various angles, biceps and triceps isometrics, closed kinetic chain exercise 9-12 wks: elastic band and isometrics	None
Mulieri et al.[45] 2010 (Home Group)	0-8 wks	0-8 wks: Pendulum 9 wks: Discontinue sling use 9+wks: 55° ER	None	0-8 wks: Elbow, wrist, and hand	14+ wks: Elastic band exercises and isometrics	14+ wks: 55° ER

Abbreviations: AAROM, active assisted range of motion; ADL, activities of daily living; AROM, active range of motion; ER, external rotation; IR, internal rotation, PROM, passive range of motion; PT, physical therapy

TABLE 4. Rehabilitation Guidelines post Reverse Total Shoulder Arthroplasty

Study	Sling	PROM	AROM	Resisted Exercise	Precautions
Boudreau et al.[7] 2007	0-4 wks	0-6 wks: Elevation 90-120°, ER 30°, 6-12 wks: Flexion and ER as tolerated 12-16 wks: All movements as tolerated	0-6 wks: Elbow, wrist, and hand, 6-12 wks: Shoulder as tolerated	0-6 wks: Submaximal deltoid and scapular isometrics 6-12 wks: Deltoid isometrics 12-16 wks: Slow strength progression for deltoid and scapula 4+ months: Stretch and strengthen with maintenance programs	0-6 wks: Avoid IR, adduction, and extension 6-12 wks: No adduction, IR or extension 12-16 wks: Do not exceed 1.4 kilograms, enforce good mechanics for elevation 4+ months: 6.8 kilograms
Blacknall et al.[3] 2017*	Comfort only	None	0-6 wks: Assisted elevation to 90° and ER to 30°, 6-12 wks: 0-90° active short level arm flexion, incline surface, progress to straight arm flexion, 12-16 wks: ROM as tolerated	0-3 wks: Deltoid isometrics 3-6 wks: Vigorous isometrics 6-12 wks: Progress to isotonics as tolerated 12+ wks: Progressive resistance	0-6 wks: Avoid ER, IR, abduction, and extension
St. Pierre & Frankle[54] 2011	0-4 wks	0-6 wks: Pendulums (supports 2 weeks, then unsupported) 6-12 wks: As tolerated 12-16 wks: As tolerated, add sleeper stretch	0-6 wks: Elbow, wrist, and hand, table slides for supported elevation and wand assisted elevation in supine 12-16 wks: As tolerated	4-6 wks: Shoulder isometrics, scapular musculature and distal arm 6-10 wks: ER and IR 10 wks - 6 months: Weights to active exercise, wall push ups, functional specificity	None
Romano et al.[46] 2017**	0-2 wks	0-12 wks: As tolerated	0-6 wks: Flexion 60-120°, ER 20-30° 6+ wks: As tolerated	0-6 wks: Deltoid and scapular isometrics 6-12 wks: Deltoid and scapular musculature using elastic band	0-6 wks: If subscapularis repaired, no PROM ER for 4 wks and no resisted IR for 2 months

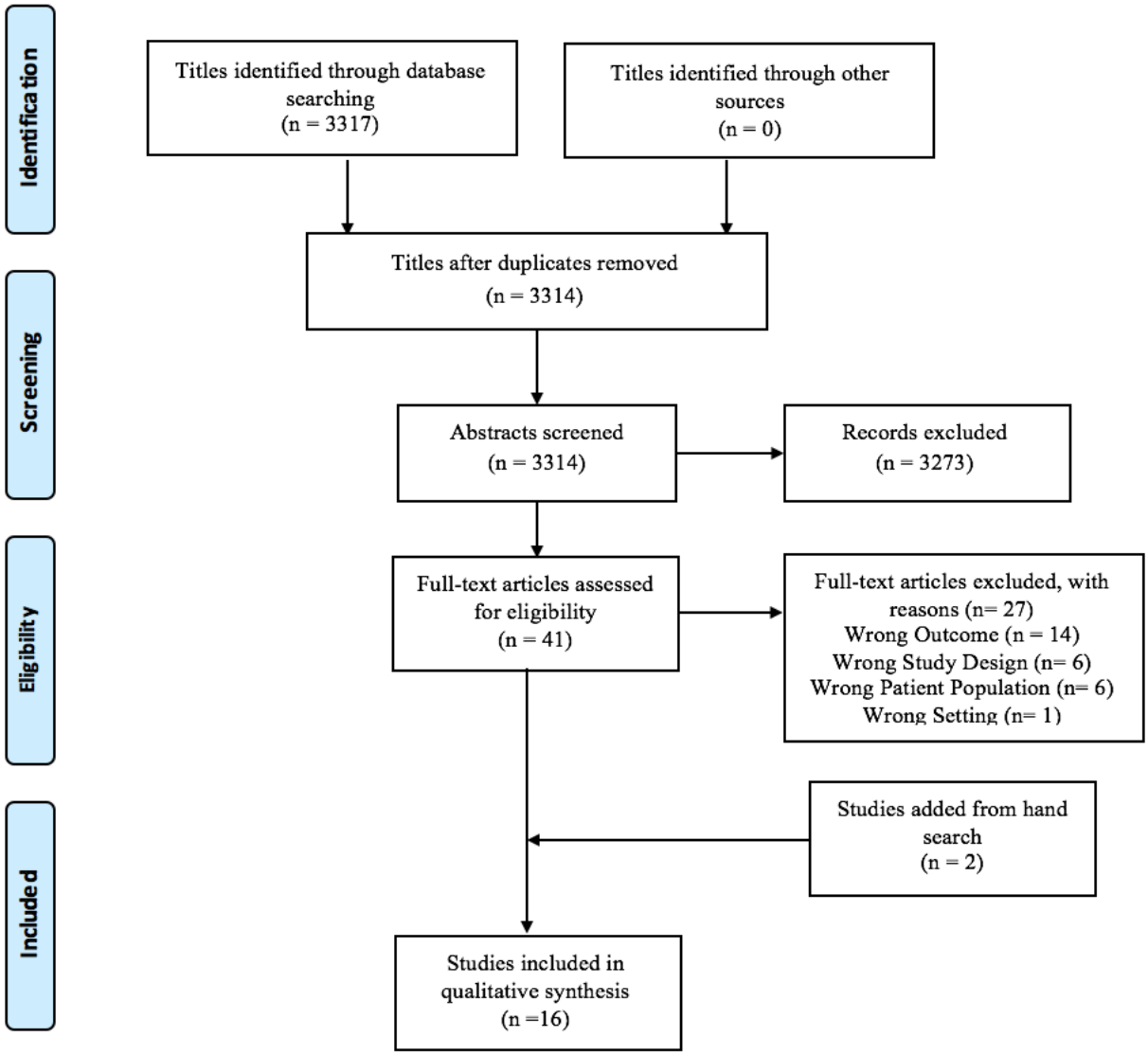
(Group A)					
Romano et al.[46] 2017** (Group C)	0-4 wks	0-12 wks: As tolerated	0-6 wks: Flexion 60-120°, ER 20-30° 6+ wks: As tolerated	0-6 wks: Deltoid and scapular isometrics 4 wks: Begin AROM exercises 8 wks: Deltoid and scapular musculature using elastic band	0-6 wks: If subscapularis repaired, no PROM ER for 4 wks and no resisted IR for 2 months
Wolff et al.[60] 2017	2-6 wks	0-6 wks: No PROM 6+ wks: As tolerated	Does not say	6-12 wks: Deltoid and scapular strength progression: isometric to isotonic	0-6 wks: Avoid IR, adduction, and extension 6-12 wks: Continue no adduction, IR, and extension 4+ months: 6.8 kilograms

