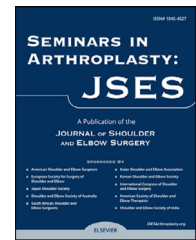


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The impact of modifiable risk factors on shoulder arthroplasty outcomes

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ABSTRACT

Shoulder arthroplasty is being performed with increasing frequency. The literature describing the risk factors that can influence patient outcomes and implant longevity has grown as well. Among these risk factors, increased body mass index, tobacco use, and alcohol use are especially relevant given their impact on overall health, recovery, and potential complications. This study compiles the existing research on these factors and reviews their impact on postoperative outcomes following shoulder arthroplasty. Terms including “bone health,” “national,” “clinical,” “alcohol,” “alcohol use disorder,” “tobacco,” “smoking,” “body mass index,” and “database” were used to query PubMed, Google Scholar, and OVID for appropriate research articles. Identified studies after the year 1995 were included. The impacts of these risk factors on postsurgical outcomes, readmissions, and clinical benchmarks were included in our analysis. Obesity, alcohol use, and tobacco use were all found to significantly impact clinical outcomes, increase the likelihood of hospital readmission, and predispose patients to surgical and postoperative complications. However, these results differed depending on the literature being analyzed. Overall, these modifiable risk factors heavily impact the success of shoulder arthroplasty. It is prudent for surgeons to assess patients for these risk factors and properly counsel them regarding the impact they may have on shoulder arthroplasty outcomes.

Level of evidence: Level V; Review Article

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The use of shoulder arthroplasty has risen significantly in recent decades.¹⁴ Given the current aging population, the incidence of total shoulder arthroplasty (TSA) is expected to increase by 900% from 2010 to 2030.^{9,40} Recently, the influence

of various parameters such as age, indication for surgery, and glenohumeral pathology on postoperative outcomes after TSA has been analyzed.^{5,7,12,35,43,47} The effect of modifiable risk factors on postoperative outcomes after shoulder arthroplasty

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is an important area of focus. Previous studies have investigated the role of body mass index (BMI), tobacco use, and alcohol use on shoulder arthroplasty outcomes.^{1,2,15,23,38,51,54} They have found that alcohol and tobacco use are associated with an increased risk of adverse complications, unplanned readmissions, and revisions following TSA.³² Additionally, they have found BMI to negatively affect clinical outcomes and increase complications.^{23,38}

In this study, the existing literature on the effect of these aforementioned modifiable risk factors on TSA outcomes was summarized. The aim of this summary is to provide readers with evidence of the effects that these risk factors have on shoulder arthroplasty outcomes, which can be used to provide appropriate preoperative counseling and set postoperative expectations. We utilized the search terms “bone health,” “national,” “clinical,” “alcohol,” “alcohol use disorder,” “tobacco,” “smoking,” “body mass index,” and “database” to select articles from multiple sources including PubMed, Google Scholar, and OVID; articles published after the year 1995 were ultimately included. As this was a narrative review, the results were inherently heterogeneous.

Body mass index

Obesity, defined by the World Health Organization as having a BMI >30, is an increasingly prevalent disease worldwide. It was estimated that 650 million adults were considered obese as of 2016.^{20,55} Given the rising prevalence of obesity and the negative impacts of obesity on the outcomes of several orthopedic surgeries, the risks faced by obese patients undergoing TSA should be thoroughly understood to allow for optimal clinical decision-making and patient counseling.^{18,25,37}

