Risk of poor outcomes in patients who are obese following total shoulder arthroplasty (TSA) and reverse TSA: A systematic review and meta-analysis

Abstract

Background

A systematic review was performed to investigate the impact of obesity on outcomes following total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RTSA).

Methods

Electronic databases and grey literature were searched for studies that evaluated the influence of obesity (Body Mass Index [BMI] ≥ 30 kg/m^2) on TSA and RTSA outcomes. Fifteen studies were identified, with ten studies reporting on predetermined outcomes considered in the TSA and RTSA population. Unadjusted data was pooled in statistical meta-analysis where appropriate (RevMan 5.3; Cochrane Collaboration) or summarised in narrative. Effect sizes were expressed as odds ratios (OR) for categorical data and weighted mean differences (WMD) for continuous data.

Results

Findings suggest that patients who were obese were at increased odds of dislocation (OR=2.49 (95%CI[2.32,2.66]), fracture (OR=1.92; 95%CI[1.77,2.08]) and revision (OR=1.49;95%CI [1.40,1.58]) following TSA or RTSA. Conversely, obesity had no influence on the odds of unscheduled return to theatre (OR=0.83; 95%CI[0.43,1.61]). Postoperative forward flexion reported in patients who were obese differed from patients who were not obese (WMD=-9.8; 95%CI[-17.53,-2.07], however no difference in other functional measures including abduction (WMD=-.078; 95%CI[-7.27,5.71]) and external rotation (WMD=-1.41; 95%CI[-5.11,2.29])

were found. Although patients who were obese reported significantly higher levels of pain (MD=1.13;95%CI[0.21,2.06]), the difference was not clinically relevant.

Conclusions

Surgeons should consider advising patients who are obese of the greater risk of dislocation, fracture and revision when considering elective TSA or RTSA. Findings are limited by confounding variables, however further our understanding of additional risks associated with pre-existing obesity which will promote better-informed decisions prior to proceeding with surgery.

Keywords

Obesity; BMI; outcomes; upper limb arthroplasty; total shoulder arthroplasty; dislocation

Level of Evidence

Systematic review of level II and Level III prognostic studies

Introduction

Total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RTSA) are effective treatments commonly used in the medical care of an elderly population. With advancing age comes a greater risk of further chronic conditions, such as obesity, increasing the likelihood of comorbid patients presenting for elective arthroplasty. Obesity is common in older populations across Australia[2], England[10] and many other countries,[39] yet the available evidence on the impact of obesity on upper limb arthroplasty outcomes is inconsistent.[44]

Pain and poor joint function detrimentally impact quality of life (QoL), and are primary symptoms leading to total joint replacement. Shoulder pain for 3 months or greater has been linked to depression, anxiety and sleep disturbance.[8] Following arthroplasty, research has demonstrated significant improvements in pain, function and psychological status.[9] In a general population, obesity has been association with decreased shoulder function.[30] Furthermore, increasing BMI is correlated with the incidence and severity of rotator cuff tears, a common indication for shoulder arthroplasty.[18]

Arthroplasty patients can return to theatre for numerous reasons, such as for irrigation and debridement or revision surgery. Revision arthroplasty is a complex procedure with greater risk of complication and poorer outcome in comparison to primary arthroplasty.[14; 49] Instability and dislocation combined is identified as the most common cause for prosthesis revision following TSA and RTSA, accounting for 25.2% and 38.5% of TSA and RTSA revisions, respectively in Australia.[3]

An understanding of the relationship between pre-existing obesity and arthroplasty outcomes is essential as it may impact patient selection for different types of orthopaedic surgery. Patients must be better informed of any additional risks associated with a pre-existing chronic disease, as this may influence their decision-making. Orthopaedic surgeons may also consider alternate treatments or further pre-cautionary measures to ensure the safety and effectiveness of the arthroplasty procedure in patients identified at greater risk for poorer outcomes.

To date, research has considered a number of perioperative, short and longer-term outcomes for patients with comorbid conditions in isolation. A literature search identified a review which investigated the effect of obesity on TSA, however the authors did not address the question through systematic review nor meta-analysis.[11]

To develop a clear understanding of the impact of obesity on upper limb arthroplasty outcomes, we performed a systematic review to address the following questions: *(1) Are obese patients at an increased risk of dislocation, fracture, unscheduled return to theatre or revision following TSA or RTSA? (2) Are obese patients at an increased risk of poorer function, pain relief and QoL following TSA or RTSA?*

Materials and Methods

The present review was conducted in accordance with an *a priori* protocol of a larger review project investigating additional complications, and the influence of diabetes mellitus on upper limb arthroplasty outcomes.[44] Specific outcomes of the shoulder arthroplasty population are reported here. This review was prospectively registered on PROSPERO (CRD42016053299).

Search Strategy and Criteria

A comprehensive three-step search strategy was undertaken across the PubMed, CINAHL and Embase databases on 27 May, 2016 with no limitation on publication date. Articles in languages other than English were excluded. The grey literature search included a review of relevant conference proceedings, and Open Grey. Detailed search strategies are available in Appendix 1. The reference lists of all eligible studies were screened for additional studies.

Inclusion and Exclusion Criteria

Adults, 18 years or older, who had undergone primary upper limb arthroplasty were considered for inclusion. When the impact of obesity was considered for a combination of arthroplasty procedures including those on the lower limb, study authors were contacted for specific data on the cohort of interest. If the data was not available, or a response was not received, the paper was deemed eligible for inclusion if it included ≥70% of the population of interest (upper limb arthroplasty).

Eligible studies must have investigated the impact of obesity (BMI ≥ 30.0 kg/m^2) on outcome in isolation. The term *non-obese* has been used to describe patients categorised with a BMI <

30.0 kg/m^2. The obese category was further subdivided into *obese class 1* (BMI 30.0 – 34.9 kg/m^2) and *obese class 2* (BMI ≥ 35.0), depending of the BMI groups reported in the primary studies. *Morbidly obese* indicated a BMI of ≥ 40.0 kg/m^2 and *normal range* refers to patients with a BMI < 25.0 kg/m^2.

The review considered cohort and case-control studies for inclusion. Studies reporting on one or more of the following outcomes in the TSA or RTSA population are discussed in the present review: dislocation, fracture, function, QoL, pain, unscheduled return to theatre and revision.

Assessment of methodological quality

Methodological validity of included studies was assessed by two independent reviewers (AT , KL) using standardised critical appraisal tools (Joanna Briggs Institute [JBI] SUMARI).[28; 29] Appraisal was piloted with a subset of studies to determine suitability and consistency in understanding of the application of the tools between each reviewer. No disagreements arose, therefore consultation with a third reviewer (EA) was not required. However, assessments of appraisal questions relating to outcomes (refer cohort study design Q6, 7 and 8; Case-control study design Q8; Table 2) were re-evaluated by a single reviewer (AT). This allowed assessment to be limited to those outcomes presented in this review and differed from those assessments relevant to remaining outcomes from the larger review project.[44] All eligible studies were included in the review irrespective of their methodological quality.

Data extraction

Data was extracted from included studies using a customised data extraction template (AT). Prior to analysis, all extracted data was checked with source articles to confirm accuracy.

Where possible, unadjusted data (number of events) was extracted and used in most of the meta-analyses for multiple reasons. First, to avoid potential heterogeneity attributable to adjustment for different confounding factors between studies.[46] Secondly, BMI groupings varied between the included studies. The use of unadjusted data permitted the combination of BMI categories that aligned with classifications used in this review. Consequently, for all outcomes, we aimed to conduct a single, overall meta-analysis comparing patients who were obese versus non-obese. For categorical variables, event and sample totals were summed for each BMI group of < 30.0 versus ≥ 30.0. Conversely, for continuous variables, BMI groupings within a study could not be summed and consequently, multiple meta-analyses comparing various BMI groupings were conducted. Where various BMI categories did not align across studies, outcomes were combined in the overall meta-analysis comparing obese versus non-obese, despite variations in individual study BMI groupings. For example, Pappou et al.[37] categorised BMI as ≥ 40.0, not specifically > 30.0. This approach was necessary for meta-analyses conducted for outcomes including dislocation, revision, pain and function. Furthermore, where possible, multiple meta-analyses using the various BMI categories were also conducted for each outcome, allowing exploration of the impact of different levels of BMI on outcome.

Jiang et al.[27] simply reported the percentage of outcome events, without reporting the raw number of events. As raw figures were required for meta-analysis, they were calculated, where possible, from the data available. As the study reported on a large database, this created a potential for error in the calculation.

Data analysis

Quantitative data, where possible, was pooled in statistical meta-analysis using Review Manager (RevMan) Version 5.3 software.[38] Effect sizes with 95% confidence intervals were expressed as odds ratios (OR) for categorical data and weighted mean differences (WMD) for continuous data. A random-effects model with a Mantel-Haenszel statistical method for OR,[20] and an inverse variance method for WMD were used for the meta-analyses.[21] Where five or less studies were included in the analysis a fixed-effects model was preferentially employed.[24] Statistical heterogeneity was assessed using both the standard Chi^2 (χ^2) and I^2. Where possible, a sensitivity analysis was conducted for meta-analyses heavily weighted with the findings of a single study (> 90.0%). For outcomes where statistical pooling was not possible, findings are presented in narrative.

Results

Search and study selection

Database searching returned 9596 citations, which were transferred to Endnote X7 (Thomas Reuters, New York, USA). A further 793 records were identified from grey literature sources (Fig. 1). Following removal of duplicates, 7203 original records were screened for eligibility by one reviewer (AT). The full text of 260 studies were retrieved for further assessment of eligibility, of which 229 studies were excluded (Fig. 1). An additional 17 citations were identified via reference list screening of eligible studies. Eight records were excluded due to insufficient information to determine eligibility, following unsuccessful document retrieval requests, and requests for further information made to study authors.[12; 15; 17; 22; 23; 25; 34; 35] Twenty-three eligible studies were identified, however two could not be included in synthesis due to an overlapping patient population selected from the same national database.[16; 49] An eligible study which reported on the same patient cohort was preferentially selected when the study provided the greatest representation, most recent or readily extractable data. Following breakdown by exposure, eight studies investigated diabetes mellitus alone and are discussed in a separate paper. A total of 15 obesity studies were identified, with ten studies reporting on specific outcomes (refer Methods and Materials section) considered in the TSA or RTSA populations.[4; 6; 19; 27; 32; 36; 37; 41; 42; 50]

A total of 154 894 patients were reported across included studies, a majority of which were female (61%; 94 439 females) and mostly 65 years of age or older. Four studies reported on whether the obese cohort had a diabetic comorbidity.[4; 19; 27; 50] Follow-up duration varied across studies and outcomes, and ranged from ‘up to 30 days’, to ‘up to 20 years’ (Table 1).

