



Impact of age on shoulder range of motion and strength

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ARTICLE INFO

Keywords:

Healthy
Shoulders
Age
Range of motion (ROM)
Strength
Dynamometer

Level of evidence: Basic Science Study;
Kinesiology

Background: Total shoulder arthroplasty (TSA) is a surgical technique commonly used to treat patients with arthritis and rotator cuff deficiency. Its purpose is to reduce pain and improve shoulder function, namely range of motion (ROM) and strength. While shoulder ROM and strength have been studied extensively in patients with various shoulder pathologies, there is a dearth of knowledge with regard to the asymptomatic population.

Methods: A cross-sectional study was conducted in the outpatient orthopaedic clinic following institutional review board approval. Patients 18 years of age and older with at least one asymptomatic and healthy shoulder with no prior history of shoulder surgery, injury, or pain were enrolled in the study. Demographic information, ROM, and strength measurements were collected for 256 shoulders, evenly stratified into groups by age and sex. A goniometer was used to measure forward elevation, abduction, and external rotation, and a handheld dynamometer was utilized for measuring strength. Statistical evaluation was conducted using Pearson correlations, analysis of variance, and Bonferroni and Mann–Whitney post hoc tests, with $P < .01$ indicating a significant difference.

Results: Abduction strength ($P < .001$), external rotation strength ($P < .001$), and internal rotation strength ($P < .001$) were negatively correlated with age when viewing the data as a whole and after stratification of males and females. Age and shoulder ROM, namely abduction ($P < .001$) and forward elevation ($P < .001$), were also significantly negatively correlated, although internal rotation decreased with age as well. When comparing across age groups, abduction ($P = .001$) and forward elevation ($P = .001$) were significantly higher in group 1 (18–35) when compared to group 4 (66+), but external rotation was not significantly different between these groups. External rotation ($P = .001$) was only significantly different between groups 2 (36–50) and 4. Variation in external rotation strength was also found. Group 4 was found to have significantly less strength than all 3 of the other groups.

Conclusion: Shoulder strength significantly decreased with age, with abduction strength and external rotation strength displaying the strongest negative correlations. Decreases in strength were most prominent in patients 66 years of age and above. Shoulder ROM was not as tightly correlated with age, although abduction, forward elevation, and internal rotation were found to generally decrease over time. Differences in external rotation were not clinically significant. These correlations provide useful controls for patients of various ages regarding their clinical outcomes when presenting with shoulder pathology. Variations in current literature allow this study to verify the impact of age on shoulder ROM and strength.

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Total shoulder arthroplasty (TSA) is performed for various shoulder pathologies and is intended to reduce pain and improve function, including strength and range of motion (ROM).⁵ It can

The institutional review board of the Medical University of South Carolina approved this study (Pro00077486).

This study was conducted at the Medical University of South Carolina.

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<https://doi.org/10.1016/j.jseint.2022.08.016>

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either be an anatomic TSA (aTSA) or reverse TSA. Initially, shoulder arthroplasty was utilized primarily for older individuals with arthritis and proximal humerus fractures, but indications have expanded to younger patients for additional indications, including irreparable rotator cuff tears, acute proximal humerus fractures, chronic locked dislocations, failure of anatomic arthroplasty, and for oncologic indications.^{8,13,21}

Shoulder ROM is commonly measured before and after surgery, and optimizing ROM is important for attaining the best outcomes. Shoulder strength is also affected by surgery and a prolonged loss of

strength can adversely affect patients' quality of life and recovery. There are many patient characteristics that can affect ROM and strength; one that has not been thoroughly studied in the asymptomatic population is patient age. As indications evolve, a need to optimize function is essential and understanding the effect of age on shoulder function is important with regard to understanding normal shoulder function.

