Does diabetes affect functional outcomes after shoulder arthroplasty?

Sana'a A. Alsubheen [a, *], Joy C. MacDermid [a, b], Tom J. Overend [a], Kenneth J. Faber [b]

[a] School of Physical Therapy, Western University, London, Ontario, Canada
[b] Hand and Upper Limb Centre, St. Joseph's Health Care London, London, Ontario, Canada

ARTICLE INFO

ABSTRACT

Objectives: The purpose of this study was to assess whether diabetes affects functional and physical outcomes following shoulder arthroplasty

Methods: A cohort of 140 patients were tested preoperatively, at an early follow-up visit (between 3-6 months) and at late follow-up visit (between 1-3 years) following shoulder arthroplasty. The American Shoulder and Elbow Surgeons (ASES) Standardized Shoulder Assessment Form measured shoulder pain and function and the Short-Form-12 (SF-12) measured physical health status. Shoulder goniometry and dynamometry were used to assess motion and strength. Diabetic status was self-reported.

Results: There were significant improvements in function and physical health status for both diabetic and nondiabetic patients at the late follow-up visit. For patients with diabetes, shoulder function (ASES: 0-30) improved from 5 (5) to 18 (6) scores ($p < 0.001$) and physical health status improved from 27 (6) to 38 (8) scores ($p < 0.001$). For patients without diabetes, shoulder function improved from 8 (5) to 19 (8) scores ($p < 0.001$) and physical health status improved from 31 (8) to 40 (12) scores ($p < 0.001$). No significant differences between diabetic and nondiabetic patients was detected at the late follow-up.

Conclusion: Patients with diabetes achieve large clinical benefits from shoulder arthroplasty, with follow-up outcomes equally positive to those without diabetes. Future prospective studies with a larger sample size of patients with diabetes are needed to confirm the results of this study.

Level of evidence: II

1. Introduction

Shoulder arthroplasty surgery replaces the damaged humeral head and glenoid with prosthetic implants. This surgical procedure has been shown to significantly reduce pain, restore joint function and improve shoulder range of motion (ROM) at 2 years and beyond in patients who underwent total shoulder arthroplasty (TSA) or hemiarthroplasty (HA).[1–4] Osteoarthritis is the primary diagnosis for 77% of shoulder arthroplasty and often occurs in middle-aged or older adults. Hence, comorbid health problem can be prevalent; including hypertension and diabetes which have been reported in 63% and 20%, respectively.[5]

Diabetes has been shown to be an independent risk factor for increased risk of non-home discharge and longer hospital stays following shoulder arthroplasty.[6,7] Further, diabetes, along with hypertension and obesity, are reported to predict increased postoperative complications such as humeral fracture and joint infection.[8] However, previous research found weak associations between patient satisfaction, physical impairment and patient-reported functional outcomes in patients who have undergone arthroplasty.[9] This may reflect the diversity in presentation, patient priorities and expectations. While it is known that diabetes is associated with poor outcomes in ROM and patient-reported function after total knee arthroplasty,[10] it is unknown whether this is also true for shoulder arthroplasty.

Given the fact that the number of patients with diabetes is increasing (from 11% in 2010 to 14% by 2030),[11] the negative impact of hyperglycemia on body tissue,[12] and the adverse effect of diabetes on postoperative complications and length of hospital stays,[7,8] there is a need to investigate whether diabetes affects functional outcomes and motion after shoulder arthroplasty. The purpose of this study was to investigate the impact of diabetes on pain, patient-reported function, physical health status, and impairments in shoulder ROM and muscle strength in patients who underwent shoulder arthroplasty.

* Corresponding author. School of Physical Therapy, Western University, London, Ontario, N6G 1H1, Canada.

E-mail addresses: salsubhe@uwo.ca (S.A. Alsubheen), jmacderm@uwo.ca (J.C. MacDermid), toverend@uwo.ca (T.J. Overend), kjfaber@uwo.ca (K.J. Faber).