Methodological quality of included studies

A summary of the characteristics of included studies is presented in Table 1. Study designs included eight retrospective cohort studies,[4; 6; 19; 27; 36; 41; 42; 50] one prospective cohort study[32] and one case-control study.[37] All studies were conducted in the United States. Most studies retrospectively gathered data from national or multi-institutional healthcare and/or surgical databases (Table 1).

The majority of cohort studies (78%) recruited participant groups from the same population and all measured outcomes and/or exposures similarly to assign study groups (Table 2). However, only one study (11%) measured the outcome or exposure used to group participants in a valid and reliable way. Most studies (90%) identified key confounders, specifically age, gender or comorbidities, however not all (67%) reported strategies to deal with such factors. Whether the groups were free of the outcomes as the start of the study was *Not Applicable* for all studies as the outcomes are not relevant preoperatively. Outcomes were measured in a valid and reliable way for 67% of studies, however this was *Unclear* in 33% of studies. Completion of follow-up was *Not Applicable* given the retrospective nature of most studies. Appropriate statistical methods were reported by most studies (66%).

The case control study[37] matched controls, at minimum, on age, gender, surgical procedure and duration of follow-up, with data for matching collected from the same source population. Equivalent criteria were used for identification of cases and controls, and confounding variables were identified. The exposures were measured in the same way for each group (e.g. level of obesity was measured by BMI for both groups), however a description on how the exposure was measured was not reported (e.g. methods and/or equipment used to measure the height and weight for BMI calculation). A description of how outcomes were assessed or

diagnosed was provided, and both the length of follow-up and statistical analysis were appropriate (Table 2).

Effect of obesity on dislocation, fracture, unscheduled return to theatre and revision

Three TSA/RTSA studies[6; 19; 50] evaluated the influence of obesity on joint dislocation. One of the studies did not contribute to the effect estimate as it reported no dislocations for both obese and non-obese BMI groups.[6] Postoperative follow-up duration varied with each study and included either a minimum of 90 days or up to 1 year (Table 1). Meta-analyses revealed increased odds of dislocation in patients with a BMI ≥ 30.0 (OR = 2.49; 95% CI [2.32, 2.66]) compared to patients with a BMI < 30.0 (Fig. 2).

Analysis revealed TSA and RTSA patients who were obese had 1.92 times greater odds of periprosthetic fracture than non-obese patients (Table 3.) Furthermore, one study reported the incidence of acromial fracture between morbidly obese and non-obese RTSA patients, who were followed-up for a minimum of 2 years.[37] This study was combined with studies that reported on periprosthetic fracture to provide an overall analysis on the odds for fracture. Results revealed that patients who were morbidly obese had 1.98 times greater odds of fracture compared to non-obese patients (OR = 1.98; 95% CI [1.77, 2.21]). As the analysis was heavily weighted on the findings from Werner et al.,[50] a sensitivity analysis was conducted which presented even greater odds of fracture in patients who were morbidly obese compared to non-obese (Table 3). No statistically significant heterogeneity was observed in these meta-analyses (Table 3).

Three studies reporting on a total of 144 399 TSA and RTSA patients and were able to contribute to a meta-analysis investigating revision. Postoperative follow-up duration varied

224 across studies and included up to 2 years,[32] a minimum of 2 years[37] and up to 8 years.[50] Analysis
225 revealed that TSA and RTSA patients who were obese had 1.49 times greater odds of
226 undergoing revision compared to non-obese patients at, up to 8 years post-surgery (Fig 3: Panel
227 A). Odds of revision increased to 1.59 times in patients with a BMI ≥ 40.0 (Fig 3: Panel B).
228 No statistically significant heterogeneity was observed in these meta-analyses, however the
229 analyses were heavily weighted with the findings from a single study.[50] Results of the
230 sensitivity analysis are presented in Table 3.

231 Two studies[27; 32] reported unscheduled return to theatre (Table 1.) This analysis does not
232 include studies that explicitly stated return to theatre due to 'revision surgery'. Analysis
233 revealed that the odds of unscheduled return to theatre following TSA or RTSA were no
234 different between patients who were obese and those with a BMI < 30 (Table 3). No statistical
235 heterogeneity (I^2, 0%) was observed, however, this is expected given the large variance in the
236 study by Li et al.[32]

237 Effect of obesity on function, pain and quality of life

238 No statistically significant difference in the American Shoulder and Elbow Surgeons
239 questionnaire (ASES) was found between TSA and RTSA patients who were obese compared
240 to non-obese (Table 3). Postoperative ASES means ranged from 69 to 80 in patients who were
241 obese, compared to 78 to 84 in patients who were not obese, with higher scores indicating
242 better self-reports of pain, instability and activities of daily living. Heterogeneity was not
243 statistically significant (P = 0.08), however the I^2 statistic identified substantial statistical
244 heterogeneity between studies, limiting plausible conclusions (I^2, 61%).

245 Three studies[4; 36; 37] reported range of motion (ROM) measurements for follow-up time period
246 of, at minimum, 2 years. Two studies[4; 36] indicated that ROM measurements were active
247 movements, however the remaining study did not specify.[37] No statistically significant WMD

was observed in abduction (WMD = -0.78; 95% CI [-7.27, 5.71]) or external rotation (WMD = -1.41; 95% CI [-5.11, 2.29]) ROM between patients who were obese compared to patients who were not obese following RTSA. Conversely, meta-analysis revealed a statistically significant difference in postoperative forward flexion ROM in patients with obesity. The WMD was -9.80 degrees (95% CI [-17.53, -2.07]), indicating that patients with a BMI ≥ 30.0 demonstrated less forward flexion ROM than patients with a BMI < 30.0 following RTSA. Current research reported a minimal clinically importance difference (MCID) for active forward flexion in TSA and RTSA patients is 12 ± 4 degrees, suggesting that the difference observed in this review may be clinically relevant.[40] No statistically significant heterogeneity was observed (Table 3).

RTSA patients who were obese had a statistically significant increase in pain compared to non-obese RTSA patients, as measured by the Visual Analogue Scale for Pain (VAS – P). The WMD was 1.13 (95% CI [0.21, 2.06]), indicating patients with a BMI ≥ 30.0 experienced slightly greater postoperative pain scores than patients with a BMI < 30.0 (Table 3). No statistical heterogeneity was observed. Figure 4 shows that the VAS – P mean range was 1.3 to 3, indicating that both groups experienced no pain,[26] or mild pain. Recent research has suggested that a MCID for the VAS – P in shoulder arthroplasty patients is 1.4, indicating that although a WMD on the VAS – P was observed in patients who were obese compared to non-obese, it was not clinically relevant.[43]

Only one TSA study investigated the impact of this comorbidity on QoL.[32] The authors concluded that TSA patients who were obese and overweight failed to reach the level of physical function improvement achieved by patients with a BMI in the normal range.

Discussion

With the number of upper limb arthroplasty procedures predicted to rise, risk factors that predispose patients to poorer outcomes must be thoroughly investigated. Following resolution of any early complications, joint prostheses are ideally expected to function for 15 to 20 years before a revision is required. Unfortunately, the present review findings suggest that TSA and RTSA patients who are obese are at greater risk of revision. Revision was reported in studies with follow-up durations of up to 2 years,[32] up to 8 years,[50] and a minimum of 2 years.[37] The study with a minimum 2-year follow-up reported that the revision was performed 6.3 years post primary arthroplasty.[37] A revision required within these study follow-up periods (< 10 years) is indicative of early to mid-term failure of the prosthesis, which is a detrimental outcome.

Common causes of prosthesis revision following TSA and RTSA are instability and dislocation.[3] This review found that patients who were obese were at greater risk of dislocation following TSA or RTSA. One study reported a dislocation within one year,[50] whereas the second study simply stated a minimum 90-day follow-up without specifying how long after the arthroplasty procedure the dislocation occurred.[19] With regard to RTSA, instability of the joint can be caused by inadequate tensioning of the deltoid muscle and conjoint tendon.[7] Chalmers et al.[7] suggest that obesity contributes to instability by hindering accurate intraoperative soft tissue tensioning. A heightened risk of dislocation with increasing BMI has also been reported in the lower limb arthroplasty population. For example, obese total hip arthroplasty patients have 2.08 times greater risk of dislocation.[33] More recently, Wager et al.[48] reported a linear relationship between risk of early dislocation and BMI in a total hip arthroplasty population.

Other less common causes of revision surgery include periprosthetic and acromial fractures. This review found that TSA and RTSA patients who were obese had approximately two times greater odds of fracture than patients who were not obese. Unfortunately, most of the studies reporting incidence of fracture did not specify whether the fracture occurred intraoperatively or postoperatively. If there was a greater risk of intraoperative fracture in patients with a high BMI, it may suggest greater technical difficulties of the procedure in patients who are obese, however this could not be determined or explored further.

Shoulder pain for 3 months or longer has been linked to depression,[8] anxiety and sleep disturbance, which have been demonstrated to improve following arthroplasty.[9] Review findings found that RTSA patients who were obese reported slightly greater postoperative pain scores than non-obese patients, at a WMD of 1.13 on the VAS – P scale. As the MCID of the VAS – P is greater than this (1.4 in the shoulder arthroplasty population),[43] this finding has minimal clinical relevance. Furthermore, the VAS – P mean range was 1.3 to 3, indicating that both the obese and non-obese groups experienced no pain, or only mild pain, postoperatively. Similarly, the present review findings correspond with research on pain relief and obesity in the lower limb. Most recently, Li et al.[31] found that patients across all BMI groups, from normal through to morbidly obese, showed substantial improvements in pain at six months.