Abbreviations: AAROM, active assisted range of motion; AROM, active range of motion; ER, external rotation; IR, internal rotation, PROM, passive range of motion

* timeframes do not apply; progression is strictly criteria dependent

** differentiates progression into Group A (Cuff tear arthropathy, primary Osteoarthritis cuff deficiency with pseudoparalysis); Group B – (all others not in A or C) and Group C (rheumatoid arthritis, fracture).

FIGURE 1. PRISMA Flow Diagram



APPENDIX. Search Strategy

(((((("Shoulder Joint"[Mesh] OR "Shoulder"[Mesh] OR shoulder[tiab])) AND ("Arthroplasty, Replacement"[mesh] OR arthroplasty[tiab] OR arthroplastic[tiab] OR "total joint"[tiab] OR "replacement"[tiab] OR Periprosthetic[tiab] OR “peri-implant”[tiab] OR "Shoulder Prosthesis"[Mesh] OR "Arthroplasty, Replacement, Shoulder"[Mesh] OR hemiarthroplasty[tiab] OR prosthesis[tiab] OR prosthetic[tiab] OR endoprosthe*[tiab] OR implant[tiab] OR implants[tiab])) AND (Physical Therapy Modalities[MeSH] OR “physical therapy” [tiab] OR “physical therapies” [tiab] OR Physiotherapy[tiab] OR physiotherapies[tiab] OR Exercise[MeSH] OR Exercise[tiab] OR Exercises[tiab] OR “Exercise Therapy”[tiab] OR “Resistance Training” [tiab] OR Rehabilitation[MeSH] OR Rehabilitation[subheading] OR Rehabilitation[tiab] OR Rehabilitate[tiab] OR Rehabilitating[tiab] OR Rehabilitates[tiab] OR Rehabilitated[tiab] OR "therapy"[Subheading])) AND ((randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized[tiab] OR randomised[tiab] OR randomization[tiab] OR randomisation[tiab] OR randomly[tiab] OR trial[tiab] OR groups[tiab] OR Clinical trial[pt] OR “clinical trial”[tiab] OR “clinical trials”[tiab] OR "evaluation studies"[Publication Type] OR "evaluation studies as topic"[MeSH Terms] OR "evaluation study"[tiab] OR evaluation studies[tiab] OR "intervention studies" [tiab] OR "intervention study"[tiab] OR "intervention studies"[tiab] OR "case-control studies"[MeSH Terms] OR "case-control"[tiab] OR "cohort studies"[MeSH Terms] OR cohort[tiab] OR "longitudinal studies"[MeSH Terms] OR "longitudinal”[tiab] OR longitudinally[tiab] OR "prospective"[tiab] OR prospectively[tiab] OR "retrospective studies"[MeSH Terms] OR "retrospective"[tiab] OR "follow up"[tiab] OR "comparative study"[Publication Type] OR "comparative study"[tiab] OR systematic[subset] OR "meta-analysis"[Publication Type] OR "meta-analysis as topic"[MeSH Terms] OR "meta-analysis"[tiab] OR "meta-analyses"[tiab]))) NOT (Editorial[ptyp] OR Letter[ptyp] OR Case Reports[ptyp] OR case report[tiab] OR Comment[ptyp])) AND English[lang]) NOT (animals[mesh terms] NOT humans[mesh terms])