BMI: national databases studies

Several studies have examined the relationship between obesity and TSA outcomes using national databases. In a review of all total shoulder arthroplasties identified in the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database from 2006 to 2012, no impact of patient BMI on 30-day complications was observed, but there was a significant increase in operating time in patients with higher BMIs²³. Another study analyzed TSA patients identified from the NSQIP database between 2005 and 2013. The authors concluded that only morbidly obese patients experienced an increased risk of postoperative complications and longer length of stay (LOS), while patients classified as obese (30–39.9 kg/m²) experienced a decreased risk of postoperative complications and shorter LOS¹⁷. A retrospective study of nearly 150,000 patients identified in the claims-based private insurance database PearlDiver (PD) found that both obesity and super obesity (BMI > 50 kg/m²) were significantly associated with increased rates of complications following TSA.⁵⁰ Conversely, a 2022 study also using the PD database found no effect of obesity on postsurgical complications at 2 and 5 years postoperatively.¹ In a matched analysis of patients identified from the PD database, obese patients experienced significantly more complications and

infections following TSA, but obesity was not an independent risk factor for mechanical surgical complications or revision rates.⁸ The literature found that morbid obesity was often a risk factor for complications following TSA; however, the effect of traditional levels of obesity (BMI > 30 kg/m²) has not been consistently reaffirmed, with some studies finding no effects and others finding higher rates of complications and infections.

BMI: institutional studies

Clinical studies on the effects that obesity had on patient outcomes following TSA generally agree that obese patients still experience significant improvements in functional outcomes, range of motion (ROM), and pain.^{31,34,38,44} However, while the consensus seems to be that obesity is not a significant risk factor for negative postoperative outcomes, the literature remains divided on the effects that obesity has on the rate of complications, and some studies suggest that obese patients do not achieve similar postoperative outcomes as nonobese patients. For example, in a review of 45 morbidly obese patients that had undergone primary shoulder arthroplasties by a single surgeon, the patients generally experienced positive long-term outcomes²⁸. Similarly, a single institution study following 67 TSA patients for two years postoperatively found that obesity did not affect short-term improvement in shoulder function but did impede significant improvement in overall physical function.²⁹ In another study, patient BMI had a marginal association with the incidence of 90-day readmission in TSA procedures and the incidence of 3-year deep infection in reverse total shoulder arthroplasty (rTSA) procedures.⁴

Conversely, a meta-analysis of 6 studies drawing from institutional databases did not find a significant association between obesity and complication rates following anatomic total shoulder arthroplasty (aTSA) and rTSA.²⁴ Yaqma et al⁵⁶ similarly found no significant associations between BMI and postoperative outcomes or patient satisfaction. One single institution study found that patients with BMI >35 experienced worse functional outcomes following rTSA than non-obese patients, while another reported that TSA patients experienced positive functional outcomes regardless of BMI, but obese and morbidly obese patients did not always achieve outcomes comparable to nonobese patients.^{22,45} Additionally, in a multi-institutional analysis of rTSA and aTSA patients, Reid et al observed significantly inferior patient-reported outcomes (PROs) scores from obese patients with worse ROM compared to normal weight patients.³⁸ However, these differences were not found to be clinically significant. Other single institution studies report no significant difference by BMI group in complications, PROs, or ROM following TSA^{30,39}; the longest follow-up study in the current literature, at 11.4 years on average, corroborates these findings.⁵² For a summary of included studies, see [Table I](#).

Tobacco use

Tobacco use is a key modifiable risk factor for chronic disease. It is predicted that approximately one billion people will die

Table I – Studies focusing on the impact of BMI on shoulder replacement outcomes.