Three new studies eligible for this review were published after the search was conducted (27 May, 2016).[1; 45; 47] Wagner et al.[47] presented comparable results, demonstrating that for every 1-unit increase in BMI greater than, or equal to 30, there was a five per cent increased risk of revision due to mechanical failure. However, no significant associations were found between BMI groups and outcomes including reoperation and revision (all reasons).[47] This study also

examined the risk of periprosthetic fracture and dislocation and, contrary to the present results, found no association with obese and non-obese categories.[47]

Present review findings corroborate with most of the results from a retrospective cohort study which investigated the mid-term functional outcomes and QoL of obese patients following TSA and RTSA.[45] The study reported improvements in postoperative ASES scores and active external rotation across all BMI categories.[45] However, lower levels of improvement in active external rotation were noted.[45] Vincent et al.[45] also reported no significant effects of obesity on additional patient-reported outcome measures of function, pain and general health including the Shoulder Pain and Disability Index (SPADI), University of California at Los Angeles Shoulder Rating scale (ULCA), Constant score and Short Form-12 (SF – 12). However, lower SF – 12 scores were found in patients who were morbidly obese. The final study identified presented conflicting results, suggesting no association between high BMI and risk of aseptic revision.[1]

When considering the findings presented, there are several limitations worth noting. Firstly, patient and surgical factors can also impact on a number of outcomes investigated in this review. Younger age (less than 65 years) has been significantly associated with early revision.[49] Similarly, increasing age, female gender and rheumatoid arthritis have been identified as risk factors for periprosthetic fracture of the humerus.[13] Furthermore, surgical technique and implant type was not uniform across included studies, which may have influenced outcomes such as dislocation. Secondly, the level of evidence of included studies was low, however this is an inherent consequence of research investigating risk due to exposure. A further issue is the use of BMI as a measurement tool to define obesity, given the measure has several well-acknowledged shortcomings.[5] Similarly, studies rarely specified the equipment used to measure BMI. Researchers should endeavour to report additional information including what

equipment was used to measure height and weight, who performed these measurements and what patients wore while being measured.

The review process also imposed several limitations. Firstly, the comprehensive search strategy, with no publication date limits, was designed to locate all the available evidence, however, despite this, the restriction to include only English-language studies leaves the review at risk of language bias. The selection of studies for inclusion in this review was performed by only one reviewer, which can potentially cause errors of omission. Similarly, despite cross-checking all extracted data with study articles prior to analysis, data extraction was only conducted by a single reviewer, increasing the risk for errors in data handling. Finally, whilst the use of unadjusted data provided several advantages for data analysis, it leaves findings susceptible to other confounders such as comorbidity which could not be accounted for.

Conclusions

The results of the systematic review revealed that odds of revision surgery increased, with increasing BMI in shoulder arthroplasty patients. Similarly, obesity was found to increase the odds of dislocation and fracture, however had no influence on the odds of unscheduled return to theatre. No association was found between obesity and abduction or external rotation ROM, however a statistically significant difference in postoperative forward flexion was observed. Patients who were obese reported significantly higher levels of pain, however the difference was not clinically relevant and limited evidence was available regarding the impact of obesity on QoL. Notably, findings were limited by confounding variables such as the influence of patient and surgical factors. In addition, authors rarely described the method or equipment used to measure BMI, which should be reported to improve the comparability across studies in the future. Nevertheless, surgeons should consider advising patients who are obese of the greater

368 risk of dislocation, fracture and revision to promote well-informed decisions, and allow for
369 precautionary measures to be undertake prior to proceeding with surgery.

References

1. Anakwenze O, Fokin A, Chocas M, Dillon MT, Navarro RA, Yian EH et al. Complications in total shoulder and reverse total shoulder arthroplasty by body mass index. J Shoulder Elbow Surg 2017;26:1230-1237. doi:10.1016/j.jse.2016.11.055
2. Australia's health 2016 [Internet]. Canberra: Australian Institute of Health and Welfare (AIHW); 2016. Australia's health series no. 15. Cat. no. AUS 199; [cited 2017 Feb 24]. Available from: https://www.aihw.gov.au/reports/australias-health/australias-health-2016/contents/summary
3. Australian Orthopaedic Association National Joint Replacement Registry. Annual Report 2016. [cited 2017 Sep 07]. Available from: https://aoanjrr.sahmri.com/annual-reports-2016
4. Beck JD, Irgit KS, Andreychik CM, Maloney PJ, Tang X, Harter GD. Reverse total shoulder arthroplasty in obese patients. J Hand Surg Am 2013;38:965-970. doi:10.1016/j.jhsa.2013.02.025
5. Buss J. Limitations of body mass index to assess body fat. Workplace Health Saf 2014;62:264. doi:10.3928/21650799-20140514-0410
6. Chalmers PN, Gupta AK, Rahman Z, Bruce B, Romeo AA, Nicholson GP. Predictors of early complications of total shoulder arthroplasty. J Arthroplasty 2014;29:856-860. doi:10.1016/j.arth.2013.07.002
7. Chalmers PN, Rahman Z, Romeo AA, Nicholson GP. Early dislocation after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2014;23:737-744. doi:10.1016/j.jse.2013.08.015

8. Cho CH, Jung SW, Park JY, Song KS, Yu KI. Is shoulder pain for three months or longer correlated with depression, anxiety, and sleep disturbance? J Shoulder Elbow Surg 2013;22:222-228. doi:10.1016/j.jse.2012.04.001
9. Cho CH, Song KS, Hwang I, Coats-Thomas MS, Warner JJP. Changes in Psychological Status and Health-Related Quality of Life Following Total Shoulder Arthroplasty. J Bone Joint Surg Am 2017;99:1030-1035. doi:10.2106/JBJS.16.00954
10. Conolly A, Davies B. Health Survey for England 2017: Adult and child overweight and obesity [Internet]. NHS Digital; 2018 [cited 2019 Apr 28]. Available from: https://files.digital.nhs.uk/3F/6971DC/HSE17-Adult-Child-BMI-rep.pdf.
11. De Martino I, Gulotta LV. The Effect of Obesity in Shoulder Arthroplasty Outcomes and Complications. Orthop Clin North Am 2018;49:353-360. doi:10.1016/j.ocl.2018.02.010
12. Del Toro MD, Nieto I, Guerrero F, Palomino J, NuHo E, Corzo-Delgado JE et al. Clinical features and prognosis of prosthetic joint infection: A multicentre cohort in Andalusia, Spain. Clin Microbiol Infect. 2010;16:S416-S417. doi: 10.1111/j.1469-0691.2010.03239.x
13. Della Rocca GJ, Leung KS, Pape HC. Periprosthetic fractures: epidemiology and future projections. J Orthop Trauma 2011;25 Suppl 2:S66-70. doi:10.1097/BOT.0b013e31821b8c28
14. Dines JS, Fealy S, Strauss EJ, Allen A, Craig EV, Warren RF et al. Outcomes analysis of revision total shoulder replacement. J Bone Joint Surg Am 2006;88:1494-1500. 10.2106/JBJS.D.02946
15. Farng E, Zingmond D, Krenek L, Soohoo NF. Factors predicting complication rates after primary shoulder arthroplasty. J Shoulder Elbow Surg 2011;20:557-563. doi:10.1016/j.jse.2010.11.005

16. Garcia GH, Fu MC, Webb ML, Dines DM, Craig EV, Gulotta LV. Effect of Metabolic Syndrome and Obesity on Complications After Shoulder Arthroplasty. Orthopedics 2016:1-8. doi:10.3928/01477447-20160517-03
17. Goodman S. Findings contradict notions about obese patients and outcomes after TJR. Orthopedics Today 2013;33:18-20 13p.
18. Gumina S, Candela V, Passaretti D, Latino G, Venditto T, Mariani L et al. The association between body fat and rotator cuff tear: the influence on rotator cuff tear sizes. J Shoulder Elbow Surg 2014;23:1669-1674. doi:10.1016/j.jse.2014.03.016
19. Gupta AK, Chalmers PN, Rahman Z, Bruce B, Harris JD, McCormick F et al. Reverse total shoulder arthroplasty in patients of varying body mass index. J Shoulder Elbow Surg 2014;23:35-42. doi:10.1016/j.jse.2013.07.043
20. Higgins JPT, Green S (editors). Cochrane Handbook for Systematic Reviews of Interventions. Part 9.4.4.1 Mantel-Haenszel methods. Version 5.1.0. The Cochrane Collaboration; 2011. [updated 2011 Mar; cited 2018 Jan 29]. Available from: www.handbook.cochrane.org
21. Higgins JPT, Green S (editors). Cochrane handbook for systematic reviews of interventions. Part 9.4.5.1 Which measure for continuous outcomes? Version 5.1.0. The Cochrane Collaboration. 2011. [updated 2011 Mar; cited 2018 Jan 29]. Available from: www.handbook.cochrane.org
22. Huang R, Callinan SM, Bercik MJ. Total joint arthroplasty can be safe in the super morbidly obese. Curr Orthop Pract 2013;24:452.
23. Ishii K, Harigane K, Mitsugi N, Taki N, Saito T, Mochida Y et al. Surveillance of surgical site infection in patients with rheumatoid arthritis. Int J Rheum Dis 2012;15:45.
24. Jackson D, Turner R. Power analysis for random-effects meta-analysis. Res Synth Methods 2017. doi:10.1002/jrsm.1240

25. Jain NB, Guller U, Pietrobon R, Bond TK, Higgins LD. Comorbidities increase complication rates in patients having arthroplasty. Clin Orthop Relat Res 2005:232-238.
26. Jensen MP, Chen C, Brugger AM. Interpretation of visual analog scale ratings and change scores: a reanalysis of two clinical trials of postoperative pain. J Pain 2003;4:407-414
27. Jiang JJ, Somogyi JR, Patel PB, Koh JL, Dirschl DR, Shi LL. Obesity is Not Associated with Increased Short-term Complications After Primary Total Shoulder Arthroplasty. Clin Orthop Relat Res 2016;474:787-795. doi:10.1007/s11999-015-4584-3
28. The Joanna Briggs Institute. JBI Critical Appraisal Checklist for Case Control Studies [Internet]. [cited 2017 Apr 27]. Available from: http://joannabriggs.org/research/critical-appraisal-tools.html
29. The Joanna Briggs Institute. JBI Critical Appraisal Checklist for Cohort Studies. [Internet]. [cited 2017 Apr 26]. Available from: http://joannabriggs.org/research/critical-appraisal-tools.html
30. Kane S, Conus S, Haltom D, Hirshorn K, Pak Y, Vigdorchik J. A shoulder health survey: correlating behaviors and comorbidities with shoulder problems. Sports Health 2010;2:119-134. doi:10.1177/1941738109338358
31. Li W, Ayers DC, Lewis CG, Bowen TR, Allison JJ, Franklin PD. Functional Gain and Pain Relief After Total Joint Replacement According to Obesity Status. J Bone Joint Surg Am 2017;99:1183-1189. doi:10.2106/JBJS.16.00960
32. Li X, Williams PN, Nguyen JT, Craig EV, Warren RF, Gulotta LV. Functional outcomes after total shoulder arthroplasty in obese patients. J Bone Joint Surg Am 2013;95:e160. doi:10.2106/jbjs.l.01145