Previous studies have investigated the effect of aging on ROM in healthy shoulders and in the setting of shoulder arthroplasty. One study found shoulder abduction, extension, and external rotation decreases while internal rotation increases with age.⁴ Additionally, the authors found a decrease in forward elevation in patients under 40 years old was likely not solely related to aging. Levy et al¹⁹ found that age was not predictive of final postoperative motion of the shoulder after TSA. Furthermore, they noted that an increased body mass index (BMI) caused a limited internal rotation regardless of treatment. Since BMI can affect shoulder ROM, it needs to be accounted for when comparing patients' age to their shoulder ROM. Conversely, other studies determined increasing age negatively influenced postoperative active forward flexion and active abduction.^{10,11} Sex was also found to influence shoulder ROM, with females experiencing greater postoperative internal and external rotation than men.¹¹ Since sex can influence shoulder ROM, it also needs to be considered along with other variables while examining the effect of aging.

Prior studies also investigated the effect of aging on shoulder strength. While men typically demonstrate higher strength measurements than women, aging negatively affects all shoulder strength measures for both sexes.^{3,4,15} Aging can cause a decrease in muscle mass, which may be reflected in a decrease in shoulder strength. Kallman et al¹⁷ investigated this idea and found that younger subjects were stronger and older subjects weaker than predicted based solely on muscle mass. This implies that there are other physiological factors that trigger strength reduction over the course of one's lifetime. It is important to understand factors affecting shoulder strength at different ages in order to optimize outcomes and determine optimal methods of rehabilitation.

Prior research also investigated the effect of age on healing after shoulder arthroplasty, including Hartzler et al¹⁴ who found that a younger age (<60 years) yielded lower functional improvement after reverse shoulder arthroplasty, while Gallinet et al¹² observed a decrease in tuberosity healing as patient age increased. As such, age is an important variable with regard to outcomes after shoulder surgery.

Since aging can influence patients' shoulder ROM and strength, investigating the asymptomatic shoulder in regard to aging can act as a control to help examine clinical outcomes after shoulder surgery. Control group data can be utilized to compare the effects of age and shoulder pathology in altering the shoulder ROM and strength. This could have implications in the evaluation of comparative postoperative outcomes for shoulder surgery by accounting for factors which may predispose patients to relatively poorer baseline and postoperative results.

As such, the purpose of this study is to investigate the effects of age on ROM and strength in the asymptomatic shoulder. We hypothesize that aging will negatively impact shoulder ROM and strength.

Materials and methods

Study population

Patients ≥ 18 years of age presenting with joint pain or mechanical symptoms of the knee, hip, and/or elbow, and their family members or friends were recruited at two of the Medical University

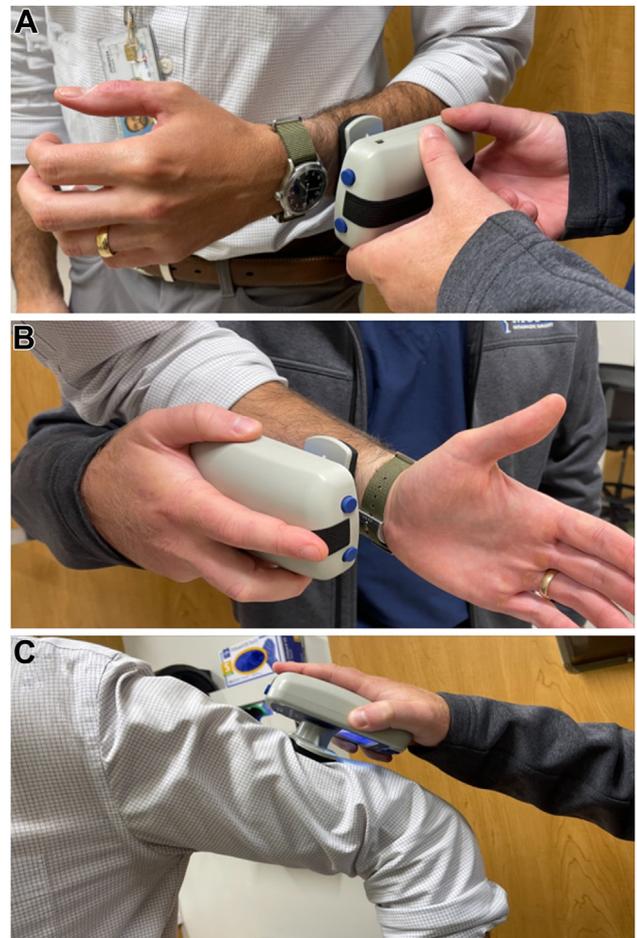


Figure 1 Evaluation of external rotation strength (A), abduction strength (B), and internal rotation strength (C). Jain et al provided the example for the strength test with the subject exerting a force against the examiner for 5 seconds, as measured by a handheld dynamometer.