2. Materials and methods

2.1. Study design and patients

A retrospective analysis of a prospective cohort of 140 patients undergoing shoulder arthroplasty at an upper extremity surgical unit was conducted. Patients' demographic characteristics were collected and recorded into a computerized database before the surgical intervention (Baseline), and at the time of early follow-up visit (3–6 months), and again at the time of their late follow-up visit (1–3 years). Shoulder pain, function, ROM, muscle strength, and physical health status were examined across these three time-points. In this study, patients were classified into two groups: patients with diabetes and patients without diabetes based on self-report using the Self-Administered Comorbidity Questionnaire (SCQ) which is an efficient method to classify comorbidity, and has been shown to concur with medical chart retraction.[13] This cohort included patients who were treated with a mix of surgical interventions such as TSA, HA, and reverse TSA (rTSA). The local Research Ethics Board (REB) approved the study and written consents were obtained from all patients before the study.

2.2. Outcome measures

2.2.1. Primary outcome

The primary outcome measure of shoulder was pain and function assessed using the American Shoulder and Elbow Surgery (ASES) Standardized Shoulder Assessment Form.[14] The ASES has been shown to be a valid and responsive measure of shoulder pain and function after shoulder arthroplasty.[15] A full description of this form is published.[14] The minimal clinically important difference (MCID) value for shoulder pain on the Visual Analogue Scale (VAS: 0–10) is a decrease of 1.6 points and for the 100-point ASES scale is an increase of 13.6 points.[16] In this study, information from patients' self-evaluation section were collected [pain severity (VAS: 0–10) and activities of daily living (0–30 scores per side)]. ASES scores were compared to norms established in an age-matched controls.[17]

2.2.2. Secondary outcomes

The secondary outcomes measured ROM, muscle strength and physical health status.

Physical health status was assessed using the Physical Component Summary (PCS) of the Short Form-12 (SF-12) survey.[18] The SF-12 has been shown to be a valid and reliable assessment tool[18] and has been used to assess patients after shoulder arthroplasty.[19] The MCID is 4.5 points for the PCS on the SF-12 survey.[20]

Shoulder ROM was assessed in flexion, abduction, and external and internal rotation using a standard goniometer. Shoulder ROM were measured using standardized procedures with known high reliability (Intraclass Correlation Coefficients (ICCs) > 0.97).[21–23] The MCID values for shoulder active forward flexion is 12°, active abduction is 7°, and active external rotation is 3°.[16]

Isometric muscle strength was assessed for shoulder flexors, abductors, and external and internal rotators using the JTech PowerTrack handheld dynamometer (JTech; JTech Medical, Salt Lake City, UT, USA), with known concurrent validity[24] and reliability (ICCs 0.89–0.98).[25] Shoulder muscle strength and ROM scores were compared to norms established in an age-matched controls and with similar testing procedures.[26,27]

2.3. Inclusion and exclusion criteria

Patients were included if they completed the SCQ to identify the presence of diabetes; the ASES and/or the SF-12 questionnaires; and if their shoulder muscle strength and ROM were measured at baseline, at early follow-up and at late follow-up visits. Exclusion criteria included inability or refusal to complete tests/measures.