33. Liu W, Wahafu T, Cheng M, Cheng T, Zhang Y, Zhang X. The influence of obesity on primary total hip arthroplasty outcomes: A meta-analysis of prospective cohort studies. Orthop Traumatol Surg Res 2015;101:289-296. doi:10.1016/j.otsr.2015.01.011
34. Luessenhop CP, Higgins LD, Brause BD, Ranawat CS. Multiple prosthetic infections after total joint arthroplasty. Risk factor analysis. J Arthroplasty 1996;11:862-868.
35. Matsen FA, 3rd, Li N, Gao H, Yuan S, Russ SM, Sampson PD. Factors Affecting Length of Stay, Readmission, and Revision After Shoulder Arthroplasty: A Population-Based Study. J Bone Joint Surg Am 2015;97:1255-1263. doi:10.2106/jbjs.n.01107
36. Mau EM, Roche CP, Zuckerman JD. Effects of Body Mass Index on Outcomes in Total Shoulder Arthroplasty. Bull Hosp Jt Dis (2013) 2015;73:99-106.
37. Pappou I, Virani NA, Clark R, Cottrell BJ, Frankle MA. Outcomes and Costs of Reverse Shoulder Arthroplasty in the Morbidly Obese: A Case Control Study. J Bone Joint Surg Am 2014;96:1169-1176. doi:10.2106/jbjs.m.00735
38. Review Manager (RevMan) [Computer program]. Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014.
39. Samper-Ternent R, Al Snih S. Obesity in Older Adults: Epidemiology and Implications for Disability and Disease. Rev Clin Gerontol 2012;22:10-34
40. Simovitch R, Flurin PH, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the minimal clinically important difference. J Shoulder Elbow Surg 2018;27:298-305. 10.1016/j.jse.2017.09.013
41. Singh JA, Sperling J, Schleck C, Harmsen W, Cofield R, Singh JA et al. Periprosthetic fractures associated with primary total shoulder arthroplasty and primary humeral head replacement: a thirty-three-year study. J Bone J Surg Am 2012;94-A:1777-1785 1779p. doi:10.2106/JBJS.J.01945

42. Singh JA, Sperling JW, Cofield RH. Revision surgery following total shoulder arthroplasty: analysis of 2588 shoulders over three decades (1976 to 2008). J Bone Joint Surg Br 2011;93:1513-1517. doi:10.1302/0301-620x.93b11.26938
43. Tashjian RZ, Hung M, Keener JD, Bowen RC, McAllister J, Chen W et al. Determining the minimal clinically important difference for the American Shoulder and Elbow Surgeons score, Simple Shoulder Test, and visual analog scale (VAS) measuring pain after shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:144-148. doi:10.1016/j.jse.2016.06.007
44. Theodoulou A, Krishnan J, Aromataris E. The influence of diabetes mellitus and obesity on upper limb arthroplasty outcomes: a systematic review protocol. JBI Database System Rev Implement Rep 2017;15:3-9. doi:10.11124/JBISRIR-2016-002940
45. Vincent HK, Struk AM, Reed A, Wright TW. Mid-term shoulder functional and quality of life outcomes after shoulder replacement in obese patients. Springerplus 2016;5:1929. doi:10.1186/s40064-016-3624-0
46. Voils CI, Crandell JL, Chang Y, Leeman J, Sandelowski M. Combining adjusted and unadjusted findings in mixed research synthesis. J Eval Clin Pract 2011;17:429-434. doi:10.1111/j.1365-2753.2010.01444.x
47. Wagner ER, Houdek MT, Schleck C, Harmsen WS, Sanchez-Sotelo J, Cofield R et al. Increasing Body Mass Index Is Associated with Worse Outcomes After Shoulder Arthroplasty. J Bone Joint Surg Am 2017;99:929-937. doi:10.2106/JBJS.15.00255
48. Wagner ER, Kamath AF, Fruth KM, Harmsen WS, Berry DJ. Effect of Body Mass Index on Complications and Reoperations After Total Hip Arthroplasty. J Bone Joint Surg Am 2016;98:169-179. doi:10.2106/JBJS.O.00430

515 49. Werner BC, Burrus MT, Begho I, Gwathmey FW, Brockmeier SF. Early revision
516 within 1 year after shoulder arthroplasty: patient factors and etiology. J Shoulder Elbow
517 Surg 2015;24:e323-330. doi:10.1016/j.jse.2015.05.035
518 50. Werner BC, Burrus MT, Browne JA, Brockmeier SF. Superobesity (body mass index
519 >50 kg/m2) and complications after total shoulder arthroplasty: an incremental effect
520 of increasing body mass index. J Shoulder Elbow Surg 2015;24:1868-1875.
521 doi:10.1016/j.jse.2015.05.046

522

Legends

Figure Legend

Fig 1. PRISMA Flow diagram outlining process of study selection and inclusion. *

** Two studies reported on both obesity and diabetes mellitus, that is, a total of 21 unique studies identified prior to breakdown by exposure.*

***LoS** = Length of Stay; **QoL** = Quality of Life; **UTI** = Urinary Tract Infection; **VTE** = Venous Thromboembolism*

Fig 2. Forest plots of the odds of dislocation in various BMI groups. Follow-up periods: minimum 90 days and up to 1 year. (M-H: Mantel-Haenszel; CI: confidence interval; df: degrees of freedom).

Panel A: Obese (BMI ≥ 30.0) versus non-obese (BMI < 30.0) TSA/RTSA patients.

Fig 3. Forest plot of the odds of revision in various BMI groups. Follow-up period: up to 2 years, a minimum of 2 years and up to 8 years. (M-H: Mantel-Haenszel; CI: confidence interval; df: degrees of freedom; IV: inverse variance).

Panel A: Obese (BMI ≥ 30.0) versus non-obese (BMI < 30.0) TSA and RTSA patients.

Panel B: Morbidly obese (BMI ≥ 40.0) versus non-obese (BMI < 30.0) TSA and RTSA patients.

Fig 4. Weighted mean difference in postoperative pain scores between obese (BMI ≥ 30.0) versus non-obese (BMI < 30.0) reverse total shoulder arthroplasty patients. Postoperative pain was measured using the Visual Analogue Scale for Pain (0 to 10 scale, 0 = no pain). Follow-up period: minimum 2 years. (IV: inverse variance; CI: confidence interval; df: degrees of freedom; Min: minutes).

Table Legend

Table 1. Summary of characteristics of included studies

Act *= Active;* ***ASES*** *= American Shoulder and Elbow Score;* ***BMI*** *= Body Mass Index kg/m^2;* ***DM*** *= diabetes mellitus;* ***ER*** *= external rotation (degrees);* ***F*** *= Female;* ***GH*** *= Glenohumeral;* ***HR*** *= hazard ratio;* ***ICD-9*** *= International Classification of Diseases, Ninth Revision codes;* ***IR:*** *internal rotation (degrees);* ***M*** *= Male;* ***Min*** *= minutes;* ***n*** *= number of arthroplasties;* ***OA*** *= osteoarthritis;* ***OR*** *= odds ratio;* ***PH*** *= proximal humeral;* ***P-Val*** *= P-Value;* ***RA*** *= rheumatoid arthritis;* ***RC*** *= rotator cuff;* ***RR*** *= relative risk;* ***RTSA*** *= reverse total shoulder arthroplasty;;* ***SD*** *= standard deviation;* ***SST*** *= Simple Shoulder Test;* ***TSA*** *= total shoulder arthroplasty;* ***USA*** *= United States of America;* ***Yr.*** *= Year.*

[#]Mau et al.[36] reported TSA and RTSA data separately. As the RTSA subset constituted a greater proportion of the overall study sample, the data from the RTSA subset was included in the meta-analyses.

** All range of motion measurements (forward flexion, abduction, ER, IR) are measured in degrees unless otherwise stated.*

Table 2. Assessment of Methodological Quality

Total columns contain the percentage of cohort studies graded as Yes (Y), No (N), Unclear (U) or Not Applicable (NA) for each critical appraisal question. Cohort and case-control studies are reported separately.

Appraisal questions for cohort studies:

(1) Were the groups similar and recruited from the same population? (2) Were the variables (exposures/ outcomes) measured similarly to assign people to both exposed and unexposed groups? (3) Was the exposure/outcome used to group participants measured in a valid and reliable way? (4) Were confounding factors identified? (5) Were strategies to deal with confounding factors stated? (6) Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)? (7) Were the outcomes measured in a valid and reliable way? (8) Was the follow up time reported and sufficient to be long enough for outcomes to occur? (9) Was follow-up complete, and if not, were the reasons to loss to follow-up described and explored? (10) Were strategies to address incomplete follow-up utilized? (11) Was appropriate statistical analysis used?

Appraisal questions for case-control studies:

(1) Were the groups comparable other than the presence of disease in cases or the absence of disease in controls? (2) Were cases and controls matched appropriately? (3) Were the same criteria used for identification of cases and controls? (4) Was exposure measured in a standard, valid and reliable way? (5) Was exposure measured in the same way for cases and controls? (6) Were confounding factors identified? (7) Were strategies to deal with confounding factors stated? (8) Were outcomes assessed in a standard, valid and reliable way for cases? (9) Was the exposure period of interest long enough to be meaningful? (10) Was appropriate statistical analysis used?

