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Shoulder motion decreases as body mass increases in patients with asymptomatic shoulders

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Background: Higher complication rates are reported after shoulder arthroplasty in obese patients. Understanding the effect of body mass index (BMI) on range of motion (ROM) in asymptomatic shoulders may be useful in evaluating clinical outcomes for patients of varying BMIs presenting with shoulder pathology. The purpose of this study is to investigate patient characteristics, in particular BMI, that may affect ROM outcomes after shoulder arthroplasty.

Methods: Individuals aged 18 years or older (mean 57.21 ± 16.27 years) were recruited with asymptomatic shoulder presentation and without history of shoulder injury. A total of 224 shoulders were grouped into 4 BMI categories, and ROM was measured with a goniometer. Analysis was performed between patient demographics and ROM.

Results: Analyzed continuously, BMI negatively correlated with ROM for internal rotation (IR; $r = -0.511$, $P < .01$), forward elevation (FE; $r = -0.418$, $P < .01$), and external rotation (ER; $r = -0.328$, $P < .01$). ROM analyzed by BMI category revealed a dose effect of BMI vs ROM. Obese patients demonstrated a significant decrease in IR whereas morbidly obese patients had significant decreases for all ranges: IR ($r = -0.469$, $P < .01$), FE ($r = -0.452$, $P < .01$), and ER ($r = -0.33$, $P < .01$). Normal- and overweight patients revealed no significant correlations with ROM.

Conclusion: As BMI is negatively correlated with ROM of the asymptomatic shoulder, patients with higher BMIs may be predisposed to diminished outcomes postoperatively. These baseline correlations will allow surgeons to make postoperative expectations and anticipate poorer outcomes of shoulder ROM in obese patients.

Total shoulder arthroplasty (TSA) is a common and successful orthopedic procedure to treat severe primary or secondary osteoarthritis caused by instability, osteonecrosis, inflammatory joint diseases, and in some cases, complex proximal humeral fractures.[11,13] The volume of shoulder arthroplasty continues to increase and is the fastest-growing arthroplasty procedure in the world, with younger patients undergoing increased rates of shoulder arthroplasty surgery.[13] Improvements in range of motion (ROM) and strength along with a reduction in pain are goals of shoulder arthroplasty. Optimization of ROM can be achieved through accurate implant placement and new technology such as personalized guides, planning software, and intraoperative implant guidance systems. However, before ROM can be truly optimized, an understanding of the factors that affect ROM must be understood and quantified. One factor that plays a role in the outcome of shoulder arthroplasty is obesity.

The obesity epidemic in America is associated with serious health risks.[4] A 2017 report from the CDC found that between 2015-2016, the prevalence of obesity was 39.8% in adults and 18.5% in youth, a 19.1% and 4.6% increase, respectively, from the year 1999-2000.[4] As the prevalence increases, orthopedic surgeons can expect to see an increase in the number of obese patients. Obesity is associated with many comorbidities that may complicate treatment as well as require modifications for preoperative, intraoperative, and postoperative procedures.[12] Obesity is also associated with increased complications during orthopedic interventions.[12]

Several studies indicate higher rates of complications following TSA in obese and morbidly obese patients,[1,8] but there is a relative lack of literature regarding the differences in ROM outcomes after TSA between normal and obese patients.[7,18] Although some studies report comparable ROM between obese and nonobese patients, there is some evidence to suggest that obesity may be associated

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with poorer ROM, both at baseline and postoperatively.[1,14,17,18] Warrender et al[18] report significantly lower preoperative and postoperative forward elevation (FE) for obese patients compared with nonobese patients undergoing rotator cuff repair. However, this study did not evaluate preoperative or postoperative differences in internal rotation (IR) between obese and nonobese patients.

Beck et al[1] reported clinical outcomes for normal-weight, overweight, and obese patients after primary reverse TSA. Although obese patients demonstrated lower ROM scores for FE, abduction, and external rotation (ER) compared with normal- and overweight patients, the differences were not statistically significant. Both normal- and overweight patients experienced significant gains in all 3 ROM metrics whereas obese patients experienced significant improvements only in elevation and abduction but not ER. However, IR was not reported in this study. Statz et al[17] demonstrated that morbidly obese patients post–primary reverse shoulder arthroplasty experienced significant improvements in abduction, ER, and IR; however, they found that a higher BMI was significantly correlated with lower simple shoulder test scores and less elevation. Finally, an ergonomics study of 20 obese and 20 nonobese male patients (mean age <30 years in both groups) with healthy shoulders revealed differences only in extension and adduction ROM, which reached statistical significance.[14] IR was not measured in this study.