3. Statistical analysis

Statistical analyses were performed using SPSS, version 23 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were performed to evaluate normality using a Kolmogorov-Smirnov (K-S) test. Descriptive statistics were calculated for the patients' demographics, and for each outcome measure at each time point. Continuous measures were reported as means and standard deviations and categorical measures were reported as numbers and percentages. In bivariate analysis, patients with and without diabetes groups were compared using independent sample t-test for continuous data (age and all outcomes measures at baseline) and Chi-square test for categorical data. A General Linear Model (GLM) with repeated measures was used to assess significant differences in the primary and secondary measures over time, and between patients with and without diabetes at baseline, at early follow-up and at late follow-up visits while controlling for the type of surgery (total arthroplasty, reverse total arthroplasty, and hemi-arthroplasty) and the indication for surgery. Mauchly's test was used to assess the assumption of sphericity. When sphericity was violated, degrees of freedom (df) were corrected using Huynh-Feldt estimates of sphericity.[28] To assess the effectiveness of surgical intervention, we calculated the between group effect sizes by reporting the Standardized Response Mean (SRM) $= \delta\chi/SD\delta\chi$. The $\delta\chi$ is the mean between-group differences, and the SD$\delta\chi$ is the pooled standard deviation reflecting the variability of change between the two groups. To allow and facilitate clinical decision making, benchmark values of trivial (<0.20), small ($\geq$0.20 to < 0.50), moderate ($\geq$0.50 to < 0.80) or large ($\geq$0.80), proposed by Cohen, were utilized.[29] An alpha level (α) of 0.05 was used to indicate statistical significance. Significant interactions were followed by pairwise comparisons using a Bonferroni correction.

4. Results

4.1. Descriptive statistics

Patients who underwent shoulder arthroplasty and met the inclusion criteria were included in the analysis of ASES (n = 140), SF-12 (n = 103), shoulder ROM (n = 140), and shoulder muscle strength (n = 127). The demographic characteristics of patients who completed one or both surveys are summarized in Table 1 and the demographic characteristics of patients whose shoulder ROM and muscle strength were measured are summarized in Table 2. No significant differences between patients with and without diabetes were observed for age, sex, affected side, reason for surgery, and the type of surgical intervention. Within this cohort, 55% of the patients were treated with total shoulder arthroplasty, 30% of the patients were treated with reverse total shoulder arthroplasty, and 15% of the patients were treated with hemiarthroplasty. The main reason for surgery was joint arthritis (73%) while other reasons included shoulder fractures, dislocation and rotator cuff tear resulting from falls (27%). Patients were tested at baseline (pre-operative), and at two time-point post-surgery: at the late follow-up visit (3–6 months), and again at the late follow-up visit (1–3 years).

4.2. Effect of surgical interventions

4.2.1. Primary outcome

Table 3 presents the means and SD of the responses for the ASES pain and function scores at each point in time. There was significant

Table 1
Demographic characteristics of patients who underwent shoulder arthroplasty and completed one or both of the self-reported surveys.

Variable	ASES		SF-12	
	Diabetes		Diabetes	
	Yes	No	Yes	No
Total number (n)	28 (20%)	112 (80%)	20 (19%)	83 (81%)
Age (years)	75 (9)	70 (11)	73 (9)	73 (8)
Sex				
Male	10 (7%)	47 (34%)	9 (9%)	36 (35%)
Female	18 (13%)	65 (46%)	11 (11%)	47 (46%)
Dominant side				
Right	24 (17%)	104 (74%)	18 (18%)*	75 (74%)
Left	4 (3%)	8 (6%)	2 (2%)*	7 (7%)
Affected side				
Right	21 (15%)	66 (47%)	17 (17%)	47 (46%)
Left	7 (5%)	46 (33%)	3 (3%)	36 (35%)
Medical problems:				
Heart disease	7 (5%)	22 (16%)	7 (7%)*	11 (11%)
Hypertension	18 (13%)*	36 (26%)	14 (14%)*	25 (24%)
Lung disease	6 (4%)*	5 (4%)	3 (3%)	4 (4%)
Primary osteoarthritis	24 (17%)	83 (59%)	17 (17%)	55 (53%)
Rheumatoid arthritis	2 (1%)	22 (16%)	2 (2%)	11 (11%)
Others (cancer, depression, kidney and blood disease)	34 (24%)	116 (83%)	26 (26%)	81 (79%)
Reason for surgery:				
Arthritis	16 (13%)	60 (47%)	11 (11%)	51 (50%)
Rotator cuff tear	3 (2%)	4 (3%)	1 (1%)	3 (3%)
Others (fracture, dislocation, revised surgery)	9 (6%)	48 (33%)	8 (8%)	29 (28%)
Type of surgery:	n = 26	n = 110		
Total arthroplasty	16 (12%)	63 (47%)	11 (11%)	50 (49%)
Reverse total arthroplasty	8 (6%)	36 (26%)	6 (6%)	23 (23%)
Hemiarthroplasty	2 (2%)	11 (9%)	3 (3%)	9 (9%)

