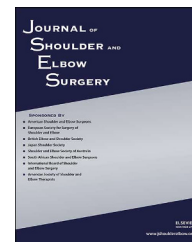


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Return to weightlifting after shoulder arthroplasty: an ASES multicenter study predicting performance after reverse shoulder arthroplasty and anatomic shoulder arthroplasty

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ABSTRACT

Background: Return to sport and sport-specific performance following shoulder arthroplasty are not well-characterized, particularly in strength-based activities such as weightlifting. This study evaluates return-to-weightlifting rates, exercise-specific performance, and patient-reported outcomes following reverse shoulder arthroplasty (rTSA) and anatomic shoulder arthroplasty (aTSA).

Methods: We conducted a multicenter analysis of patients from 24 American Shoulder Elbow Society (ASES) surgeons across 17 institutions who underwent rTSA or aTSA and completed sport-specific return to sport questionnaires. Study parameters were defined by the Delphi method, requiring 75% agreement for consensus. Data collected included pre- and post-operative participation, timing of return, and patient-reported outcomes on performance, frequency, enjoyment, and satisfaction relative to pre-operative status. Specific weightlifting abilities (bench press, bicep curl, overhead press, deltoid raise, and pushups) were assessed. Subgroup analyses included age- and sex-matched comparisons of rTSA and aTSA for glenohumeral osteoarthritis (GHOA) and rTSA for GHOA vs. rotator cuff arthropathy. Statistical analyses included t-tests, chi-square or Fisher exact test, and multivariable logistic regression. Statistical significance was set at $P < .05$.

Results: Among 175 weightlifters (mean follow-up of 23.3 ± 7.6 months), 93.1% returned to weightlifting and 79.4% reported maintained or improved performance. Most returned by 3–6 months (39.3%), with an additional 29.5% returning by 7–12 months. Propensity-

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matched analysis of 54 rTSA patients and 54 aTSA patients for GHOA found similar return rates (rTSA: 98.1% vs. aTSA: 96.3%, $P > .999$) and likelihood of improved or maintained performance (rTSA: 90.7% vs. aTSA: 79.6%, $P = .176$). However, rTSA patients were more likely to maintain or increase weightlifting frequency (90.7% vs. 72.2%, $P = .026$) and had higher improvement in deltoid raise ability (82.6% vs. 50.0%, $P = .020$). No significant differences were found in bench press, overhead press, biceps curls, or pushups. Within the rTSA cohort, GHOA patients reported greater post-operative enjoyment (95.6% vs. 76.0%, $P = .021$) and a percent who improved or maintained frequency (86.7% vs. 60.0%, $P = .025$) compared to rotator cuff arthropathy patients. Multivariate regression found no significant predictors of worse post-operative performance (all $P > .05$).

Conclusion: Most patients resume weightlifting after shoulder arthroplasty, often maintaining or improving performance. Although outcomes are comparable by arthroplasty type, rTSA may afford better deltoid function and increased participation frequency. Additionally, pre-operative diagnosis appears to influence enjoyment and engagement following rTSA, despite similar improvements across specific exercises. These findings highlight the complex nature of recovery and the value of personalized pre-operative counseling.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: rTSA; aTSA; Weightlifting; Return to sport; Shoulder arthroplasty; Glenohumeral osteoarthritis; Rotator cuff arthropathy; Multicenter

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As rates of shoulder arthroplasty continue to rise globally, understanding return-to-sport (RTS) outcomes has become increasingly important for guiding post-operative counseling, rehabilitation protocols, and surgical decision-making.^{4,24} This growth is driven largely by the expanding use of reverse shoulder arthroplasty (rTSA),^{31,38} alongside a shifting demographic toward younger, more active individuals with higher functional demands and expectations for post-operative performance.⁶ Consequently, RTS—particularly for upper-body dominant activities—has emerged as an important metric of surgical success and patient satisfaction.^{2,24,33,37}

Both anatomic total shoulder arthroplasty (aTSA) and rTSA have demonstrated excellent clinical outcomes and pain relief across a spectrum of indications.²¹ However, despite these successes, data on sport-specific functional recovery remain limited. While prior studies report RTS rates ranging from 75 to 85%,² most focus on low- to moderate-demand activities such as golf, swimming, and tennis,^{9,14,26} which impose different biomechanical demands on the shoulder.²² In contrast, literature focused on strength-based activities such as weightlifting—which involve large closed and open chain forces and dynamic shoulder loading¹¹—remains sparse, with available studies limited by small sample sizes, lack of propensity score matching, and assessment of few outcome parameters.³ Recent estimates indicate that approximately 45% of the U.S. population participates in some form of resistance training,¹⁵ underscoring the clinical relevance of understanding post-operative outcomes specific to these activities.