Table 3. Meta-analysis summary table

OR = Odds Ratio; **MD** = Weighted Mean Difference; **H – M** = Mantel – Haenszel; **I – V** = Inverse Variance; **CI** = Confidence Interval; **Vs.** = Versus; **Random** = Random Effects Model; **VAS – Pain** = Visual Analogue Scale for Pain; **ASES** = American Shoulder and Elbow Score

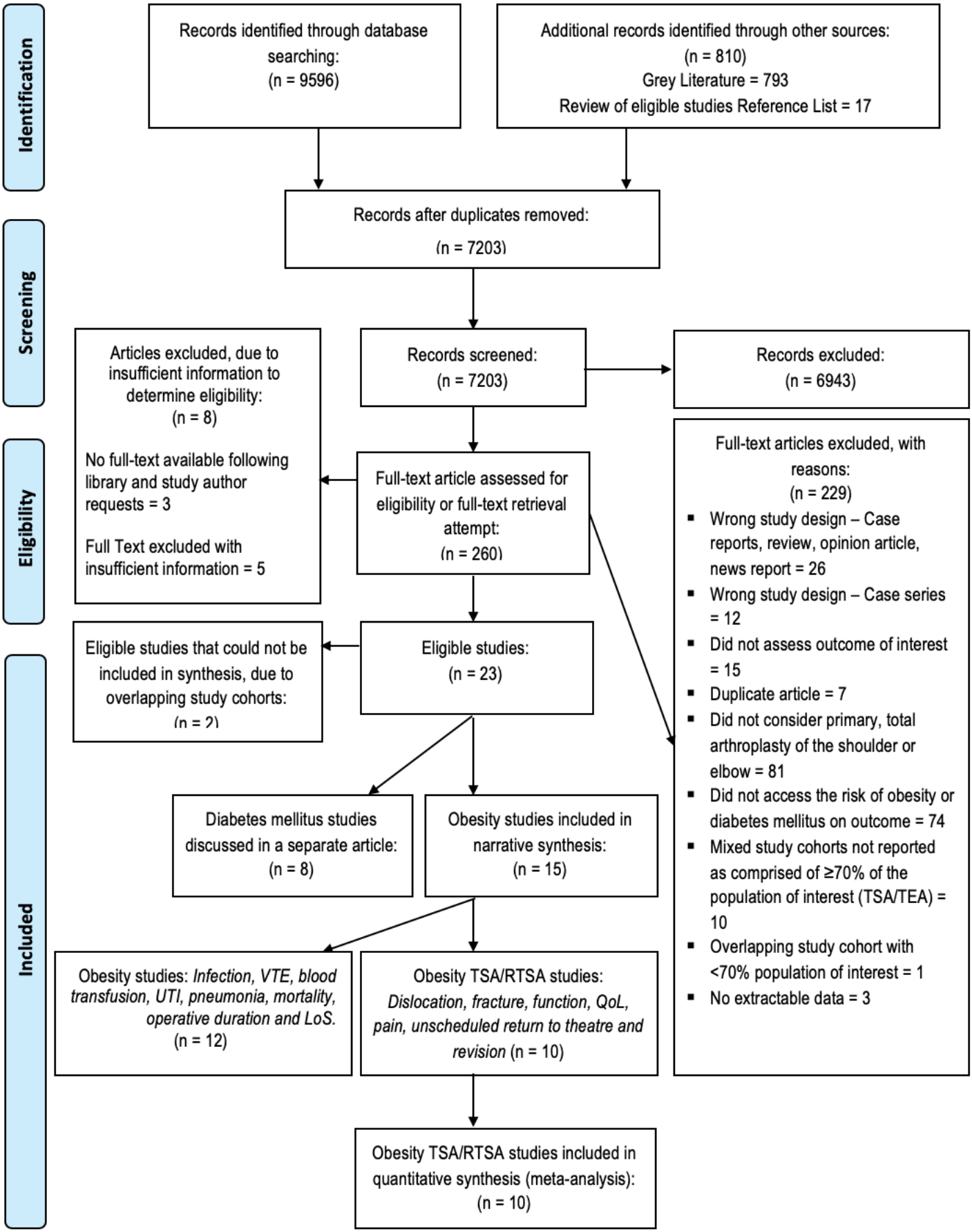
(ALL) = All studies that reported this outcome were combined in the meta-analysis comparing BMI < 30.0 versus ≥ 30.0, despite variations in individual study BMI groupings.

Body Mass Index (kg/m^2) Groups:

Normal: < 25.0, *Overweight:* 25.0 – 29.9, *Obese:* 30.0 – 39.9 (or *Obese Class 2:* 35.0 – 39.9), *Morbidly Obese:* ≥ 40.0; *Non-obese:* < 30.0

[#] **Sensitivity analysis – Removal of heavily weighted study**

- Fracture - Morbidly Obese Vs. Non-obese
- Revision (ALL) - Obese Vs. Non-obese


Identification
Screening
Eligibility
Included
Records identified through database searching: (n = 9596)
Additional records identified through other sources: (n = 810)
Grey Literature = 793
Review of eligible studies Reference List = 17
Records after duplicates removed: (n = 7203)
Records screened: (n = 7203)
Records excluded: (n = 6943)
Articles excluded, due to insufficient information to determine eligibility: (n = 8)
No full-text available following library and study author requests = 3
Full Text excluded with insufficient information = 5
Full-text article assessed for eligibility or full-text retrieval attempt: (n = 260)
Full-text articles excluded, with reasons: (n = 229)
Wrong study design – Case reports, review, opinion article, news report = 26
Wrong study design – Case series = 12
Did not assess outcome of interest = 15
Duplicate article = 7
Did not consider primary, total arthroplasty of the shoulder or elbow = 81
Did not access the risk of obesity or diabetes mellitus on outcome = 74
Mixed study cohorts not reported as comprised of ≥70% of the population of interest (TSA/TEA) = 10
Overlapping study cohort with <70% population of interest = 1
No extractable data = 3
Eligible studies that could not be included in synthesis, due to overlapping study cohorts: (n = 2)
Eligible studies: (n = 23)
Diabetes mellitus studies discussed in a separate article: (n = 8)
Obesity studies included in narrative synthesis: (n = 15)
Obesity studies: Infection, VTE, blood transfusion, UTI, pneumonia, mortality, operative duration and LoS. (n = 12)
Obesity TSA/RTSA studies: Dislocation, fracture, function, QoL, pain, unscheduled return to theatre and revision (n = 10)
Obesity TSA/RTSA studies included in quantitative synthesis (meta-analysis): (n = 10)

Panel A

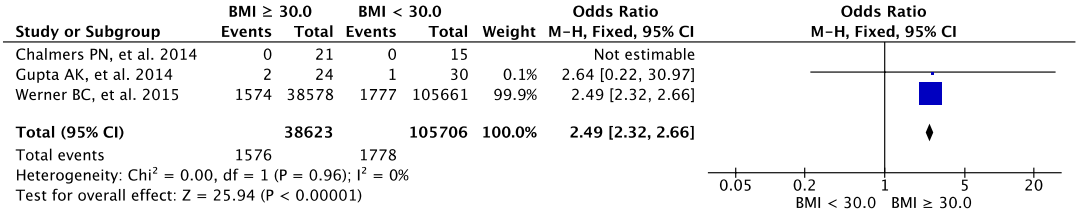
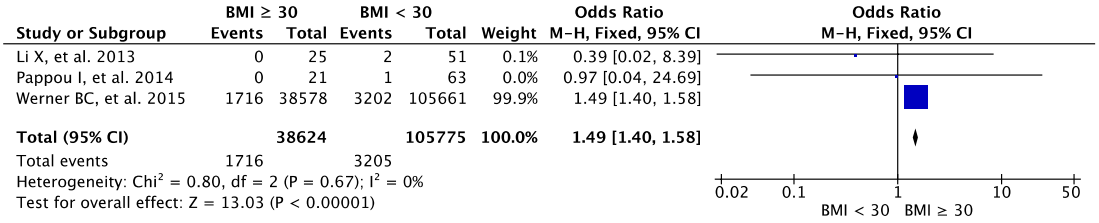


Fig 2. *Forest plots of the odds of dislocation in various BMI groups. Follow-up periods:* minimum 90 days and up to 1 year. *(M-H: Mantel-Haenszel; CI: confidence interval; df: degrees of freedom).*

Panel A: Obese (BMI ≥ 30.0) versus non-obese (BMI < 30.0) TSA/RTSA patients.

Panel A



Panel B

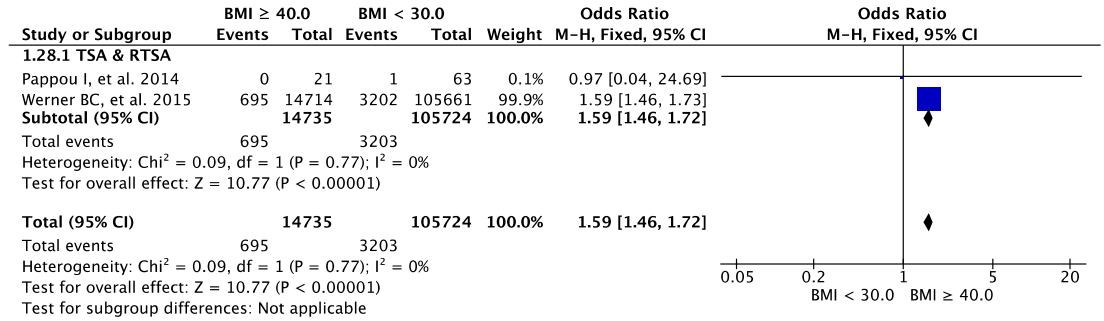


Fig 3. *Forest plot of the odds of revision in various BMI groups. Follow-up period: up to 2 years, a minimum of 2 years and up to 8 years. (M-H: Mantel-Haenszel; CI: confidence interval; df: degrees of freedom; IV: inverse variance).*

Panel A: Obese (BMI ≥ 30.0) versus non-obese (BMI < 30.0) TSA and RTSA patients.

Panel B: Morbidly obese (BMI ≥ 40.0) versus non-obese (BMI < 30.0) TSA and RTSA patients.