Independent sample *t-test* was used to detect difference in age (mean (SD)) between groups. Chi-square test was used to detect differences between groups in all categorical data (reported as number and percentage). *Significant difference between groups, $p < 0.05$. ASES: American Shoulder and Elbow Surgeons, SF-12: Short Form-12 survey.

Table 2
Demographic characteristics of patients who underwent shoulder arthroplasty and whose shoulder motion and/or muscle strength were measured.

Variable	ROM		Muscle strength	
	Diabetes		Diabetes	
	Yes	No	Yes	No
Total number (n)	27 (19%)	113 (81%)	23 (18%)	104 (82%)
Age (years)	73 (8)	71 (9)	74 (9)	70 (9)
Sex				
Male	12 (9%)	54 (39%)	11 (9%)	51 (40%)
Female	15 (11%)	59 (42%)	12 (9%)	53 (42%)
Dominant side				
Right	24 (17%)	104 (74%)	21 (17%)	97 (76%)
Left	3 (2%)	9 (6%)	2 (2%)	7 (6%)
Affected side				
Right	23 (16%)*	70 (50%)	20 (16%)*	66 (52%)
Left	4 (3%)*	43 (31%)	3 (2%)*	38 (30%)
Medical problems:				
Heart disease	8 (6%)*	14 (10%)	5 (4%)	14 (11%)
Hypertension	17 (12%)*	34 (24%)	16 (13%)*	35 (28%)
Lung disease	5 (4%)*	3 (2%)	4 (3%)	7 (6%)
Primary osteoarthritis	23 (16%)*	62 (44%)	20 (16%)*	68 (54%)
Rheumatoid arthritis	3 (2%)	12 (9%)	2 (2%)	12 (9%)
Others (cancer, depression, kidney and blood disease)	32 (23%)	90 (64%)	27 (22%)	89 (69%)
Reason for surgery:				
Arthritis	16 (13%)	60 (46%)	14 (14%)	63 (54%)
Rotator cuff tear	2 (2%)	1 (1%)	1 (1%)	1 (1%)
Others (fracture, dislocation, revised surgery)	10 (8%)	46 (35%)	7 (6%)	40 (33%)
Type of surgery:				
Total arthroplasty	19 (14%)	65 (48%)	15 (12%)	62 (50%)
Reverse total arthroplasty	6 (5%)	36 (26%)	6 (5%)	31 (25%)
Hemiarthroplasty	2 (1%)	11 (8%)	2 (2%)	9 (7%)

Independent sample *t-test* was used to detect difference in age (mean (SD)) between groups. Chi-square test was used to detect differences between groups in all categorical data (reported as number and percentage). *Significant difference between groups, $p < 0.05$. ROM: range of motion.

Table 3
A comparison of changes in pain, function, ROM, and muscle strength between patients with and without diabetes who underwent shoulder arthroplasty.