Resistance training confers well-established musculoskeletal and systemic health benefits, including increased bone mineral density, improved cardiovascular health, and better management of osteoarthritis symptoms,^{23,41,42} making successful return a meaningful goal for patients. Historically, aTSA has been regarded as the gold standard treatment for osteoarthritis, particularly in younger, high-demand patients with intact rotator cuffs,^{7,34,35} due to its anatomic reconstruction that preserves native biomechanics and potentially optimizes range of motion and strength.^{17,42} However, accumulating evidence supports an expanding role of rTSA in this population,^{27,30,40,43} presenting an

opportunity to better understand how these procedures compare in facilitating return to high-demand activities.

The purpose of this study is to evaluate return-to-weightlifting rates, exercise-specific performance, and patient-reported outcomes in a multicenter cohort of patients undergoing rTSA and aTSA. Our data may help to better inform patient expectations, optimize rehabilitation strategies, and guide clinical decision-making.

Materials and methods

Study design

We conducted a multicenter retrospective cohort study involving patients treated by 24 American Shoulder and Elbow Surgeons (ASES) surgeons across 17 institutions who underwent rTSA or aTSA and completed sport-specific RTS questionnaires. Study parameters—including inclusion and exclusion criteria—and questionnaire design were established through the Delphi method, requiring 75% agreement for consensus.

Inclusion criteria consisted of patients undergoing either rTSA or aTSA between April 2021 and April 2024 with a minimum of 1-year and a maximum of 3-year post-operative follow-up. Eligible pre-operative diagnoses included glenohumeral osteoarthritis (GHOA), rotator cuff arthropathy (RCA), post capsulorrhaphy arthritis, fracture sequelae, acute fracture, avascular necrosis, inflammatory arthritis, massive rotator cuff tear without arthritis, and revision arthroplasty. Patients with diverse pre-operative diagnoses were included to enhance external validity and reflect real-world arthroplasty practice, with diagnosis-specific effects evaluated through prespecified subgroup analyses.

Timing of patient contact varied by institution, with all eligible patients invited to participate; only those who completed the RTS questionnaires were included in the study. Exclusion criteria included incomplete questionnaires, follow-up less than 1 year or greater than 3 years, or comorbidities precluding sport participation.

Post-operative rehabilitation protocols were not standardized across institutions and were determined by the treating surgeon; however, they generally followed similar phase-based principles, including early protected range of motion, progressive strengthening, and gradual RTS activities as tolerated.

Weightlifting-specific questionnaires

The RTS questionnaires assessed participation in several sports, including golf, pickleball, tennis, running, weightlifting, yoga, and swimming. Patients could report participation in up to 2 sports, with this study focusing on weightlifting outcomes. The primary outcome of interest was post-operative weightlifting performance relative to pre-operative level, categorized as improved/stayed the same or worsened. Performance was assessed using patient-reported categorical comparisons to pre-operative baseline rather than objective strength or load-based measurements. Secondary outcomes included the ability to return to weightlifting (yes/no), frequency of participation compared to pre-operative level (increased/same vs. decreased), and enjoyment relative to pre-operative status (more/same vs. less). Patients rated overall satisfaction with their operative shoulder during weightlifting activities on a numeric scale from 0 (least satisfied) to 10 (most satisfied). Time to return to weightlifting was recorded in predefined intervals: <3 months, 3-6 months, 7-12 months, and 12+ months. Additionally, detailed weightlifting-specific functional assessments were performed. Patients reported their ability to perform bench press, bicep curls, overhead press, deltoid raises, and pushups before and after surgery. The proportion of patients unable to perform each exercise was recorded pre- and post-operatively, and improvements rates were calculated as the percentage of patients who regained the ability to perform the exercise.