For these reasons, investigating the effects of BMI on ROM in asymptomatic shoulders provides a useful control in evaluating the clinical outcomes for patients of varying BMIs presenting with shoulder pathology. Control group data allow for a comparison of the interaction between BMI and the presence of a shoulder pathology in affecting shoulder ROM. Variation in ROM due to obesity may have implications in the evaluation of comparative postoperative outcomes for shoulder surgery. A thorough accounting for factors that affect ROM is important. IR is of particular interest as a ROM outcome in the context of evaluating the comparative outcomes of anatomic vs. reverse TSA, as poorer IR outcomes have been shown in some large-scale analyses of reverse TSA relative to anatomic TSA.[3,19] IR and other ROM have an effect on patient-reported outcomes. Worsening ROM is reflected in worse overall outcome scores as well as patient impairment with ADLs. Current functional grading systems and tools such as the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form specifically rely on ROM in its calculations. It is important to recognize the driving force behind these scores, and how factors such as obesity can affect them. In the era of a shift from volume to value, we need to understand what drives patient outcomes because the hospital and physician reimbursement will be tied to it.

The purpose of this study is to determine if BMI affects ROM in patients with normal asymptomatic shoulders. We aim to determine if there is a relationship between the ROM of the healthy shoulder, with particular attention to IR, and the BMI of the patient. Also, we want to quantify the effect of other potential factors such as age, sex, and hand dominance on the ROM of the healthy shoulder. We hypothesize that obese and morbidly obese patients demonstrate restricted ROM relative to patients with normal BMI and that age is an independent cause of declining ROM.

Methods

A cross-sectional study was conducted to examine shoulder ROM of a normal healthy shoulder. This experiment was approved by the institutional review board before its initiation. Patients aged 18 years or older (mean 57.2 ± 16.3 years) presenting with symptoms (pain, instability, or motion loss) of the knee, hip, and/or elbow, or as the siblings, friends, or family members of the patients were recruited at an orthopedic outpatient clinic. Patients with a history of shoulder surgery (arthroscopic or open), chronic pain, or injury (fractures, dislocations, rotator cuff injuries, labral tears, or any soft tissue or bony damage) for at least one shoulder, patients who subjectively rated their shoulder mobility and function as less than 90% of "normal" (where 100% is a subjectively "normal" shoulder) for at least one shoulder, and patients who subjectively rate their shoulder pain as greater than 1 of 10 (where 10 is the worst pain imaginable) for at least one shoulder were excluded from the study. Patient demographic information including age, BMI, race, and handedness was recorded into a protected form. Bilateral shoulder ROM evaluation of 224 shoulders in 118 study participants was performed by a single examiner. Prior to beginning the study, the examiner received training for the selected measurement techniques from one of the group's senior investigators. FE and ER were measured by visual approximation using a goniometer within 5° of motion. IR was approximated using a scoring system developed by Flurin et al.[3] Vertebral level reached by the thumb was estimated visually and converted to the following scores: 0° = 0, hip = 1, buttocks = 2, sacrum = 3, L5-L4 = 4, L3-L1 = 5, T12-T8 = 6, and T7 or higher = 7 (Fig. 1).

Data analysis was conducted with IBM-SPSS Statistics, version 25 (IBM, Armonk, NY, USA). Pearson correlation assessed the relationships among the continuous variables. Correlation coefficients varied between 0.45-0.47. Alpha was established at $P \leq .05$. Independent *t*-test analysis was used to find mean differences of ROM between categories of BMI. Analysis of variance was used to compare race and categories of BMI with the descriptive variables. Bonferroni post hoc analysis was used to compare between the 5 races as well as categories of BMI.

Results

BMI was negatively correlated with ROM for all planes of motion including IR ($r = -0.511$, $P < .01$), FE ($r = -0.418$, $P < .01$), and ER ($r = -0.328$, $P < .01$) (Table I). ROM analyzed by BMI category