Variable	Baseline		Early follow-up visit (3—6 months)		Late follow-up visit (1—3 years)		Effect size
	Diabetes		Diabetes		Diabetes		
	Yes	No	Yes	No	Yes	No	
ASES							
Pain (0—10)	7 (3)	6 (3)	2 (1)*	2 (2)*	2 (2)*	2 (2)*	1.0
Function: Affected side (0—30)	5 (5)†	8 (5)	13 (5)*	15 (7)*	18 (6)*	19 (8)*	0.9
Un-affected side (0—30)	21 (8)	22 (8)	24 (5)*	24 (6)*	25 (4)*	25 (6)*	
SF-12							
Physical health status (0—100)	27 (6)†	31 (8)	35 (8)*	39 (9)*	38 (8)*	40 (12)*	0.6
Mental health status (0—100)	48 (13)	53 (11)	48 (12)	55 (9)	53 (6)	53 (10)	
Shoulder ROM (degrees):							
Flexion: Affected	85 (31)†	98 (24)	108 (18)*	112 (26)*	132 (28)*	132 (32)*	2.2
Unaffected	146 (33)	153 (22)	156 (19)*	158 (21)*	156 (21)	155 (22)	
Abduction: Affected	65 (23)†	76 (25)	90 (21)*	96 (28)*	115 (33)*	119 (36)*	0.7
Unaffected	137 (39)	150 (26)	150 (25)*	152 (27)	150 (32)	152 (26)	
External rotation: Affected	20 (12)	24 (12)	36 (18)*	36 (18)*	47 (16)*	47 (23)*	0.5
Unaffected	57 (21)	61 (21)	64 (21)	62 (22)	70 (15)*	68 (19)*	
Internal rotation: Affected	3 (3)†	6 (10)	24 (11)*	27 (15)*	37 (14)*	38 (19)*	0.2
Unaffected	53 (19)	51 (16)	55 (16)	52 (15)	60 (13)	55 (19)	
Shoulder muscle strength (kg):							
Flexors: Affected	2 (1)†	4 (3)	4 (2)*	5 (4)*	4 (2)*	5 (3)*	1.4
Unaffected	5 (2)†	7 (5)	5 (2)	7 (4)	5 (2)	6 (3)	
Abductors: Affected	2 (1)†	4 (3)	4 (2)*	5 (3)*	4 (1)*	5 (3)*	1.0
Unaffected	5 (2)†	8 (5)	6 (2)	8 (4)	5 (2)	7 (3)	
External rotators: Affected	2 (1)†	3 (1)	3 (2)*	3 (2)*	4 (2)*	4 (2)*	1.0
Unaffected	4 (2)†	6 (3)	5 (2)	6 (2)	5 (1)	6 (2)	
Internal rotators: Affected	3 (2)†	4 (2)	4 (2)	5 (2)	4 (2)*	6 (3)*	1.4
Unaffected	6 (2)	8 (7)	6 (2)	8 (4)	6 (2)	7 (3)	

General linear modules-repeated measures were used to detect changes over time and between groups. Values are reported as mean (SD). *significant effect of time (p < 0.05) between baseline and early follow-up visit and between baseline and late follow-up visit. †significant mean difference between groups as detected by independent sample t-test.
ROM: Range of Motion, ASES: American Shoulder and Elbow Surgeons, SF-12: Short From-12 survey.

improvement over time (from baseline to late follow-up visit) on pain scores (VAS: 0—10) for patients with diabetes [7 (3.3) to 2 (2.4), p < 0.001], and for patients without diabetes [6 (3.0) to 2 (2.3), p < 0.001].

Similarly, there were significant improvements over time on function scores (ASES: 0—30) of the affected shoulder for patients with diabetes [5 (4.6) to 18 (6.3), p < 0.001] and for patients without diabetes [7 (4.9) to 19 (7.3), p < 0.001]. Pairwise comparisons revealed a significant improvement between each time point (p < 0.001) for the function score of the affected shoulder, and between baseline and late follow-up visit for pain scores.

Despite the higher pain (non-significant) and poorer function (mean difference (MD) = 3 points, p = 0.032) of patients with diabetes at baseline, the differences between groups became nonsignificant at the late follow-up visit (Table 3).

When we controlled for the type of surgery and indication for surgery the improvement over time in ASES pain and function scores remained significant (p < 0.001) and the differences in pain and function between patients with and without diabetes remained nonsignificant. In addition, the interaction between time and type of surgery and between time and reason for surgery were nonsignificant, indicating that surgical subgroups experienced similar patterns of recovery.