Delphi method

The Delphi method is an iterative consensus-building survey process among a group of experts.²⁹ Eight contributing ASES surgeons utilized this method to define study parameters and develop the weightlifting-specific questionnaires. Consensus was defined as a minimum of 75% agreement on each questionnaire. Anonymity was maintained throughout to minimize bias. The process included 16 rounds of closed and open-ended questions, with responses aggregated and shared after each round among the group. Items lacking consensus were revised and redistributed until consensus was reached. No participant dropout occurred during this process.

Statistical analysis

Data were assessed for normality to determine appropriate parametric or nonparametric testing. Continuous variables are reported as means and standard deviations, while categorical variables are reported as counts and percentages.

Two propensity score-matched analyses were performed: one comparing primary rTSA versus aTSA outcomes in patients with GHOA, and the other comparing rTSA outcomes in patients with GHOA versus RCA. Matching was based on age

Table I – Weightlifting participant cohort demographics

Parameter	n = 175
Age	66.6 ± 9.1
Sex	
Male	73.1% (128)
Female	26.9% (47)
Type of arthroplasty	
rTSA	66.3% (116)
TSA	33.7% (59)
BMI	28.3 ± 4.8
Follow-up A (mo)	23.3 ± 7.6
ASA comorbidity score >2, n = 29	16.6% (29)
Comorbidities	
Hypertension	36.6% (64)
Hypercholesterolemia	35.4% (62)
Diabetes mellitus	6.9% (12)
Osteoporosis	3.4% (6)
Obesity	29.7% (52)
History of smoking	21.7% (38)
Prior ipsilateral shoulder surgery	27.4% (48)
Complications	3.4% (6)
Primary diagnosis	
GHOA	70.3% (123)
RCA	14.9% (26)
PCA	3.4% (6)
Fracture sequelae	2.3% (4)
Acute fracture	1.1% (2)
Avascular necrosis	0.6% (1)
Inflammatory arthritis	1.1% (2)
Massive cuff tear without arthritis	1.7% (3)
Failed arthroplasty	4.0% (7)

GHOA, glenohumeral osteoarthritis; RCA, rotator cuff arthropathy; rTSA, reverse shoulder arthroplasty; BMI, body mass index; TSA, anatomic total shoulder arthroplasty; PCA, post capsulorrhaphy arthritis; ASA, American Society of Anesthesiologists Physical Status Classification System.

and sex. Categorical variables were compared using Pearson's chi-squared test, and continuous variables were analyzed using the Wilcoxon test.

A multivariable logistic regression model included clinically relevant variables such as revision status, post-operative complications, and underlying diagnosis to identify patient factors associated with worse post-operative performance across weightlifting activities. Results are presented as odds ratios with 95% confidence intervals. Wald statistics and analysis of variance plots were generated to assess the relative strength of predictor variables.

All statistical analyses were performed using open-source R statistical software (R Foundation for Statistical Computing, Vienna, Austria), with multivariable models fit using the rms package (Ref – FE HJ. rms: Regression Modeling Strategies. <https://cran.r-project.org/web/packages/rms/>).

Results

Overall weightlifter demographics

(Table I) One hundred seventy-five patients indicated that they participated in weightlifting, with a mean follow-up of

Table II – Weightlifting participant outcome breakdown

Parameter	Weightlifting participants (n = 175)
Still playing post-operatively?	
Yes	93.1% (163)
Performance level compared to pre-operative	
Improved/stayed the same	79.4% (139)
Enjoyment level compared to pre-operative	
More enjoyable/same amount	87.4% (153)
Frequency of participation compared to pre-operative	
More frequently/same amount	77.1% (135)
How long after surgery did you resume sport participation?	n = 173
<3 mo	19.7% (34)
3-6 mo	39.3% (68)
7-12 mo	29.5% (51)
12+ mo	11.6% (20)
Satisfaction score	
0-10	9.2 ± 1.9

23.3 ± 7.6 months. The mean age was 66.6 ± 9.1 years, with 73.1% (n = 128) males and a mean body mass index (BMI) of 28.3 ± 4.8. rTSA was performed in 66.3% of patients (n = 116), while 33.7% underwent aTSA (n = 59). The primary diagnosis was GHOA in 70.3% of patients (n = 123) and RCA in 14.9% (n = 26).