of South Carolina's orthopaedic outpatient clinics. They were stratified into 4 age groups: 18-35, 36-50, 51-65, and >65. These patients had no history of shoulder surgery, injury, or pain. Screening questions were performed to exclude patients describing their shoulder as less than 90% normal shoulder function (with 100% being a normal, healthy shoulder) and pain greater than 1 on a 1 to 10 pain scale (with 10 being the most pain possible).

Study design

A cross-sectional study was conducted to examine the ROM and strength of the asymptomatic and healthy shoulder. Demographic data such as name, age, race, sex, height, weight, and handedness were recorded. Shoulder ROM, including forward elevation, abduction, and external rotation, was measured using a goniometer. Internal rotation was measured by approximating the vertebral level reached by the thumb. A scoring system of 0 = 0, hip = 1, buttocks = 2, sacrum = 3, L5-L4 = 4, L3-L1-5, T12-T8 = 6, and T7 and above = 7 was used. Shoulder strength was measured using a Lafayette handheld dynamometer (Model 01165). External rotation, internal rotation, and abduction strength were all measured using a technique described by Jain et al,¹⁶ which involves the patient exerting a maximum force for 5 seconds against the matched examiner's resistance (Fig. 1). Shoulder ROM and strength were measured for 256 shoulders.

Table I
Means and standard deviations for each age group.

	Group 1	Group 2	Group 3	Group 4
Range of motion (°)	-	-	-	-
Abduction	178.11 ± 6.198	172.44 ± 13.111	171.78 ± 12.013	166.16 ± 15.552
Forward elevation	177.95 ± 5.066	175.91 ± 8.305	172.53 ± 11.565	166.17 ± 13.712
External rotation	83.53 ± 10.467	84.72 ± 10.929	81.17 ± 11.079	81.66 ± 11.014
Strength (In Lbs)	-	-	-	-
Abduction	22.084 ± 5.4943	22.563 ± 7.7083	19.028 ± 6.7324	14.648 ± 4.8834
Internal rotation	19.092 ± 5.5697	20.300 ± 6.0888	17.420 ± 5.7064	14.845 ± 4.7645
External rotation	19.720 ± 6.0946	20.313 ± 6.6026	17.259 ± 5.6024	14.603 ± 4.7580

Statistical analysis

All statistics and data analysis were conducted with IBM SPSS Statistics for Windows, version 28 (IBM, Armonk, NY, USA). Since the data were not normally distributed, a nonparametric analysis of variance was used to determine statistically significant differences in shoulder strength and ROM between age groups. Mann–Whitney post hoc tests were then conducted to further clarify these differences for all strength measurements and all ROM measurements excluding internal rotation, which was analyzed with a chi-square analysis. Pearson correlations were used to model age as a continuous variable against strength. Males and females were divided into separate groups to help better analyze differences between age groups. Data were considered to be statistically significant at $P < .01$.

Results

A total of 256 shoulders were evaluated and further divided based on age. Average ROM and strength measurements were recorded for each group (Table I). Mann–Whitney was used as the post hoc test.