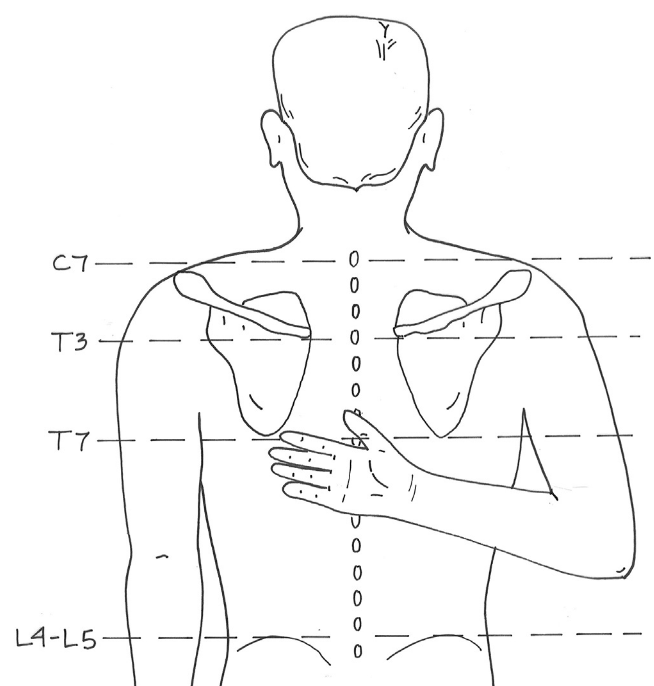

Figure 1 Measurement of internal rotation.

Table I
Correlations between BMI and ROM

	BMI <25			BMI 25-29.99		
	FF	IR	ER	FF	IR	ER
Pearson correlation	−0.42*	−0.51*	−0.33*	−0.25	−0.08	−0.05
Significance (2-tailed)	.001	.001	.001	.058	.533	.687
n	224	224	224	59	59	59
Mean	172.44 ± 3.34	6.86 ± 0.47	63.84 ± 8.51	168.39 ± 9.02	6.49 ± 0.89	57.37 ± 10.44
		BMI 30-30.99			BMI ≥40	
	FF	IR	ER	FF	IR	ER
Pearson correlation	−0.16	−0.30*	−0.04	−0.45†	−0.47†	−0.31†
Significance (2-tailed)	.164	.01	.746	.001	.001	.001
n	74	74	74	48	48	48
Mean	165.81 ± 9.40	6.35 ± 0.97	57.16 ± 9.22	162.6 ± 11.85	5.31 ± 1.80	53.65 ± 11.75
		BMI <30			BMI ≥30	
	FF	IR	ER	FF	IR	ER
Pearson correlation	−0.32†	−0.25*	−0.36†	−0.325†	−0.522†	−0.255*
Significance (2-tailed)	.001	.012	<.001	.001	.001	.005
n	102	102	102	122	122	122
Mean	170.10 ± 7.45	6.65 ± 0.74	60.1 ± 10.15	164.55 ± 10.50	5.94 ± 1.45	55.78 ± 10.39

BMI, body mass index; *ROM*, range of motion; *FF*, forward flexion; *IR*, internal rotation; *ER*, external rotation.
FF and ER are measured in degrees; IR is measured with the vertebral level scoring system.
* Denotes a correlation with a *P*-value < .05.
† Denotes a correlation with a *P*-value ≤ .001.

similarly revealed a dose effect of BMI such that increasing BMI resulting in a greater degree of shoulder motion loss. Obese class I revealed a significant correlation for IR only, whereas obese class II–morbid obesity was significant for all planes of motion: IR ($r = -0.469$, $P < .01$), FE ($r = -0.452$, $P < .01$), and ER ($r = -0.33$, $P < .01$). The normal weight class revealed a moderate, significant correlation for ER ($r = -0.38$, $P = .013$), whereas the pre-obese class revealed no significant correlations with ROM ($P > .05$). Significant differences were found when groups were compared to the morbidly obese group. Bonferroni analysis revealed significant differences between morbidly obese and normal-weight and pre-obese groups for forward flexion, between morbidly obese and all other groups for IR, and between morbidly obese and normal weight for ER (Table II).

When the 2 lowest BMI groups (normal weight and pre-obese) were combined, they revealed the significant correlations with ROM: IR ($r = -0.249$, $P = .012$), FE ($r = -0.323$, $P < .01$), and ER ($r = -0.364$, $P < .01$). When the 2 highest BMI groups (obese class 1 and morbidly obese) were combined, they also revealed the following significant correlations with ROM: IR ($r = -0.522$, $P < .01$), FE ($r = -0.325$, $P < .01$), and ER ($r = -0.255$, $P < .01$). When comparing these 2 groups, there were significant differences in forward flexion ($t_{222} = -4.61$, $P < .01$) and IR ($t_{216.472} = -4.70$, $P < .001$) between groups. In the BMI <30 group, forward flexion was on average 5.55° greater, and IR was 0.70 vertebral levels higher than the BMI ≥30 group.