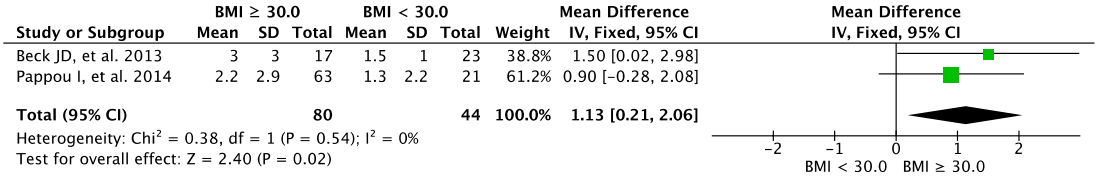


Fig 4. *Weighted mean difference in postoperative pain scores between obese (BMI ≥ 30.0) versus non-obese (BMI < 30.0) reverse total shoulder arthroplasty patients. Postoperative pain was measured using the Visual Analogue Scale for Pain (0 to 10 scale, 0 = no pain) Follow-up period: minimum 2 years. (IV: inverse variance; CI: confidence interval; df: degrees of freedom; Min: minutes).*

Table 1. Summary of characteristics of included studies

Included study	Methods	Exposure, Arthroplasty procedure	Participants	Setting	Complications and postoperative outcomes	
Jiang et al.[27]	**Study design:** Retrospective cohort study **Follow-up:** Up to 30 days **Country of origin:** USA **No. of surgeons performing procedure:** Not reported **Surgical technique:** Not reported	**Exposure:** 1. BMI = 18.5-25 2. BMI = 25-30 3. BMI = 30-35 4. BMI >35 **Procedure:** TSA and RTSA **Indication for procedure:** Not reported	**Sample size:** Total *n = 4267* 1. n = 738 2. n = 1463 3. n = 1126 4. n = 940 **Demographics:** *Age: average yr.* (SD) 1. 72 (11) 2. 71 (10) 3. 69 (10) 4. 67 (9) *Gender: (F: M)* 1. 494: 244 2. 717: 746 3. 574: 552 4. 583: 357	**Setting:** The American College of Surgeons National Surgical Quality Improvement Program database was analysed from 2006 to 2013 for all patients who underwent a primary TSA, including anatomic TSA and reverse TSA. **Exclusions:** Patients were excluded if they had a BMI less than 18.5 kg/m2, lacked documented preoperative height and weight, or had previous shoulder hardware, fracture,	**Return to theatre:** n (%) **(Unknown causes)** 1. 10.3 (1.4) 2. 8.8 (0.6) 3. 7.9 (0.7) 4. 6.6 (0.7) *Adjusted RR (95% CI); P-Val* 2. 0.29 (0.07–1.29); 0.103 3. 0.56 (0.14–2.23); 0.408 4. 0.58 (0.12–2.89); 0.504	

			Ethnicity/Nationality: White/Hispanic (%): 1. 86 2. 85 3. 89 4. 94 Black (%): 1. 3 2. 3 3. 3 4. 7 Asian (%): 1. 2 2. < 1 3. < 1 4. < 1 *DM comorbidity: n (%)* 1. 59.0 (8) 2. 175.6 (12) 3. 132.8 (18) 4. 253.8 (27)	pathologic fracture, tumour, or associated infection.		
Werner et al.[50]	**Study design:** Retrospective cohort study	**Exposure:** 1. Non-obese (BMI < 30)	**Sample size:** Total *n = 144 239* 1. n = 105 661 2. n = 23 864	**Setting:** Patients who underwent TSA or RTSA from 2005 to 2012 were identified by	**Dislocation (1 Yr.):** n (%) 1. 1777 (1.7) 2. 867 (3.6) 3. 666 (4.8)	**Revision TSA (8 Yrs.)**: n (%) 1. 3202 (3.0) 2. 1021 (4.3)

	Follow-up: Infection, dislocation, component loosening, periprosthetic fracture = 1 year. Revision TSA = up to 8 years. VTE = 90 days medical complications **Country of origin:** USA **No. of surgeons performing procedure:** Not reported	2. Obese (BMI = 30-39.9) 3. Morbidly obese (BMI = 40-49.9) 4. Super obese (BMI => 50) **Procedure:** TSA and RTSA **Indication for procedure:** Not reported	3. n = 13 759 4. n = 955 **Demographics:** *Age: (%)* **< 65 Years** 1. 6.4 2. 7.8 3. 15.4 4. 27.1 **65 – 80 Years** 1. 68.6 2. 76.9 3. 74.7 4. 68.4 **> 80 Years** 1. 25.0 2. 15.2 3. 9.9 4. 4.5 *Gender: (F: M): n (%)* 1. 62763 (59.4): 42898 (40.6) 2. 15130 (63.4): 8734 (36.6) 3. 9893 (71.9):	ICD-9 procedure codes: 81.80 and 81.88. Patient data was collected from the PearlDiver patient records database. **Exclusions:** No patients undergoing shoulder HA were included.	4. 41 (4.3) *OR (95% CI); P-Val* **4 vs 1:** 1.8 (1.2–2.6); .004 **4 vs 2:** 1.3 (0.9–1.9); .278 **4 vs 3:** 1.0 (0.7–1.5); .941 **PP fracture (1 Yr.):** n (%) 1. 1454 (1.4) 2. 615 (2.6) 3. 368 (2.7) 4. 26 (2.7) *OR (95% CI); P-Val* **4 vs 1:** 1.4 (0.9–2.2); .222 **4 vs 2:** 1.3 (0.8–2.1); .336 **4 vs 3:** 0.9 (0.6–1.5); .909	3. 653 (4.7) 4. 42 (4.4) *OR (95% CI); P-Val* **4 vs 1:** 1.5 (1.1–2.0); .019 **4 vs 2:** 1.1 (0.8–1.5); .538 **4 vs 3:** 1.0 (0.7–1.4); .97 **Medical complications (90 Days):** n (%) 1. 4295 (4.1) 2. 2967 (12.4) 3. 2630 (19.1) 4. 271 (28.4) *OR (95% CI); P-Val* **4 vs 1:** 2.7 (2.2–3.4) <.0001 **4 vs 2:** 2.1 (1.7–2.6) <.0001 **4 vs 3:** 1.6 (1.3–1.9) <.0001

	Surgical technique: Not reported		3866 (28.1) 4. 801 (83.9): 154 (16.1) *Ethnicity/Nationality:* Not reported *DM comorbidity: n (%)* 1. 29662.6 (28.1) 2. 11454.7 (48.0) 3. 8379.2 (60.9) 4. 660.9 (69.2)			
Gupta et al.[19]	**Study design:** Retrospective cohort study **Follow-up:** Minimum 90 days **Country of origin:** USA	**Exposure:** 1. Normal BMI (BMI < 25) 2. Class 1 obesity (BMI = 25 – 35) 3. Class 2 Obesity (BMI > 35) **Procedure:** RTSA	**Sample size:** Total *n = 119* 1. n = 30 2. n = 65 3. n = 24 **Demographics:** *Age:* Mean (SD) Total: 73.3 (9.8) 1. 75.7 (8.2) 2. 74.1 (9.8) 3. 68.4 (10.5)	**Setting:** Patients who had undergone primary RTSA with a minimum 90-day postoperative follow-up were included. Department of Orthopedic Surgery, Rush University Medical Center, Chicago, IL, USA. **Exclusions:**	**Dislocation:** n (%) 1. 1 (3.3) 2. 2 (3.1) 3. 2 (8.3)	

	No. of surgeons performing procedure: Not reported **Surgical technique:** Not reported	**Indication for procedure:** RC tear arthropathy: 45 massive/ irreparable RC tear: 19 End-stage GH arthritis with irreparable RC tear: 35 Inflammatory arthropathy: 6 PH malunion with associated irreparable RC tear: 12	*Gender (F: M):* n (%) Total: 76 (64): 43 (36) 1. 22 (73): 8 (27) 2. 37 (57): 28 (43) 3. 18 (75): 6 (25) *Ethnicity/Nationality:* Not reported *DM comorbidity:* Authors reported DM comorbidity for all patients that had a complication of interest. Of the outcomes of interest in this review, 1 patient with a BMI > 40.0 experienced a dislocation.	Patients with previous shoulder arthroplasty, if RTSA was performed as a revision for a failed prior arthroplasty (hemiarthroplasty or TSA), prior deep space infection requiring explantation, or incomplete records.		
Chalmers et al.[6]	**Study design:** Retrospective cohort study	**Exposure:** 1. Normal BMI: (BMI < 25)	**Sample size:** Total *n = 127* 1. 15 2. 91 3. 21	**Setting:** All patients who underwent TSA by the senior author with a minimum of 90-days	**Dislocation:** n (%) 1. 0 (.0) 2. 2 (2.2) 3. 0 (0.0)	

	Follow-up: Minimum 90 days **Country of origin:** USA **No. of surgeons performing procedure:** 1 **Surgical technique:** Not reported	2. Obesity class I: (BMI: 25-35) 3. Obesity class II: (BMI: > 35.0) **Procedure:** TSA **Indication for procedure:** n OA: 120 Post-traumatic arthropathy: 4 Instability related arthropathy: 3	**Demographics:** *Age:* Mean 1. 66.3 2. 65.8 3. 65.2 *Gender (F: M):* n (%) 1. 10 (67): 5 (33) 2. 36 (40): 55 (60) 3. 13 (62): 8 (38) *Ethnicity/Nationality:* Not reported *DM comorbidity:* Not reported	of post-operative follow-up. Department of Orthopedic Surgery, Rush University Medical Center, Chicago, Illinois **Exclusions:** History of prior ipsilateral shoulder arthroplasty, or incomplete peri- or post-operative records.		
Li et al.[32]	**Study design:** Prospective cohort study **Follow-up:**	**Exposure:** 1. Normal (BMI < 25) 2. Overweight: (BMI: 25 – 29.9)	**Sample size:** Total *n = 76* 1. 26 2. 25 3. 25	**Setting:** Patients had unconstrained anatomic TSA in a single hospital between 1 January, 2009 and 31 January, 2010	**Function:** **Preop. vs Post-op (2 Yrs.)** *ASES Score: Mean (SD)* 1. 38.4 (15.5) **vs** 80.2 (19.4)	**Pain:** (points) **Preop. vs. Post-op (2 Yrs.)** *VAS – Pain* 1. Preop.: 62; Post-op: 12 2. Preop.: 68; Post-op: 18

	Up to 2 years **Country origin:** USA **No. of surgeons performing procedure:** Multiple **Surgical technique:** Unconstrained anatomic TSA	3. Obese: (BMI ≥ 30) **Procedure:** TSA **Indication for procedure:** OA, RA, or posttraumatic arthritis	**Demographics:** *Age:* Mean *(SD)* 1. 71 (9) 2. 71 (11) 3. 68 (8) *Gender (F: M):* n Total: 49: 27 1. 17: 9 2. 15: 10 3. 18: 8 *Ethnicity/Nationality:* Not reported *DM comorbidity:* Not reported	were enrolled into the prospective total shoulder registry, grouped according to BMI, and followed prospectively for two years **Exclusions:** Patients had undergone a hemiarthroplasty, reverse shoulder arthroplasty or any revision surgery as the index procedure.	2. 37.4 (18.1) **vs** 75.2 (24.9) 3. 35.8 (12.5) **vs** 80.0 (20.6) **Quality of life: Preop. vs. Post-op (2 Yrs.)** *SF-36 PCS:* Mean (SD) 1. 38.3 (6.5) **vs** 53.1 (11.3) 2. 36.1 (8.0) **vs** 39.8 (12.2) 3. 36.3 (8.4) **vs** 40.7 (12.4) *SF-36 MCS:* Mean (SD) 1. 47.4 (14.3) vs. 52.8 (10.0) 2. 49.7 (11.6) vs. 51.7 (11.5) 3. 51.5 (12.5) vs. 52.9 (11.6)	3. Preop.: 66; Post-op: 11 **Return to theatre:** n (%) **Cause: Deep infection** 1. 0 (0.0) 2. 1 (4.0) 3. 0 (0.0) **Revision TSA (2 Yrs.):** n (%) 1. 2 (7.7) 2. 0 (0.0) 3. 0 (0.0)