Author	Year	Database type	Sample size	Follow-up time	Main finding	Primary endpoints						
						PROs	ROM	Readmissions	Revisions	Surgery-related complications	Medical complications	Radiographic complications
Agarwal et al ¹	2022	National	17,372	Midterm	Higher BMI was not associated with increased surgical complications	-	-	-	X	X	-	-
Anakwenze et al ⁴	2017	Institutional	4630	Midterm	Higher BMI was associated with increased 90-d readmissions (aTSA) and deep infection (rTSA)	-	-	X	X	X	-	-
Cogan et al ⁸	2023	National	113,634	Midterm	Higher BMI was associated with higher rates of readmission and medical complications but not surgical/mechanical complications or revision rates	-	-	X	X	X	X	-
Garcia et al ¹⁷	2016	National	4751	Short-term	Morbid obesity is associated with increased LOS and postoperative complications	-	-	-	-	X	X	-
Izquierdo-Fernández et al ²²	2018	Institutional	35	Midterm	BMI >35 was associated with worse functional outcomes	X	-	-	-	X	-	X
Jiang et al ²³	2016	National	4796	Short-term	BMI was associated with increased surgical times but not 30-d complications	-	-	-	-	X	X	-
Klein et al ²⁴	2020	Institutional*	978	Midterm	Obese patients, but not morbidly obese, had comparable PROs and complication rates to the nonobese	X	-	-	-	-	-	-
Linberg et al ²⁸	2009	Institutional	45	Midterm	Morbidly obese patients achieved improved shoulder pain and function but had high rates of dissatisfaction	X	X	-	X	X	-	X
Li et al ²⁹	2013	Institutional	76	Midterm	Shoulder, but not physical, function improved regardless of patient BMI	X	-	-	X	X	-	-
Morris et al ³¹	2016	Institutional	77	Midterm	PROs, ROM, and complication rates are comparable regardless of BMI	X	X	-	-	X	-	X
Pappou et al ³⁴	2014	Institutional	84	Midterm	Morbidly obese patients achieved comparable functional outcomes but had higher postoperative care needs	X	X	X	X	X	-	X
Reid et al ³⁸	2022	Institutional	3575	Midterm	Clinical outcomes were similar following rTSA and aTSA regardless of a patient's preoperative BMI	X	X	-	X	X	-	X
Savin et al ³⁹	2018	Institutional	245	Midterm	PROs and ROM improved preoperatively to postoperatively without differences based on BMI	X	X	-	X	X	-	-
Statz et al ⁴⁴	2016	Institutional	41	Midterm	rTSA provides favorable outcomes for the morbidly obese	X	X	-	X	X	-	X
Vincent et al ⁴⁵	2016	Institutional	310	Midterm	BMI did not impact PRO scores but was associated with lower postoperative external rotation	X	X	-	X	X	-	X

(continued on next page)

Table 1 – (continued)

Author	Year	Database type	Sample size	Follow-up time	Main finding	Primary endpoints					
						PROs	ROM	Revisions	Surgery-related complications	Medical complications	Radiographic complications
Werner et al ⁴⁹	2015	National	221,381	Short-term	Obesity is associated with early revision after shoulder arthroplasty	-	-	X	-	-	-
Werner et al ⁵⁰	2015	National	144,239	Short-term	Increasing BMI was associated with more postoperative, medical, and shoulder-specific complications	-	-	X	X	-	-
White et al ⁵²	2022	Institutional	128	Long-term	Significant improvements in PROs and ROM were seen regardless of BMI, but higher BMI was associated with younger age at surgery	X	X	X	-	-	X
Wiater et al ³⁰	2017	Institutional	130	Midterm	BMI had minimal impact on postoperative outcomes	X	-	-	X	-	X
Yaqma et al ⁵⁶	2022	Institutional	233	Midterm	Patient PRO, satisfaction, and complication rates did not differ based on BMI for proximal humeral fracture patients	X	-	-	X	-	X

aTSA, anatomic total shoulder arthroplasty; BMI, body mass index; rTSA, reverse total shoulder arthroplasty; LOS, length of stay; PRO, patient-reported outcome; ROM, range of motion.

* Signifies a meta-analysis.

from smoking-related diseases by the end of the 21st century. Given tobacco's multitude of adverse effects on bone health, recent attention has been given to how tobacco use affects orthopedic surgical outcomes.