Weightlifting participant outcome breakdown

(Table II) Overall, 93.1% of participants (n = 163) returned to weightlifting post-operatively. Among the 12 participants who did not return to weightlifting, 4 (33.3%) reported it was due to reasons unrelated to their shoulder. Additionally, 79.4% of participants (n = 139) reported their performance either improved or stayed the same after surgery. Moreover, 87.4% of participants (n = 153) reported more or the same enjoyment since surgery. Also, 77.1% of participants (n = 135) reported more or the same frequency of participation since surgery. Most participants (39.3%, n = 68) returned to weightlifting between 3 and 6 months post-operatively, while 29.5% (n = 51) returned between 7 and 12 months post-operatively, and an additional 19.7% (n = 34) returned less than 3 months after surgery. Overall, patients reported a mean surgery satisfaction score of 9.2 ± 1.9.

Age and sex propensity score–matched reverse shoulder arthroplasty vs. anatomic shoulder arthroplasty for glenohumeral osteoarthritis

(Tables III and IV) After propensity score matching by age and sex for patients undergoing rTSA for GHOA and aTSA for GHOA, both cohorts consisted of 54 participants. There were no significant differences in age (rTSA: 66.9 ± 6.9 years versus aTSA: 66.3 ± 7.3 years; P = .775), sex (rTSA: 77.8% male versus aTSA: 79.6% male, P > .999), or BMI (rTSA: 29.0 ± 4.7 versus aTSA: 28.3 ± 5.0, P = .702). There were no differences in the overall ability to return to weightlifting (rTSA: 98.1%, n = 53 vs. aTSA: 96.3%, n = 52, P > .999), post-operative satisfaction with their

Table III – Weightlifting participant breakdown of age- and sex-matched rTSA and TSA cohorts

Parameter	Weightlifting		
	rTSA for OA n = 54	TSA for OA n = 54	P value
Age*	66.9 ± 6.9	66.3 ± 7.3	.775
Sex*			
Male	77.8% (42)	79.6% (43)	>.999
Female	22.2% (12)	20.4% (11)	
BMI	29.0 ± 4.7	28.3 ± 5.0	.702
Still lifting weights post-operatively?			
Yes	98.1% (53)	96.3% (52)	>.999
Performance level compared to pre-operative			
Improved/stayed the same	90.7% (49)	79.6% (43)	.176
Enjoyment level compared to pre-operative			
More enjoyable/same amount	94.4% (51)	88.9% (48)	.486
Frequency of participation compared to pre-operative			
More frequently/same amount	90.7% (49)	72.2% (39)	.026*
How long after surgery did you resume sport participation?			
<3 mo	18.5% (10)	20.4% (11)	.307
3-6 mo	40.7% (22)	38.9% (21)	
7-12 mo	24.1% (13)	33.3% (18)	
12+ mo	16.7% (9)	5.6% (3)	
Satisfaction score			
0-10	9.6 ± 0.8	9.1 ± 1.9	.264

OA, osteoarthritis; rTSA, reverse shoulder arthroplasty; BMI, body mass index; TSA, anatomic total shoulder arthroplasty.
* Significance is P ≤ .05.

shoulder during weightlifting (rTSA: 9.6 ± 0.8, aTSA: 9.1 ± 1.9, P = .264), enjoyment level (more enjoyable/same amount) while weightlifting (rTSA: 94.4%, n = 51 vs. aTSA: 88.9%, n = 48, P = .486), or whether patients reported that their performance level had improved or stayed the same (rTSA: 90.7%, n = 49 vs. aTSA: 79.6%, n = 43, P = .176). However, rTSA patients reported greater weightlifting frequency (more frequent/same amount) (rTSA: 90.7%, n = 49 vs. aTSA: 72.2%, n = 39, P = .026).

Age and sex propensity score–matched reverse shoulder arthroplasty for glenohumeral osteoarthritis vs. rotator cuff arthropathy

(Table V) After propensity score matching by age and sex for patients undergoing rTSA for GHOA and RCA, the cohorts consisted of 45 and 25 patients, respectively. There were no significant differences in age (GHOA: 68.4 ± 6.2 years vs. RCA: 69.2 ± 4.6 years; P = .654), sex (GHOA: 71.1% male vs. RCA: 64.0% male, P = .730), BMI (rTSA: 28.6 ± 4.9 vs. RCA 301.3 ± 7.8, P = .493), overall ability to return to weightlifting (GHOA: 97.8%, n = 44 vs. RCA: 88.0%, n = 22, P = .127), performance (improved or stayed the same, GHOA: 84.4%, n = 38 vs. RCA: 64.0%, n = 16, P = .097), subjective satisfaction with their shoulder while weightlifting (9.6 ± 0.8 vs. 8.5 ± 2.9, P = .066) or time to resume weightlifting post-operatively (P > .999).