Mau et al.[36#]	**Study design:** Retrospective cohort study **Follow-up:** Ave. 39.8 ± 18.7 Months (Minimum 2 years) **Country of origin:** USA **No. of surgeons performing procedure:** 12 **Surgical technique:** Prosthesis: Equinoxe (Exactech,	**Exposure:** 1. BMI <25 2. BMI 25 – 35 3. BMI > 35 **Procedure:** TSA and RTSA **Indication for procedure:** Degenerative arthritis = 499 RC arthropathy OR OA= 612	**Sample size:** *TSA* 1. 110 2. 290 3. 99 *RTSA* 1. 196 2. 357 3. 59 **Demographics:** *Age:* Mean (SD) *TSA* 1. 68.1 (9.8) 2. 66 (8.9) 3. 63.7 (7.2) *RTSA* 1. 73.5 (7.7) 2. 71.3 (7.7) 3. 68.9 (8.6) *Gender (F: M):* n 1. 79: 31 2. 134: 156 3. 52: 47	**Setting:** Patient data was gathered from a multi-institutional database. Patients were treated using either TSA or RTSA with one platform shoulder system. **Exclusions:** None reported	**TSA Group** **Function:** **Preop. vs. Post-op** *SST:* Mean (SD) 1. 4.3 (2.6) vs 10.5 (2.2) 2. 3.8 (2.7) vs 10.4 (2.4) 3. 3.0 (2.8) vs 10.0 (2.8) *ULCA:* Mean (SD) 1. 14.8 (3.7) vs 31.3 (5.1) 2. 14.6 (3.9) vs 30.1 (6.0) 3. 12.8 (4.3) vs 30.2 (5.7) *ASES:* Mean (SD) 1. 40.0 (15.0) vs 87.4 (17.7) 2. 38.5 (12.6) vs 84.2 (19.9) 3. 31.1 (15.8) vs 81.2 (21.4) *Constant:* Mean (SD) 1. 39.2 (14.1) vs 73.1 (12.5) 2. 37.8 (12.6) vs 71.2 (15.1) 3. 31.0 (11.6) vs 67.9 (17.4)	**RTSA Group** **Function:** **Preop. vs. Post-op** *SST:* Mean (SD) 1. 2.7 (2.3) vs 10.0 (2.4) 2. 2.8 (2.8) vs 9.9 (2.6) 3. 2.9 (2.9) vs 10.3 (2.2) *ULCA:* Mean (SD) 1. 12.1 (3.9) vs 30.1 (5.2) 2. 12.4 (4.2) vs 30.3 (4.9) 3. 12.8 (5.1) vs 30.5 (4.9) *ASES:* Mean (SD) 1. 35.0 (16.0) vs 84.3 (17.3) 2. 32.3 (17.0) vs 84.4 (17.3) 3. 33.0 (21.4) vs 86.0 (15.3) *Constant:* Mean (SD) 1. 30.2 (14.0) vs 71.1 (14.4) 2. 30.1 (14.8) vs 71.5 (15.2) 3. 30.8 (18.2) vs 72.2 (15.1)

	Inc., Gainesville, Florida)		*RTSA* 1. 138: 58 2. 217: 140 3. 34: 25 Ethnicity/Nationality: Not reported DM comorbidity: Not reported		*SPADI:* Mean (SD) 1. 79.0 (19.1) vs 13.8 (20.4) 2. 80.6 (21.8) vs 18.4 (24.9) 3. 90.0 (21.3) vs 22.1 (26.1) *Act abduction:* Mean (SD)* 1. 83.5 (28.0) vs 122.9 (29.8) 2. 80.2 (27.1) vs 120.1 (30.2) 3. 77.4 (25.7) vs 116.2 (31.9) *Act forward flexion:* Mean (SD)* 1. 100.3 (33.5) vs 144.4 (30.8) 2. 95.8 (30.6) vs 139.9 (32.0) 3. 88.7 (27.3) vs 141.2 (34.2) *IR:* Mean (SD)*	*SPADI:* Mean (SD) 1. 85.2 (22.1) vs 20.2 (23.8) 2. 83.1 (21.8) vs 21.5 (24.8) 3. 79.2 (25.1) vs 19.9 (20.4) *Act abduction:* Mean (SD)* 1. 60.0 (33.5) vs 102.7 (24.9) 2. 65.0 (35.5) vs 106.1 (26.0) 3. 69.2 (34.1) vs 105.7 (25.7) *Act forward flexion:* Mean (SD)* 1. 80.5 (40.7) vs 140.4 (26.0) 2. 82.7 (41.0) vs 139.6 (28.4) 3. 85.7 (41.2) vs 132.6 (32.6) *IR:* Mean (SD)* 1. 3.1 (1.8) vs 4.9 (1.4)

					1. 3.3 (1.6) vs 5.7 (1.2) 2. 2.8 (1.5) vs 5.2 (1.4) 3. 2.7 (1.4) vs 4.4 (1.6) *Act ER:* Mean (SD)* 1. 17.2 (19.9) vs 50.2 (20.6) 2. 16.2 (19.9) vs 45.7 (20.4) 3. 14.2 (17.1) vs 42.6 (19.7)	2. 2.9 (1.8) vs 4.5 (1.7) 3. 2.4 (1.7) vs 4.0 (1.7) *Act ER:* Mean (SD)* 1. 10.7 (21.8) vs 32.3 (13.1) 2. 13.2 (21.2) vs 32.8 (16.2) 3. 14.5 (21.0) vs 31.1 (14.2)
Beck et al.[4]	**Study design:** Retrospective cohort study **Follow-up:** Minimum 2 years **Country of origin:** USA **No. of surgeons performing procedure:** 1	**Exposure:** 1. Normal (BMI: 18.5 – 24.9) 2. Overweight: (BMI: 25 – 29.9) 3. Obese: (BMI ≥ 30) **Procedure:** RTSA **Indication for procedure:** RC arthropathy	**Sample size:** Total n = 76 1. 23 2. 36 3. 17 **Demographics:** *Age:* Mean (range) Total: 75 (51 – 88) *Gender (F: M):* n 1. 13: 10 2. 19: 17 3. 12: 5 *Ethnicity/Nationality:* Not reported	**Setting:** Patients undergoing RTSA for rotator cuff arthropathy by a single surgeon from 1 January, 2005 to 1 March, 2010. Inclusion criteria included patient age > 18 years, primary diagnosis of RC arthropathy, minimum 2-year follow-up, and subsequent RTSA by the senior author (G.D.H.). **Exclusions:** Patients with history of infection.	**Function:** Post-op *Act forward flexion:* Mean (SD)* 1. 134 (32) 2. 129 (43) 3. 117 (44) *Act abduction:* Mean (SD)* 1. 99 (26) 2. 100 (41) 3. 86 (27) *Act ER:* Mean (SD)* 1. 26 (15) 2. 33 (17) 3. 23 (18)	**Pain:** (points) Mean (SD) *VAS – Pain – Post-Op.* 1. 1.5 (1) 2. 2.6 (3) 3. 3.0 (3)

	Surgical technique: Deltoid-splitting approach; Deltopectoral approach.		*DM comorbidity: n (%)* 1. 1 (4.3) 2. 7 (19.4) 3. 8 (47.1)			
Pappou et al.[37]	**Study design:** Case-control Study **Follow-up:** Minimum 2 years **Country of origin:** USA **No. of surgeons performing procedure:** 1	**Exposure:** 1. Obese (BMI ≥ 40) 2. Controls (BMI < 30) **Procedure:** RTSA **Indication for procedure:** RC tear arthropathy = 68 Massive RC tear = 8 RA = 8	**Sample size:** Total *n = 84* 1. 21 2. 63 **Demographics:** *Age:* Mean (range) 1. 69.2 (7.1) 2. 71.1 (6.4) *Gender (F: M):* n 1. 17: 4 2. 50: 13 *Ethnicity/Nationality:* Not reported *DM comorbidity:* Not reported	**Setting:** A prospective database was retrospectively searched for morbidly obese patients with a BMI of ≥40 kg/m2 who had undergone primary RTSA for a reason other than fracture from 1 January, 2003 to 31 December, 2010. Three controls for each morbidly obese patient were matched on the basis of age, sex, surgical indication, and duration of follow-up. **Exclusions:**	**Function:** Mean (SD) **Preop. vs Post-op** *VAS – Function* 1. 2.1 (2.1) vs 6.9 (2.4) 2. 3.6 (2.4) vs 7.8 (2.2) *ASES Score:* Mean (SD) 1. 32.0 (12.8) vs 69.0 (16.0) 2. 39.9 (17.8) vs 78.2 (18.6) *SST:* Mean (SD) 1. 1.1 (1.1) vs 7.0 (3.4) 2. 2.1 (1.9) vs 8.2 (2.9) *Forward flexion:* Mean (SD)* 1. 61 (26) vs 139 (39)	**Pain:** Mean (SD) **Preop. vs Post-op** *VAS – Pain* 1. 6.6 (1.9) vs 2.2 (2.9) 2. 6.2 (2.2) vs 1.3 (2.2) **Acromial fracture**: n (%) 1. 2 (9.5) 2. 1 (1.6) **Revision:** n (%) **Cause: Humeral stem loosening** 1. 0 (0.0) 2. 1 (1.6) (Revision occurred at 75 months post RTSA)