Tobacco use: national database studies

Four studies to date have examined the effect of tobacco use on TSA outcomes on a national scale. A review of 196,325 nonsmokers (93.1%) and 14,461 smokers (6.9%) from the Nationwide Readmission Database from 2011 to 2015 found that smoking leads to an increased risk of postoperative readmission and medical and surgical complications, including revision within 90 days, wound complications, and instability of the prosthesis after TSA.⁴² Another retrospective review of 164,527 patients (92% nontobacco users) from the Nationwide Readmission Database from 2016 to 2018 found higher rates of readmission, revisions, shoulder complications, and medical complications in tobacco users overall; however, when examining the cohort with multivariate analysis, readmission, revision, and complication rates did not differ between tobacco users and nonusers.⁵¹ A retrospective review of 221,381 patients from the PD database undergoing shoulder arthroplasty showed smoking as a risk factor for early revision within one year (odds ratio 1.6 [confidence interval 1.3-2.0], $P < .0001$).⁴⁹ A retrospective review of 14,465 patients undergoing TSA from the NSQIP database identified smoking as a risk factor for surgical complications, wound complications, and surgical-site infections.³ These highly powered national database studies affirm tobacco's negative effects on postoperative outcomes after TSA.

Tobacco use: institutional studies

Smaller institutional studies have shown similarly negative effects of tobacco on TSA outcomes. A retrospective case-control study of 1834 patients from an alternative institutional registry who underwent both aTSA and rTSA showed that current and former smokers were at a significantly higher risk of periprosthetic infection compared to nonsmokers (hazard ratios, 7.3 and 4.6, respectively), and that current smokers had a higher risk of postoperative fractures than former smokers (hazard ratio, 3.6) and nonsmokers (hazard ratio, 7.0).²¹ The available data also suggest that tobacco use can influence PROs after TSA. A large retrospective review of 1089 aTSA patients and 1332 rTSA patients from an international multicenter registry found that tobacco use had no negative effect on ROM and PROs after aTSA at a mean follow-up period of over four years, but did have a negative effect on PROs after rTSA.¹⁶ After rTSA, tobacco use negatively influenced postoperative internal rotation score by 0.7 points, shoulder function score by 0.6 points, simple shoulder test score by 1.2 points, The University of California-Los Angeles shoulder scale score by 1.6 points, and American Shoulder and Elbow Surgeons Score by 8.7 points. Tobacco users experienced greater postoperative pain, with an increased visual analog scale (VAS) pain score by 0.8 points.¹⁶ Another single institution study of 186 patients, 21 of whom were current smokers and 89 of whom were former smokers, reported increased pain scores after rTSA after over two years;

however, there was no correlation between smoking and outcomes or complications.⁴⁶ A third study of 163 patients (28 current smokers, 47 former smokers, 88 nonsmokers) undergoing TSA showed that smokers reported increased preoperative and postoperative pain, as well as increased narcotic use at 12 weeks.⁴⁸ VAS pain scores decreased from 5.8 to 1.8 in the nonsmoking group ($P < .001$), while only 7.1 to 4.3 in the smoking group ($P < .001$). Mean opioid use was 2348 mg for current smokers and 1637 mg and 1623 mg for nonsmokers and former smokers, respectively ($P < .003$). Despite these negative effects of smoking in the short- and mid-term, the data considering long-term outcomes remain mixed. A study of 78, 49, and 16 nonsmoker, former smoker, and current smoker shoulders, respectively, showed that smoking status had no significant effect on VAS, American Shoulder and Elbow Surgeons Score, and simple shoulder test scores at an average of 10.7 years follow-up.⁵³ ROM also was not significantly different other than in forward elevation (average 149.7 degrees for smokers vs. 130.9 degrees for nonsmokers). However, smokers did have a higher likelihood of needing revision surgery and earlier shoulder replacement. Thus, although there is some variability in the reported outcomes of smokers to nonsmokers, the evidence suggests that, in general, smokers have poorer outcomes and have a higher incidence of major complications. For a summary of included studies, see [Table II](#).