Table IV – Weightlifting participant sport specific breakdown of age- and sex-matched rTSA and TSA cohorts

Parameter	Weightlifting		P value
	rTSA for OA n = 54	TSA for OA n = 54	
Unable to bench press at a satisfactory level			
Pre-operative	64.8% (35)	59.3% (32)	.692
Post-operative	20.4% (11)	24.1 (13)	.817
Unable to bicep curl at a satisfactory level			
Pre-operative	33.3% (18)	29.6% (16)	.836
Post-operative	16.7% (9)	13.0% (7)	.787
Unable to overhead press at a satisfactory level			
Pre-operative	83.3% (45)	77.8% (42)	.627
Post-operative	35.2% (19)	29.6% (16)	.681
Unable to deltoid raise at a satisfactory level			
Pre-operative	42.6% (23)	40.7% (22)	>.999
Post-operative	7.4% (4)	20.4% (11)	.095
Unable to perform pushups at a satisfactory level			
Pre-operative	75.9% (41)	42.6% (23)	<.001*
Post-operative	31.5% (17)	20.4% (11)	.272

OA, osteoarthritis; rTSA, reverse shoulder arthroplasty.

* Significance is $P \leq .05$.

Table V – Weightlifting participant breakdown of comparing age- and gender-matched diagnoses of OA and RCA for rTSA

Parameter	rTSA for OA n = 45	rTSA for RCA n = 25	P value
Age	68.4 ± 6.2	69.2 ± 4.6	.654
Sex			
Male	71.1% (32)	64.0% (16)	.730
Female	28.9% (13)	36.0% (9)	
BMI	28.6 ± 4.9	31.3 ± 7.8	.493
Still lifting weights post-operatively?			
Yes	97.8% (44)	88.0% (22)	.127
Performance level compared to pre-operative			
Improved/stayed the same	84.4% (38)	64.0% (16)	.097
Enjoyment level compared to pre-operative			
More enjoyable/same amount	95.6% (43)	76.0% (19)	.021*
Frequency of participation compared to pre-operative			
More frequently/same amount	86.7% (39)	60.0% (15)	.025*
How long after surgery did you resume sport participation?			
<3 mo	22.2% (10)	20.0% (5)	>.999
3-6 mo	37.8% (17)	40.0% (10)	
7-12 mo	26.7% (12)	24.0% (6)	
12+ mo	14.6% (29)	12.0% (3)	
Satisfaction score			
0-10	9.6 ± 0.8	8.5 ± 2.9	.066

OA, osteoarthritis; RCA, rotator cuff arthropathy; rTSA, reverse shoulder arthroplasty.

* Significance is $P \leq .05$.

There was a significant difference in enjoyment level (more enjoyable or same, GHOA: 95.6%, n = 43 vs. RCA: 76.0%, n = 19, $P = .021$) and frequency of weightlifting (more frequently or same amount, GHOA: 86.7%, n = 39 vs. RCA: 60.0%, n = 15, $P = .025$) in favor of those undergoing rTSA for GHOA (Tables V and VI).

Exercise specific breakdown of matched reverse shoulder arthroplasty vs. anatomic shoulder arthroplasty cohorts for glenohumeral osteoarthritis

(Table IV) There were no significant differences between rTSA and aTSA groups in the pre-operative inability to perform the

Table VI – Weightlifting participant breakdown of comparing age- and gender-matched diagnoses of OA and RCA for rTSA