Age was also found to be an independent predictor for ROM. As age increased, all measures of ROM decreased: IR ($r = -0.26$, $P < .01$), FE ($r = -0.34$, $P < .01$), and ER ($r = -0.46$, $P < .01$). Handedness was found to have no significant correlation with ROM in any direction. Race categories were not found to have significant correlations with ROM.

Discussion

The results of this study demonstrate that BMI independently affects shoulder ROM, especially in obese and morbidly obese individuals. Although this study specifically focuses on demographics such as BMI, age, and race, there have been a number of studies that have investigated factors influencing overall outcomes of TSA. The factors range from radiographic anatomic disposition to non-modifiable risk factors such as age and race to modifiable risk factors such as BMI. An early 2000s multicenter clinical outcome study evaluated 128 shoulders in 118 patients and found that postoperative ER was dependent on the degree of measured preoperative ER, indicating a significant role of the anatomic makeup of the glenohumeral joint. Another study by Matsen et al[10] looked at both mental and physical factors preoperatively and found correlations between higher preoperative physical function, social function, mental health, shoulder function, and postoperative shoulder function after TSA. In 2011, Henn et al[6] found that preoperative expectations played a large role in postoperative outcomes. Increased and decreased patient expectations correlated with better and poorer overall outcomes, respectively. These studies all yield similar data in that preoperative factors affect postoperative ROM. Our goal was to determine the variables that contribute to making this idea true.

A recent study by Zwerus et al[21] found that elbow ROM is similarly affected by age, race, and BMI. Although this does not directly investigate the shoulder joint, it expands on the idea that upper extremity ROM is significantly affected by many different factors.

Levy et al[7] conducted a study that aimed to define the factors affecting shoulder ROM post TSA. They retrospectively reviewed preoperative and postoperative ROM in 230 patients and found that preoperative motion is the factor most predictive of postoperative motion in all directions. They also found that both BMI and diabetes were negatively correlated with preoperative IR only.[7] These findings somewhat contradicted the possibly underpowered findings by Donigan et al,[2] which were unable to correlate preoperative motion with postoperative outcomes. Although we do agree with the findings by Levy et al supporting the correlation between preoperative and postoperative ROM, we do not agree that BMI only affects IR.

A recent retrospective analysis by Savin et al reports that that patients undergoing TSA, RTSA, and HA can expect good functional outcomes, with improvements in pain, function, and outcome scores, irrespective of BMI.[15] Although we did not look at ROM in the postoperative shoulder, the evidence found in our study supports the idea that BMI affects ROM in asymptomatic shoulders. Knowing this, we believe that BMI may play a role in ROM of postoperative shoulders as well.

In our study, BMI demonstrated a statistically significant, dose-dependent, negative correlation with shoulder motion including IR, ER, and FE. Similarly, when separating BMI into traditional discrete categories, the higher BMI categories of obese and morbidly obese

Table II
Bonferroni analysis of ROM between BMI categories

BMI* (I)	BMI (J)	Mean difference (I − J)	Standard error	Significance	95% confidence interval	
					Lower	Upper
FF						
1	2	4.052	1.826	.165	−0.81	8.91
	3	6.631*	1.746	.001	1.98	11.28
	4	9.838*	1.912	<.001	4.75	14.93
2	1	−4.052	1.826	.165	−8.91	0.81
	3	2.579	1.589	.636	−1.65	6.81
	4	5.786*	1.77	.008	1.07	10.5
3	1	−6.631*	1.746	.001	−11.28	−1.98
	2	−2.579	1.589	.636	−6.81	1.65
	4	3.207	1.688	.352	−1.29	7.7
4	1	−9.838*	1.912	<.001	−14.93	−4.75
	2	−5.786*	1.77	.008	−10.5	−1.07
	3	−3.207	1.688	.352	−7.7	1.29
IR						
1	2	0.369	0.223	.6	−0.23	0.96
	3	0.509	0.214	.108	−0.06	1.08
	4	1.548*	0.234	<.001	0.93	2.17
2	1	−0.369	0.223	.6	−0.96	0.23
	3	0.14	0.194	>.99	−0.38	0.66
	4	1.179*	0.217	<.001	0.6	1.76
3	1	−0.509	0.214	.108	−1.08	0.06
	2	−0.14	0.194	>.99	−0.66	0.38
	4	1.039*	0.206	<.001	0.49	1.59
4	1	−1.548*	0.234	<.001	−2.17	−0.93
	2	−1.179*	0.217	<.001	−1.76	−0.6
	3	−1.039*	0.206	<.001	−1.59	−0.49
ER						
1	2	6.464*	2.007	.009	1.12	11.81
	3	6.675*	1.92	.004	1.56	11.79
	4	10.191*	2.102	<.001	4.59	15.79
2	1	−6.464*	2.007	.009	−11.81	−1.12
	3	0.211	1.747	>.99	−4.44	4.86
	4	3.727	1.946	.341	−1.45	8.91
3	1	−6.675*	1.92	.004	−11.79	−1.56
	2	−0.211	1.747	>.99	−4.86	4.44
	4	3.516	1.855	.356	−1.42	8.46
4	1	−10.191*	2.102	<.001	−15.79	−4.59
	2	−3.727	1.946	.341	−8.91	1.45
	3	−3.516	1.855	.356	−8.46	0