Alcohol use disorder

Excessive alcohol consumption is also an important risk factor that can lead to poor TSA outcomes. Estimates suggest that the prevalence of alcohol use disorder (AUD) has increased over the past 10 years.¹⁹ Given that the volume of shoulder arthroplasty continues to rise, it is important to understand the potential impact that AUD has on TSA outcomes, especially given that alcohol use is associated with decreased bone mineral density and bone formation.^{10,41}

AUD: national database studies

One study compared short-term complications and readmissions of 164,527 patients who had undergone TSA between 2016 and 2018, 0.3% of which had a prior diagnosis of AUD.⁵⁴ Patients with AUD tended to be younger at the time of TSA, had a longer postoperative LOS, incurred greater healthcare costs, and were more likely to be readmitted within 90 days postoperatively. Patients with AUD were more likely to suffer postoperative dislocations and required a revision surgery more often, though subsequent multivariate analysis of the demographics and medical comorbidities only identified that AUD was an independent risk factor for postoperative liver complications.

Another study by Ponce et al queried the Nationwide Inpatient Sample and identified 5658 patients with AUD and 416,713 patients without AUD who had undergone TSA between 2002 and 2011.³⁶ This study also observed that patients with AUD were younger at the time of surgery and were more likely to have associated comorbidities compared to non-AUD patients. After adjusting for demographics and comorbidities,

their data showed that patients with AUD were more likely to develop pneumonia, acute renal failure, and deep vein thrombosis. Additionally, they found that AUD was associated with an increased odds of longer inpatient LOS (4.8 ± 5.3 days vs. 2.7 ± 2.4 days, $P < .001$). Nassi et al identified 3198 patients with AUD and who had undergone rTSA between January 1, 2005, and March 31, 2014.³³ The AUD group was compared with a control group which was matched in a 1:5 ratio, accounting for demographic features and comorbidities. The study demonstrated that patients with AUD had a longer inpatient LOS (3 vs. 2 days, $P < .0001$) and greater surgical costs (\$14,539.47 vs. \$13,324.77, $P < .0001$) while also being more likely to experience various perioperative (e.g., urinary tract infections) complications. Leroux et al²⁶ conducted a study using the PD to identify risk factors associated with long-term postoperative opioid use. From a population of 79,287 patients who had shoulder arthroplasty between 2007 and 2015, patients with a history of alcohol abuse were found to be at significant risk of chronic opioid use (odds ratio: 1.56, $P = .002$), a finding that has been supported for other procedures as well.⁶

AUD: institutional studies

Multiple studies have also analyzed the impact of AUD on TSA at the institutional level. In a retrospective cross-sectional study, Serrano et al¹³ examined 70 patients who had undergone TSA at a single institution. Functional outcomes (QuickDASH) were worse for patients with chronic alcohol use ($P = .028$). While most of the current literature on this subject has found evidence to support a relationship between AUD and increased complications after TSA, there were two studies that found no such relationship. Leschinger et al²⁷ performed a retrospective review of 346 patients that received TSA between 1998 and 2009. They identified 19 patients who met the criteria for excessive alcohol consumption (>30 g/d for men, >20 g/d for women). Comparison of those patients with the control group revealed no increased risk for complications. Similarly, Donigan et al reviewed 163 patients at a single institution that had undergone either hemiarthroplasty or TSA and found no correlation between the number of comorbidities and outcomes of patients.¹¹ Thus, further research ought to be done to investigate the effect of AUD on TSA, as the studies to date have demonstrated mixed results. For a summary of included studies, see [Table III](#).

Conclusion

Obesity, smoking, and AUD are among the most prevalent modifiable risk factors in patients undergoing TSA. High BMI was found to increase the risk for short-term complications after TSA, while long-term clinical outcomes appeared to be comparable regardless of patient BMI. Tobacco use and excessive alcohol use were found to negatively influence outcomes in both institutional and national database studies. Surgeons should educate patients undergoing TSA on the effect that these risk factors have on the outcome of their surgery so that patients can develop realistic expectations and modify these risk factors, if desired and possible. This study

Table II – Studies focusing on the impact of tobacco use on shoulder replacement outcomes.