Parameter	Weightlifting		P value
	rTSA for OA n = 45	rTSA for RCA n = 25	
Unable to bench press at a satisfactory level			
Pre-operative	68.9% (31)	52.0% (13)	.253
Post-operative	24.4% (11)	24.0% (6)	>.999
Unable to bicep curl at a satisfactory level			
Pre-operative	35.6% (16)	40.0% (10)	.912
Post-operative	13.3% (6)	12.0% (3)	>.999
Unable to overhead press at a satisfactory level			
Pre-operative	84.4% (38)	72.0% (18)	.350
Post-operative	37.8% (17)	40.0% (10)	>.999
Unable to deltoid raise at a satisfactory level			
Pre-operative	51.1% (23)	44.0% (11)	.748
Post-operative	15.6% (7)	12.0% (3)	>.999
Unable to perform pushups at a satisfactory level			
Pre-operative	82.2% (37)	56.0% (14)	.037*
Post-operative	33.3% (15)	28.0% (7)	.848

OA, osteoarthritis; RCA, rotator cuff arthropathy; rTSA, reverse shoulder arthroplasty.

* Significance is $P \leq .05$.

Table VII – Factors predictive of worse post-operative performance in weightlifting

Sport parameter	β -coef	Confidence	Interval	P value
		2.5	97.5	
Revision arthroplasty	0.64	0.07	5.85	.694
Complication	2.32	0.34	15.9	.390
Diagnosis of RCA	2.22	0.88	5.60	.092

RCA, rotator cuff arthropathy.

bench press at a satisfactory level (rTSA: 64.8%, aTSA: 59.3%, $P = .692$) or in post-operative inability (rTSA: 20.4%, aTSA: 24.1%, $P = .817$). Similarly, the improvement rates between groups were not significantly different (rTSA: 68.6%, aTSA: 59.4%, $P = .435$).

No significant differences were observed in the pre-operative or post-operative inability rates among groups performing bicep curl (pre: rTSA 33.8%, aTSA 29.6%, $P = .836$; post: rTSA 16.7%, aTSA 13.0%, $P = .787$; improvement: rTSA 50.0%, aTSA 56.3%, $P = .719$) and overhead press (pre: rTSA 83.3%, aTSA 77.8%, $P = .627$; post: rTSA 35.2%, aTSA 29.6%, $P = .681$; improvement: rTSA 57.8%, aTSA 61.9%, $P = .697$).

However, the rTSA group demonstrated a significantly greater improvement in the ability to perform deltoid raises (rTSA: 82.6% improvement vs. aTSA: 50.0%, $P = .020$), despite similar pre-operative and post-operative inability rates. This finding is consistent with the known biomechanical reliance on the deltoid for arm elevation following rTSA. Additionally, a significant difference was observed in pre-operative inability to perform push-ups, with a higher proportion of rTSA patients unable to perform the exercise compared to aTSA patients (rTSA: 75.9%, aTSA: 42.6%,

$P < .001$). However, no significant differences were found at the post-operative time point (rTSA: 31.5%, aTSA: 20.4%, $P = .272$), or in improvement rates (rTSA: 58.5%, aTSA: 52.2%, $P = .624$).

Exercise specific breakdown of matched reverse shoulder arthroplasty for glenohumeral osteoarthritis vs. rotator cuff arthropathy cohorts

(Table VI) There were no significant differences between the GHOA and RCA cohorts in the inability to perform the bench press (pre: GHOA 68.9%, RCA 52.0%, $P = .253$; post: GHOA 24.4%, RCA 24.0%, $P > .999$; improvement: GHOA 64.5%, RCA 53.8%, $P = .509$), bicep curl (pre: GHOA 35.6%, RCA 40.0%, $P = .912$; post: GHOA 13.3%, RCA 12.0%, $P = .697$; improvement: GHOA 62.5%, RCA 70.0%, $P = .697$), overhead press (pre: GHOA 84.4%, RCA 72.0%, $P = .350$; post: GHOA 37.8%, RCA 40.0%, $P > .999$; improvement: GHOA 55.3%, RCA 44.4%, $P = .757$), or deltoid raise (pre: GHOA 51.1%, RCA 44.0%, $P = .748$; post: GHOA 15.6%, RCA 12.0%, $P > .999$; improvement: GHOA 69.6%, RCA 72.7%, $P = .849$).

A significant difference was found in pre-operative inability to perform push-ups, with a higher proportion of GHOA patients unable to perform the task compared to RCA patients (OA: 82.2%, RCA: 56.0%, $P = .037$). Post-operatively, this difference was no longer significant (OA: 33.3%, RCA: 28.0%, $P = .848$), and improvement rates were similar between groups (OA: 59.5%, RCA: 50.0%, $P = .542$).