4.2.2. Secondary outcomes

There was significant improvement over time, between baseline and early follow-up visit and between baseline and late follow-up visit on the physical health status for patients with diabetes [27

(5.7) to 38 (8.2), p < 0.001] and for patients without diabetes [31 (7.5) to 40 (11.5), p < 0.001] (Table 3). Despite the significant poorer physical health status of patients with diabetes at baseline (MD = 4 points, p < 0.033), both groups recovered to a similar physical health status at the late follow-up visit (Table 3).

As shown in Table 3, there was significant improvement over time of the affected shoulder ROM for both groups (p < 0.001). The independent sample t-test revealed significant differences between groups at baseline in flexion (MD = 13°, p < 0.02), and abduction (MD = 11°, p < 0.044). However, these differences became nonsignificant at the late follow-up visit.

Similar to shoulder ROM, muscle strength of the affected shoulder significantly improved over time for both groups (p < 0.001) as shown in Table 3. Despite the significantly weaker shoulder flexors (MD = 2 kg, p < 0.013), abductors (MD = 2 kg, p < 0.001), and external (MD = 1 kg, p < 0.009) and internal (MD = 1 kg, p < 0.006) rotator muscle groups at baseline, patients with diabetes regain similar muscle strength as patients without diabetes at the late follow-up visit.

The analysis of covariance, when the type of surgery and indication for surgery were controlled for, revealed that the improvements over time in physical health status, ROM and muscle strength remained significant (p < 0.001) and the differences between diabetic and non-diabetic patients remained nonsignificant for physical health status, ROM and for muscle strength. In addition, the interaction between time and type of surgery and between time and reason for surgery were non-significant for the secondary outcome measures.

5. Discussion

This study demonstrated that patients with and without diabetes have equally positive improvements in shoulder function, ROM, strength and in physical health status following shoulder arthroplasty, despite the small but significantly poorer function and physical health status that patients with self-reported diabetes present with prior to surgery. In addition, the improvements in shoulder pain, function, and ROM of the current study all reached statistical and clinical significance with large effects size (Table 3), confirming prior studies that indicate a large benefit to shoulder arthroplasty. The overall improvements in shoulder pain, function, ROM, and strength as well as physical health status were comparable to previous studies despite the differences in sample size, outcome assessment tools, the follow up periods, and the inclusion criteria.[1–4,19] However, none of these studies have examined a subset of patients with diabetes for comparison.

Similar to previous research,[3,4] different types of surgery (TSA, HA, rTSA) were not significantly different in terms of functional improvements following surgery This may be because the indications for different surgeries successfully allocates them to the type of surgery providing the optimal outcome for that clinical presentation. However, our results differ from one study that reported a greater shoulder ROM and less pain following TSA as compared to hemiarthroplasty.[1]

Despite the reported improvements in shoulder ROM and strength, patients with and without diabetes had below-normal scores when compared to age-matched people with unaffected shoulder.[26,27] The lower scores can be attributed to several factors including the quality of the surrounding musculotendinous structures, the type of implant and fixation used, the general health status of patients, and the presence of comorbidities.[2,4,8,30] Patients should be made aware that improvement, not normality, is the expected outcome of surgery.

The clinical improvements in outcomes between patients with and without diabetes was previously investigated following total knee arthroplasty (TKA).[10] The TKA study included 20 diabetic patients with a mean age of 72 years. Similar to our study, there were small (non-significant) differences in knee ROM, muscle strength and Knee Society Score questionnaire scores between groups at baseline. However, at one year follow-up, TKR patients with and without diabetes had similar outcomes except for knee flexion which was significantly 10° less in patients with diabetes.[10] According to the authors, the difference in the rehabilitation program intensity explained the poorer knee flexion in patients with diabetes.[10] Overall, our findings concur with results found in the TKA study, that patients with diabetes achieve similar clinical benefits, as compared to their nondiabetic counterparts.