ROM, range of motion; *BMI*, body mass index; *FF*, forward flexion; *IR*, internal rotation; *ER*, external rotation.
* Category 1: BMI < 25; category 2: 25 ≤ BMI < 30; category 3: 30 ≤ BMI < 40; and category 4: BMI ≥ 40

demonstrate a significantly negative effect on shoulder ROM, especially IR. When performing a binary comparison of 2 groups with either BMI <30 or BMI ≥30, we again found that increased BMI demonstrated a statistically significant negative correlation with IR.

Although the data allow us to identify that obesity and shoulder ROM demonstrate a negative correlation, we are unable to determine the mechanistic cause. Potential theories include the idea that as a patient becomes more obese, body habitus may contribute to the inability to internally rotate the arm as a wider body girth may be more difficult to navigate through friction-generated resistance. Although data were insignificant for correlating sex and ROM, it is known that distribution of body fat differs between men and women and could play a role in preventing IR. Daily routines such as hooking a brassiere behind one's back may allow for changes in IR for women that may counteract sex differences in body habitus. Also, among obese patients, the weight of the arm is greater, which would require more effort and force to move and rotate it. There are many other factors that may play a role in shoulder ROM. Hobbies, occupation, and daily use can impact strength and flexibility, which may impact shoulder ROM. As people become more obese, their weight may limit them from performing such activities and therefore could contribute to this observed decrease in shoulder ROM. The weight of the arm may also play a role in decreasing ROM.

An important note of clarification is that the patients in this study did not have diagnosed rotator cuff injury, and the shoulders tested were completely asymptomatic shoulders with no previous pathology. It has been described that patients older than 60 years are more likely to have rotator cuff injury than those younger than 60 years.[16] In addition to age, underlying comorbidities could play a role in ROM. Because we are making the association between obesity and ROM, it is important to add that diabetes is highly prevalent in obese and morbidly obese populations. Diabetes is associated with adhesive capsulitis, a disorder that can significantly affect ROM.[20] Although we do not know the subjects' underlying comorbidities, nor do we have the radiographic imaging of their shoulders, we believe that it is safe to assume that the shoulders tested in this study are "normal" as the patients reported no subjective loss of ROM, symptomatic pain, or previous shoulder pathology. Additional limitations include the fact that the examiner was responsible for prescreening participants, so there was lack of blinding of medical history including BMI and arm dominance. Although there have been studies that have looked at the accuracy and reliability of the vertebral level scoring system.[5,9] the decision to use the vertebral level scoring system was used because of standard of care and ease to implement. In addition, the decision is supported by a study that used the vertebral level scoring system to find significant differences in ROM between anatomic TSA and reverse TSA.[3,9] Further studies should aim to confirm these results, as well as investigate the reasons underlying the decline in shoulder ROM and potentially decreased function. Future studies should aim to compare the interaction between BMI and shoulder pathology postoperatively to baseline controls, as patients with higher BMIs may be predisposed to diminished outcomes postoperatively.

Conclusions

Shoulder ROM measurement was conducted on 224 normal shoulders and was found to be affected by age, race, and BMI. As BMI increases, there is a greater likelihood of having decreased shoulder ROM. This correlation is most strongly observed in the morbidly obese. The correlations found during this study may provide useful controls in evaluating the clinical outcomes for patients of varying BMIs presenting with shoulder pathology. By using previous studies that found preoperative motion to significantly affect postoperative outcomes, we can conclude that BMI may play a significant role in postoperative ROM. These baseline correlations will allow surgeons to make postoperative expectations and anticipate poorer outcomes of shoulder ROM in obese patients.

Disclaimer

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