Predictors of worse post-operative weightlifting performance

(Table VII) Multivariate logistic regression demonstrated that RCA ($P = .092$), revision arthroplasty ($P = .694$), and

complications ($P = .390$) did not independently predict worse post-operative performance in weightlifting.

Discussion

This multicenter study demonstrates that patients undergoing shoulder arthroplasty return to weightlifting at very high rates, with 93.1% resuming activity and 79.4% maintaining or improving performance. Compared with the average RTS rate of 80.7% (range, 57.1%–97.3%) reported in a meta-analysis of 613 mixed-sport shoulder arthroplasty patients,² our cohort exhibited one of the highest levels of sport-specific recovery. Patient satisfaction was also high, with a mean score of 9.2/10, emphasizing that modern arthroplasty techniques allow patients to achieve meaningful participation in physically demanding recreational activities. Most patients returned to weightlifting within 6 months (59.0%), consistent with previously reported RTS timelines.¹² These findings are notable considering prior surveys have shown the majority of surgeons advise against weightlifting after shoulder arthroplasty, with 57% recommending against it following aTSA and over 80% following rTSA.²⁵

Prior studies have demonstrated variability in recreational and sport participation following shoulder arthroplasty. Ames et al³ evaluated 36 high-demand weightlifters following aTSA and found that only 63.9% resumed the activity. Similarly, Tangtiphaiboonana et al³⁷ reported an overall RTS rate of 70.1% among RSA patients, with just 62.9% returning to high-demand sports such as resistance training, compared to 76.7% for low- and medium-demand activities such as elliptical/treadmill and swimming. These discrepancies emphasize the need for research targeting strength-based exercises specifically, as RTS rates for weightlifting may differ substantially from those of lower-demand activities. One likely explanation for the lower rates in prior studies is their relatively small sample sizes, which may limit generalizability and inflate variability in RTS estimates. In addition, definitions of “weightlifting” or “high-demand activity” may not have been standardized across studies, making direct comparisons difficult. By contrast, our multicenter study includes a much larger cohort of self-identified weightlifters, providing a more reliable estimate of return to this activity. This distinction is important, as it suggests that weightlifting after shoulder arthroplasty may be more achievable than previously reported when studied in a larger, more representative population. Moreover, weightlifting is associated with higher risk for shoulder pathology, frequently leading to injuries such as rotator cuff strains, bicipital tendinitis, and humeral stress fractures.^{13,16,20} These factors, combined with the complex biomechanics of high-load lifting, highlight the importance of defining safe thresholds for return after shoulder arthroplasty.

When comparing implant types, patients undergoing rTSA demonstrated similar rates of return and performance to those undergoing aTSA. Contrary to traditional perceptions that rTSA is less suitable for younger, active patients,^{3,5,7,8,10,24,35} our data suggest that rTSA can restore function to a level comparable to or even exceeding aTSA in certain strength domains. Previous studies have suggested

otherwise; for example, a fast-track rehabilitation study reported RTS rates of 100% for aTSA compared to 54.8% for rTSA,¹⁰ and a meta-analysis reported 92.6% versus 74.9%, respectively.²⁴ Biomechanical studies have also shown aTSA to preserve natural shoulder kinematics.^{18,19} Interestingly, our data indicate that rTSA patients were more likely to maintain or increase their training frequency compared to aTSA patients and demonstrated superior recovery in deltoid raise performance. One possible explanation is increased reliance on the deltoid after rTSA, as medialization of the center of rotation may improve its mechanical advantage.

Importantly, the present study was not designed to determine the underlying mechanism responsible for these differences. Increased deltoid efficiency following rTSA should be interpreted as a hypothesis rather than a definitive explanation. Alternative mechanisms may include differences in pain during resisted loading,¹ which may be more pronounced following aTSA. From a biomechanical standpoint, micromotion at the cemented glenoid component in aTSA—particularly in the early post-operative period—may contribute to discomfort during heavy lifting,^{32,36} whereas rTSA baseplate fixation is associated with greater initial stability.²⁸ Additionally, underlying glenoid deformity, such as B2 morphology, may predispose aTSA to eccentric loading and increased micromotion compared with rTSA, potentially influencing tolerance for weightlifting activities.³⁹ These factors are likely multifactorial, and future studies are needed to better clarify the mechanisms underlying these observed differences.