Shoulder ROM differed significantly among the 4 age groups (Table II). Group 1 (18-35) displayed significantly greater abduction than groups 2 (36-50, $P = .002$), 3 (51-65, $P = .001$) and 4 (66+, $P = .001$). Similarly, abduction was significantly higher for group 2 than for group 4 ($P = .008$). Forward elevation was lower for groups 3 ($P = .002$) and 4 ($P = .001$) in comparison to group 1, as well as for group 4 compared to groups 2 ($P = .001$) and 3 ($P = .004$). External rotation only differed significantly between groups 2 and 4 ($P = .001$). Internal rotation significantly decreased overall as age increased ($P = .001$). Pearson correlations showed that age was negatively correlated with abduction ($r = -0.359$, $P < .001$) and forward elevation ($r = -0.424$, $P < .001$) (Table III). These relationships remained true when stratifying by sex. External rotation decreased with age, but this was not statistically significant ($r = -0.108$, $P < .085$).

Shoulder strength also varied between the different age groups (Table IV). Group 1 demonstrated significantly greater abduction strength than groups 3 ($P = .001$) and 4 ($P = .002$). Group 2 similarly showed higher abduction strength than groups 3 ($P = .010$) and 4 ($P = .001$). Finally, abduction strength was greater for group 3 than group 4 ($P = .001$). Internal rotation strength was lower for group 4 in comparison to groups 1 ($P = .001$), 2 ($P = .001$) and 3 ($P = .005$), as well as for group 3 compared to group 2 ($P = .005$). External rotation strength also differed between a few groups, with group 4 displaying less strength than groups 1 ($P = .001$), 2 ($P = .001$) and 3 ($P = .011$). Pearson correlations showed that age negatively correlated with abduction ($r = -0.414$, $P < .001$), external rotation ($r = -0.330$, $P < .001$), and internal rotation ($r = -0.300$, $P < .001$) strength (Table V). These relationships again remained true when stratified by sex.

Table II
Shoulder ROM comparisons between age groups.

Group comparisons*	P value
Abduction	-
1 vs. 2	.002
1 vs. 3	.001
1 vs. 4	.001
2 vs. 3	.586
2 vs. 4	.008
3 vs. 4	.026
Forward elevation	-
1 vs. 2	.122
1 vs. 3	.002
1 vs. 4	.001
2 vs. 3	.095
2 vs. 4	.001
3 vs. 4	.004
External rotation	-
1 vs. 2	.357
1 vs. 3	.151
1 vs. 4	.149
2 vs. 3	.022
2 vs. 4	.001
3 vs. 4	.961
Internal rotation	.001

ROM, range of motion.

Bolded values indicate significant P value $< .01$.

*Group 1 = 18-35, Group 2 = 36-50, Group 3 = 51-65, Group 4 = 66+.

Table III
Pearson correlations for age vs. shoulder ROM.

Range of motion	Mean (in degrees)	R value	P value
Abduction	172.12 ± 12.859	-0.359	<.001
Male	171.91 ± 12.997	-0.382	<.001
Female	172.33 ± 12.768	-0.335	<.001
Forward elevation	173.14 ± 11.086	-0.424	<.001
Male	172.43 ± 11.200	-0.517	<.001
Female	173.85 ± 10.967	-0.324	<.001
External rotation	82.77 ± 10.905	-0.108	.085
Male	79.84 ± 12.089	-0.108	.224
Female	85.70 ± 8.682	-0.118	.184

ROM, range of motion.

Bolded values indicate P value $< .01$.

Discussion

The results from this study show that age independently affects shoulder ROM and strength. Although there have been many studies comparing other factors affecting shoulder ROM and strength, such as BMI and race, the effect of age on asymptomatic shoulder ROM and strength has not been thoroughly studied, making it an important relationship to investigate.

There are many patient characteristics that can influence shoulder ROM and strength. Some studies have investigated the

Table IV
Shoulder strength comparisons between age groups.

Group comparisons*	P value
Abduction	-
1 vs. 2	.612
1 vs. 3	.001
1 vs. 4	.002
2 vs. 3	.010
2 vs. 4	.001
3 vs. 4	.001
Internal rotation	-
1 vs. 2	.307
1 vs. 3	.091
1 vs. 4	.001
2 vs. 3	.005
2 vs. 4	.001
3 vs. 4	.005
External rotation	-
1 vs. 2	.603
1 vs. 3	.076
1 vs. 4	.001
2 vs. 3	.021
2 vs. 4	.001
3 vs. 4	.011

Bolded values indicate significant P value <.01.