Author	Year	Database type	Sample size	Follow-up time	Main finding	Primary endpoints						
						PROs	ROM	Readmissions	Revisions	Surgery-related complications	Medical complications	Radiographic complications
Althoff et al ³	2020	National	14,465	Short-term	Smoking was associated with increased risk of wound complications and SSI	-	-	X	-	X	X	-
Friedman et al ¹⁶	2019	Institutional	2421	Midterm	Tobacco use had a negative impact on ROM and PROs for rTSA but not aTSA patients	X	X	-	-	-	-	-
Hatta et al ²¹	2015	Institutional	1834	Midterm	Smoking was associated with increased rates of implant infection and complications	-	-	-	X	X	-	-
Schwartz et al ⁴²	2020	National	196,325	Short-term	Tobacco use was associated with increased readmissions, revisions, and complications	-	-	X	X	X	X	-
Walters et al ⁴⁶	2020	Institutional	186	Midterm	Tobacco users were younger at the time of surgery and had increased postoperative pain but achieved similar ROM and PRO scores	X	X	-	X	X	X	X
Wells et al ⁴⁸	2018	Institutional	163	Short-term	Complication rates were similar among all patients, but tobacco users reported higher narcotic use and postoperative pain scores	X	-	X	X	X	X	-
Werner et al ⁴⁹	2015	National	221,381	Short-term	Tobacco use is associated with early revision after shoulder arthroplasty	-	-	-	X	-	-	-
White et al ⁵¹	2022	National	164,527	Short-term	Tobacco users underwent surgery earlier in life and had higher rates of readmissions, revision surgeries, and complications	-	-	X	X	X	X	-
White et al ⁵³	2023	Institutional	144	Long-term	Tobacco use was associated with higher revision rates and younger age at surgery but did not impact external rotation, internal rotation, or PROs	X	X	-	X	-	-	X

aTSA, anatomic total shoulder arthroplasty; rTSA, reverse total shoulder arthroplasty; SSI, surgical site infection; PRO, patient-reported outcome; ROM, range of motion.

Table III – Studies focusing on the impact of alcohol use on shoulder replacement outcomes.

Author	Year	Database	Sample size	Follow-up time	Main finding	PROs			Primary endpoints		Radiographic complications
						ROM	Readmissions	Revisions	Surgery-related complications	Medical complications	
Donigan et al ¹¹	2009	Institutional	163	Midterm	AUD had no appreciable impact on PROs	X	-	-	-	-	-
Esteras-Serrano et al ¹³	2018	Institutional	70	Midterm	Alcohol consumption was associated with worse PROs	X	-	-	-	-	-
Leroux et al ²⁶	2019	National	79,287	Short-term	History of alcohol abuse is associated with risk for long-term opioid use postoperatively	-	-	-	-	X	-
Leschinger et al ²⁷	2017	Institutional	275	Midterm	No significant association between alcohol consumption and surgical complications	-	-	-	X	-	-
Nassis et al ³³	2021	National	19,168	Short-term	AUD was associated with increased LOS, healthcare costs, and medical complications	-	-	-	X	X	-
Ponce et al ³⁶	2015	National	422,371	Short-term	Patients with AUD are more likely to experience perioperative complications and increased healthcare utilization	-	-	-	X	X	-
White et al ⁵⁴	2023	National	164,527	Short-term	Patients with AUD were younger at surgery, had higher overall surgical costs, and increased rates of 90-d readmissions, revisions, and complications	-	-	X	X	X	-

AUD, alcohol use disorder; LOS, length of stay; PRO, patient-reported outcome; ROM, range of motion.

demonstrates the variability of the literature that exists regarding the impact that modifiable risk factors have on shoulder arthroplasty outcomes, summarizes the existing body of literature on this topic, and identifies areas of future research.

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