Even so, these results provide reassurance for both patients and surgeons as the use of rTSA continues to expand to younger demographics. It is important to acknowledge that performance was rated relative to each patient's pre-operative baseline, and differences between rTSA and aTSA groups may be partly influenced by selection bias. In many practices, younger or higher-demand weightlifters with GHOA may be preferentially steered toward aTSA, which could set a higher bar for post-operative performance than for patients undergoing rTSA. It is also important to note that our study evaluated outcomes at a mean of only 2 years and lacked detailed complication data specific to weightlifting. Thus, our findings are best applied to guide post-operative counseling rather than implant selection, until the long-term implications of heavy resistance training on implant survival and complications are clarified.

We also explored differences within the rTSA cohort according to pre-operative diagnosis. Patients with GHOA and RCA both reported high post-operative participation, performance, and satisfaction; however, GHOA patients experienced significantly greater enjoyment and were more likely to maintain or increase their frequency. Despite these differences, both groups demonstrated comparable improvements across specific lifts—including bench press, bicep curl, overhead press, deltoid raise, and pushups—suggesting that rTSA effectively restores lifting-specific strength regardless of diagnosis. These findings imply that diagnosis influences subjective engagement and enjoyment more than objective strength recovery, highlighting the multifactorial nature of post-operative outcomes. While we hypothesize that these differences may be related to differences in immediate pain

relief, other psychosocial factors such as motivation and caution are likely at play. This underscores the importance of individualized, diagnosis-specific counseling that addresses patient expectations.

Regression analysis further demonstrated that revision arthroplasty was not associated with inferior post-operative weightlifting performance ($\beta = 0.64, P = .694$). However, both post-operative complications ($\beta = 2.32, P = .390$) and a diagnosis of RCA ($\beta = 2.22, P = .092$) carried relatively high beta coefficients, suggesting a possible negative influence on performance despite not reaching statistical significance. These trends may reflect clinically meaningful effects masked by sample size limitations, warranting further investigation with larger cohorts.

The present study has several limitations. The reliance on self-reported outcomes introduces potential recall bias and lacks objective strength measurements, such as load or muscle performance metrics. Additionally, the multicenter design, while increasing sample size and generalizability, also introduces variability in surgical techniques, implant designs, and rehabilitation protocols, which may have influenced outcomes. Another limitation is the lack of granularity in defining the absolute level of weightlifting; for example, patients competing in high-demand lifting may perceive worse recovery despite returning to substantial activity, whereas lower-demand patients may report high satisfaction. This introduces potential selection bias, particularly when comparing rTSA and aTSA cohorts. Finally, although propensity score matching was used to minimize confounding, unmeasured variables likely remain. Future studies incorporating objective strength measurements and long-term complications under high-load activity are critical for defining safe guidelines for post-operative weightlifting. Incorporating objective load-based metrics, stratification by training intensity (recreational versus competitive), and development of phase-specific RTS guidance may further refine post-operative counseling and rehabilitation strategies. In addition, although most patients maintained or improved performance post-operatively, approximately 20% reported worse performance. This suggests that return participation does not always equate to preinjury capacity. Further study is warranted to identify factors associated with suboptimal recovery. Finally, this study involves multiple comparisons across several outcome domains, which increases the potential for type I error. No multiplicity correction was applied due to the exploratory nature of the study; thus, these findings should be interpreted with caution and considered hypothesis-generating rather than confirmatory.

Despite these limitations, this analysis represents one of the largest cohorts evaluating weightlifting after shoulder arthroplasty and the first to directly compare aTSA and rTSA in this context. These findings provide a foundation for evidence-based post-operative counseling and the development of rehabilitation strategies tailored to the demands of weightlifters, with the goal of optimizing recovery.

Conclusions

Most patients resume weightlifting after shoulder arthroplasty, often maintaining or improving performance. Although

outcomes are comparable by arthroplasty type, rTSA may afford better deltoid function and increased participation frequency. Additionally, pre-operative diagnosis appears to influence enjoyment and engagement following rTSA, despite similar improvements across specific exercises. These findings highlight the complex nature of recovery and value of personalized pre-operative counseling. Even so, the long-term durability of shoulder arthroplasty implants under heavy or repetitive loading remains unknown and warrants further investigation.

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