5.1. Strength and limitations

This study provides new information on the impact of diabetes on shoulder pain, function, ROM, strength and physical health status after shoulder arthroplasty. The data of this study were prospectively collected using valid and reliable outcome measures; and the ASES scale and SF-12 survey have been used to assess functional outcomes and physical health status after shoulder arthroplasty. We evaluated a relatively large cohort of patients and used an independent assessor to evaluate outcomes. However, several limitations of the current cohort should be recognized. First, diabetes status was classified based on self-report which is subject to reporting errors. However, the Katz self-administered comorbidity scale (SCQ) has been validated to assess comorbid conditions and health services research; and shown to be equivalent to extracting this information from medical records.[13] Diabetes is the type of condition that is more likely that patients would accurately self-report, given the treatment requirements. Second, and potentially more limiting, was the fact that we did not have data about the type, the duration, the treatments of diabetes, and the level of glycemic control. It is possible that negative effects of diabetes would be selectively present in with longer duration or poorer control. Therefore, we cannot preclude that negative effects may occur in this subgroup. Lastly, although we controlled for the type of surgery and the indication for surgery and found no effect, recovery could be affected by other uncontrolled factors such as the quality and type of implant and the post-operative complications.[1,2]

6. Conclusion

Patients with and without diabetes are expected to gain similar large clinical improvements in shoulder function, motion, and strength as well as physical health status following shoulder arthroplasty. However, these improvements are not expected to reach normal values. Future large cohort studies with larger numbers of patients with diabetes and more rigorous evaluation of diabetic duration, type, and the level of glycemic control over a longer period of time could more accurately estimate the prognosis of different subgroups of patients with diabetes; and whether a dose-response relationship between glycemic control and outcomes is present.

The name of the approval giving authority

The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB).

Study number

13935E

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

Acknowledgment

References

1. Bartelt R, Sperling JW, Schleck CD, Cofield RH. Shoulder arthroplasty in patients aged fifty-five years or younger with osteoarthritis. *J Shoulder Elb Surg.* 2011;20:123–130.
2. Deshmukh AV, Koris M, Zurakowski D, Thornhill TS. Total shoulder arthroplasty: long-term survivorship, functional outcome, and quality of life. *J Shoulder Elb Surg.* 2005;14:471–479.
3. Orfaly RM, Rockwood CA, Esenyel CZ, Wirth MA. A prospective functional outcome study of shoulder arthroplasty for osteoarthritis with an intact rotator cuff. *J Shoulder Elb Surg.* 2003;12:214–221.
4. Norris TR, Iannotti JP. Functional outcome after shoulder arthroplasty for primary osteoarthritis: a multicenter study. *J Shoulder Elb Surg.* 2002;11:130–135.
5. Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. *JBJS.* 2011;93:2249–2254.
6. Ponce BA, Menendez ME, Oladeji LO, Soldado F. Diabetes as a risk factor for poorer early postoperative outcomes after shoulder arthroplasty. *J Shoulder Elb Surg.* 2014;23:671–678.
7. Mahure SA, Quien MM, Karia R, Zuckerman JD, Kwon YW. Impact of diabetes on perioperative complications in patients undergoing elective total shoulder arthroplasty. *Bull NYU Hosp Jt Dis.* 2017;75:173.
8. Jain NB, Guller U, Pietrobon R, Bond TK, Higgins LD. Comorbidities increase complication rates in patients having arthroplasty. *Clin Orthop Relat Res.*

9. Roy J-S, MacDermid JC, Goel D, Faber KJ, Athwal GS, Drosdowech DS. What is a successful outcome following reverse total shoulder arthroplasty? *Open Orthop J*. 2010;4:157.

10. Wada O, Nagai K, Hiyama Y, Nitta S, Maruno H, Mizuno K. Diabetes is a risk factor for restricted range of motion and poor clinical outcome after total knee arthroplasty. *J Arthroplast*. 2016;31:1–4.