	Surgical technique: Prosthesis: Reverse shoulder prosthesis (DJO Surgical) All received deltopectoral approach.			Patients receiving a RTSA for treatment of a PH fracture, who had incomplete clinical and radiographic data, or less than 2-year follow-up.	2. 74 (42) vs 153 (31) *Abduction:* Mean (SD)* 1. 56 (20) vs 125 (49) 2. 68 (35) vs 138 (40) *ER:* Mean (SD)* 1. 11 (25) vs 54 (35) 2. 26 (26) vs 55 (33) *IR: (vertebral levels)* 1. L5 (2) vs T12 (2) 2. L3 (2) vs T12 (2)	
Singh et al.[41]	**Study design:** Retrospective cohort study **Follow-up:** Mean: 7 years Range: 1 day -31 years **Country of origin:** USA	**Exposure:** 1. BMI = < 24 2. BMI = 25-29.9 3. BMI = 30-35.9 4. BMI = 35-39.9 5. BMI ≥ 40 **Procedure:** TSA **Indication for procedure:** RA = 452	**Sample size:** Total *n = 2588* 1. 475 2. 744 3. 521 4. 235 5. 126 **Demographics:** *Age:* Mean (median) Total: 65 (67) *Gender (F: M):* n	**Setting:** Every patient who had had a primary shoulder arthroplasty performed when they were eighteen years of age or older at the Mayo Clinic Medical Center, Rochester, Minnesota, in a thirty-three-year period from 1976 to 2008. Periprosthetic shoulder fractures were identified from the total joint registry.	**PP fracture:** n (%) 1. 7 (1.5) 2. 1 (0.1) 3. 2 (0.4) 4. 3 (1.3) 5. 2 (1.6)	

	No. of surgeons performing procedure: Not reported **Surgical technique:** Cemented implants: 2485 No cement: 103	Trauma-related = 374 OA = 1640 Other = 122	1372: 1216 *Ethnicity/Nationality:* Not reported *DM comorbidity:* Not reported	**Exclusions:** Not reported		
Singh et al.[42]	**Study design:** Retrospective cohort study **Follow-up:** Up to 20 years **Country of origin:** USA	**Exposure:** Total BMI: Mean (SD) 30 (6) **Procedure:** TSA **Indication for procedure:** n RA = 452 Trauma = 374 Tumour = 37	**Sample size:** Total *n = 2588* **Demographics:** *Age:* Mean (SD) Total: 65 (12) *Gender (F: M):* n (%) Total 1163 (53): 1044 (47) *Ethnicity/Nationality:*	**Setting:** All patients who had undergone TSA between January 1976 and December 2008 at the Mayo Clinic Medical Centre, Rochester, Minnesota. BMI data only available from 1987 onwards. **Exclusion:** Not reported	**Revision:** *Univariate regression analysis:* HR (95% CI) 1.01 (0.99,1.04) P-Val: 0.29	

	No. of surgeons performing procedure: Not reported **Surgical technique:** Not reported	OA = 1640 RC Disease = 40 Other = 30	Not reported DM comorbidity: *Not reported*			

Act *= Active;* ***ASES*** *= American Shoulder and Elbow Score;* ***BMI*** *= Body Mass Index kg/m^2;* ***DM*** *= diabetes mellitus;* ***ER*** *= external rotation (degrees);* ***F*** *= Female;* ***GH*** *= Glenohumeral;* ***HR*** *= hazard ratio;* ***ICD-9*** *= International Classification of Diseases, Ninth Revision codes;* ***IR:*** *internal rotation (degrees);* ***M*** *= Male;* ***Min*** *= minutes;* ***n*** *= number of arthroplasties;* ***OA*** *= osteoarthritis;* ***OR*** *= odds ratio;* ***PH*** *= proximal humeral;* ***P-Val*** *= P-Value;* ***RA*** *= rheumatoid arthritis;* ***RC*** *= rotator cuff;* ***RR*** *= relative risk;* ***RTSA*** *= reverse total shoulder arthroplasty;;* ***SD*** *= standard deviation;* ***SST*** *= Simple Shoulder Test;* ***TSA*** *= total shoulder arthroplasty;* ***USA*** *= United States of America;* ***Yr.*** *= Year.*

#Mau et al.[36] reported TSA and RTSA data separately. As the RTSA subset constituted a greater proportion of the overall study sample, the data from the RTSA subset was included in the meta-analyses.

******* *All range of motion measurements (forward flexion, abduction, ER, IR) are measured in degrees unless otherwise stated.*

Table 2. Assessment of Methodological Quality

Included Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Cohort study designs											
Jiang et al.[27]	Y	Y	N	Y	Y	NA	Y	Y	NA	NA	Y
Werner et al.[50]	Y	Y	N	Y	N	NA	U	Y	NA	NA	N
Gupta et al.[19]	N	Y	N	Y	Y	NA	Y	Y	NA	NA	Y
Chalmers et al.[6]	Y	Y	N	Y	Y	NA	Y	Y	NA	NA	Y
Li et al.[32]	Y	Y	N	Y	N	NA	U	Y	U	U	N
Mau et al.[36]	N	Y	N	N	N	NA	U	Y	NA	NA	N
Beck et al.[4]	Y	Y	N	Y	Y	NA	Y	Y	NA	NA	Y
Singh et al.[41]	Y	Y	Y	Y	Y	NA	Y	Y	NA	NA	Y
Singh et al.[42]	Y	Y	N	Y	Y	NA	Y	Y	NA	NA	Y
Total Y Score (%)	***77.8***	***100.0***	***11.1***	***88.9***	***66.7***	***0.0***	***66.7***	***100.0***	***0.0***	***0.0***	***66.7***
Total N Score (%)	***22.2***	***0.0***	***88.9***	***11.1***	***33.3***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***33.3***
Total U Score (%)	***0.0***	***0.0***	***0.0***	***9.1***	***0.0***	***0.0***	***33.3***	***0.0***	***11.1***	***11.1***	***0.0***
Total NA Score (%)	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***100***	***0.0***	***0.0***	***88.9***	***88.9***	***0.0***

Case – Control study design											
Pappou et al.[37]	Y	Y	Y	N	Y	Y	NA	Y	Y	Y	-

Total columns contain the percentage of cohort studies graded as Yes (Y), No (N), Unclear (U) or Not Applicable (NA) for each critical appraisal question. Cohort and case-control studies are reported separately.

Appraisal questions for cohort studies:

(1) Were the groups similar and recruited from the same population? (2) Were the variables (exposures/ outcomes) measured similarly to assign people to both exposed and unexposed groups? (3) Was the exposure/outcome used to group participants measured in a valid and reliable way? (4) Were confounding factors identified? (5) Were strategies to deal with confounding factors stated? (6) Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)? (7) Were the outcomes measured in a valid and reliable way? (8) Was the follow up time reported and sufficient to be long enough for outcomes to occur? (9) Was follow-up complete, and if not, were the reasons to loss to follow-up described and explored? (10) Were strategies to address incomplete follow-up utilized? (11) Was appropriate statistical analysis used?

Appraisal questions for case-control studies:

(1) Were the groups comparable other than the presence of disease in cases or the absence of disease in controls? (2) Were cases and controls matched appropriately? (3) Were the same criteria used for identification of cases and controls? (4) Was exposure measured in a standard, valid and reliable way? (5) Was exposure measured in the same way for cases and controls? (6) Were confounding factors identified? (7) Were strategies to deal with confounding factors stated? (8) Were outcomes assessed in a standard, valid and reliable way for cases? (9) Was the exposure period of interest long enough to be meaningful? (10) Was appropriate statistical analysis used?

Table 3. Meta-analysis summary table

Outcome	**Studies (n)**	**Total Patients (n)**	**Events**	**Heterogeneity (I^2, %)**	**Statistical Method**	**Effect Estimate**	**P- Value**
Dislocation Obese Vs. Non-obese (ALL)	3	144 329	3354	0	OR (M – H, Fixed, 95% CI)	2.49 [2.32, 2.66]	< 0.00001
Periprosthetic Facture Obese Vs. Non-obese	2	146 340	2 478	0	OR (M – H, Fixed, 95% CI)	1.92; [1.77, 2.08]	< 0.00001
Fracture Morbidly Obese Vs. Non-obese	3	121 804	1861	0	OR (M – H, Fixed, 95% CI)	1.98; [1.77, 2.21]	<0.0001
Fracture Morbidly Obese Vs. Non-obese[#] (removal of heavily weighted study)	2	1 429	13	0	OR (M – H, Fixed, 95% CI)	3.40 [0.97, 11.97]	0.06
Pain Scores (VAS – Pain) Obese Vs. Non-obese	2	124	-	0	MD (I – V, Fixed, 95% CI)	1.13; [0.21, 2.06]	0.02
ASES Functional Score Obese Vs. Non-obese	3	390	-	61	MD (I – V, Fixed, 95% CI)	-0.80; [-4.57, 2.97]	0.68
Abduction Functional Score Obese Vs. Non-obese (ALL)	3	379	-	53	MD (I – V, Fixed, 95% CI)	-0.78; [-7.27, 5.71]	0.81

External Rotation Functional Score Obese Vs. Non-obese (ALL)	3	379	-	0	MD (I – V, Fixed, 95% CI)	-1.41; [-5.11, 2.29]	0.45
Forward Flexion Functional Score Obese Vs. Non-obese (ALL)	3	379	-	0	MD (I – V, Fixed, 95% CI)	-9.80; [-17.53, -2.07]	0.01
Unscheduled Return to Theatre Obese Vs. Non-obese	2	4 343	35	0	OR (M – H, Fixed, 95% CI)	0.83; [0.43,1.61]	0.58
Revision (ALL) Obese Vs. Non-obese	3	144 399	4921	0	OR (M – H, Fixed, 95% CI)	1.49; [1.40, 1.58]	<0.0001
Revision (ALL) Obese Vs. Non-obese[#] (removal of heavily weighted study)	2	160	3	0	OR (M – H, Fixed, 95% CI)	0.57; [0.06, 5.19]	<0.0001
Revision Morbidly Obese Vs. Non-obese	2	120 459	3 898	0	OR (M – H, Fixed, 95% CI)	1.59; [1.46, 1.72]	<0.0001

OR = Odds Ratio; **MD** = Weighted Mean Difference; **H – M** = Mantel – Haenszel; **I – V** = Inverse Variance; **CI** = Confidence Interval; **Vs.** = Versus; **Random** = Random Effects Model; **VAS – Pain** = Visual Analogue Scale for Pain; **ASES** = American Shoulder and Elbow Score

(ALL) = All studies that reported this outcome were combined in the meta-analysis comparing BMI < 30.0 versus ≥ 30.0, despite variations in individual study BMI groupings.

Body Mass Index (kg/m^2) Groups:
Normal: < 25.0, *Overweight:* 25.0 – 29.9, *Obese:* 30.0 – 39.9 (or *Obese Class 2:* 35.0 – 39.9), *Morbidly Obese:* ≥ 40.0; *Non-obese:* < 30.0

[#] **Sensitivity analysis – Removal of heavily weighted study**

- Fracture - Morbidly Obese Vs. Non-obese
- Revision (ALL) - Obese Vs. Non-obese