11. Shaw JE, Sicree RA, Zimmet PZ. Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Res Clin Pract*. 2010;87:4–14.

12. Abate M, Schiavone C, Pelotti P, Salini V. Limited joint mobility in diabetes and ageing: recent advances in pathogenesis and therapy. *Int J Immunopathol Pharmacol*. 2010;23:997–1003.

13. Sangha O, Stucki G, Liang MH, Fossel AH, Katz JN. The self-administered co-morbidity questionnaire: a new method to assess comorbidity for clinical and health services research. *Arthritis Care Res*. 2003;49:156–163.

14. Richards RR, An KN, Bigliani LU, et al. A standardized method for the assessment of shoulder function. *J Shoulder Elb Surg*. 1994;3:347–352.

15. Angst F, Pap G, Mannion AF, et al. Comprehensive assessment of clinical outcome and quality of life after total shoulder arthroplasty: usefulness and validity of subjective outcome measures. *Arthritis Care Res*. 2004;51:819–828.

16. Simovitch R, Flurin P-H, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the minimal clinically important difference. *J Shoulder Elb Surg*. 2018;27:298–305.

17. Sallay PI, Reed L. The measurement of normative American Shoulder and Elbow Surgeons scores. *J Shoulder Elb Surg*. 2003;12:622–627.

18. Ware J, Kosinski M, Keller SD. A 12-item Short-Form health survey : construction of scales and preliminary tests of reliability and validity. *Med Care*. 1996;34:220–233.

19. Werner BC, Wong AC, Chang B, et al. Depression and patient-reported outcomes following total shoulder arthroplasty. *JBJS*. 2017;99:688–695.

20. Clement ND, MacDonald D, Simpson A. The minimal clinically important difference in the Oxford knee score and Short Form 12 score after total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. 2014;22:1933–1939.

21. Sabari JS, Maltzev I, Lubarsky D, Liszkay E, Homel P. Goniometric assessment of shoulder range of motion: comparison of testing in supine and sitting positions. *Arch Phys Med Rehabil*. 1998;79:647–651.

22. MacDermid JC, Chesworth BM, Patterson S, Roth JH. Intratester and intertester reliability of goniometric measurement of passive lateral shoulder rotation. *J Hand Ther*. 1999;12:187–192.

23. Cools AM, De Wilde L, Van Tongel A, Ceyssens C, Ryckewaert R, Cambier DC. Measuring shoulder external and internal rotation strength and range of motion: comprehensive intra-rater and inter-rater reliability study of several testing protocols. *J Shoulder Elb Surg*. 2014;23:1454–1461.

24. Roy J-S, MacDermid JC, Orton B, et al. The concurrent validity of a hand-held versus a stationary dynamometer in testing isometric shoulder strength. *J Hand Ther*. 2009;22:320–327.

25. Dollings H, Sandford F, O'conaire E, Lewis JS. Shoulder strength testing: the intra-and inter-tester reliability of routine clinical tests, using the Power-TrackTM II commander. *Shoulder Elbow*. 2012;4:131–140.

26. Barnes CJ, Van Steyn SJ, Fischer RA. The effects of age, sex, and shoulder dominance on range of motion of the shoulder. *J Shoulder Elb Surg*. 2001;10:242–246.

27. Van Harlinger W, Blalock L, Merritt JL. Upper limb strength: study providing normative data for a clinical handheld dynamometer. *PM&R*. 2015;7:135–140.

28. Field A. *Discovering Statistics Using IBM SPSS Statistics*. fourth ed. London,UK: Sage; 2013.

29. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. first ed. New York: Academic Press; 1977.

30. Matsen III FA, Antoniou J, Rozencwaig R, Campbell B, Smith KL. Correlates with comfort and function after total shoulder arthroplasty for degenerative joint disease. *J Shoulder Elb Surg*. 2000;9:465–469.

2005;435:232–238.