*Group 1 = 18-35, Group 2 = 36-50, Group 3 = 51-65, Group 4 = 66+.

Table V
Pearson correlations for age vs. shoulder strength.

Strength	Mean (in lbs)	R value	P value
Abduction	19.581 ± 7.0153	-0.414	<.001
Male	22.770 ± 7.1914	-0.411	<.001
Female	16.392 ± 5.1579	-0.561	<.001
Internal rotation	17.914 ± 5.8889	-0.300	<.001
Male	20.958 ± 5.6700	-0.309	<.001
Female	14.871 ± 4.3372	-0.415	<.001
External rotation	17.974 ± 6.1978	-0.330	<.001
Male	21.310 ± 6.0384	-0.380	<.001
Female	14.638 ± 4.2695	-0.423	<.001

Bolded values indicate significant P value <.01.

relationship between shoulder ROM and age. In 2001, Barnes et al⁴ measured 280 shoulders in patients ranging from 4 to 70 years old and found that shoulder ROM decreased as age increased, with the exception of IR, which increased. This is contrary to what we found in this study, as IR was found to decrease as age increased. Barnes et al also used patients from ages 0-70 and had small changes to IR in subjects older than 11 years old. Since we focused on the adult population, we did not use any patients younger than 18. They also utilized a goniometer for all of their ROM measurements including IR. Our use of the vertebral level measurement for IR could be the reason for this discrepancy, since there may have been variability in the measurements. We estimated IR based on thumb placement relative to the vertebral level, whereas other studies may have utilized a goniometer giving specific numerical values. Our finding of IR decreases while age increases is supported by other studies that have also shown a decrease in all shoulder ROM measurements, further supporting the idea that IR decreases as age increases.^{1,7} While there is some variability in reported ROM changes with aging, there is less variability when comparing shoulder ROM and strength. Shoulder strength has been reported to decrease as age increases in multiple studies, which also supports our findings.^{3,4,15}

In 2016, Levy et al¹⁹ conducted a retrospective study using 230 patients with a minimum 1-year follow-up after aTSA and found that preoperative ROM is the most important factor when

determining postoperative ROM. They also noted that BMI and diabetes both negatively correlated with IR, while age did not alter postoperative shoulder ROM. Based on this study, age should not impact postoperative ROM in comparison to preoperative ROM. This knowledge is useful for setting postoperative expectations.

When looking at the ROM values between different age groups, abduction and forward elevation were significantly different for a majority of the comparisons. Abduction was the only significant disparity between the 2 youngest age groups, while the 2 oldest groups only varied significantly in forward elevation. Surprisingly, differences in external rotation were only significant between groups 2 and 4. None of the ROM measurements were significantly different specifically between groups 2 and 3. Overall, as age increased, internal rotation significantly decreased. This implies that abduction, forward elevation, and internal rotation are expected to decrease as people age.

When looking at the strength values between different age groups, abduction strength was significantly different among all groups except between groups 1 and 2. Differences in external rotation strength were only significant when comparing the older groups to the younger groups. Internal rotation strength significantly differed between every age group except groups 1 and 2 as well as groups 1 and 3. There were no significant disparities between groups 1 and 2 for shoulder strength, implying that strength does not tend to decline between ages 18 and 50. Since group 4 had a significant decrease in abduction, external rotation, and internal rotation strength compared to the other groups, it seems that shoulder strength is expected to decrease at ages 66 and above.

This study demonstrates a loss of shoulder ROM with an increase in age, as expected. As individuals age, the amount of synovial fluid present inside joints decreases and cartilage becomes thinner.²⁰ Ligaments can also shorten and become thinner, making joints stiffer.⁶ This loss of flexibility may be a possible explanation for decreased shoulder ROM in people of older age, although reductions in physical activity as people age might also have an influence on shoulder ROM. Shoulder strength was also found to decrease with age in this study, which is again expected. We found that abduction strength had the greatest negative correlation with age, while internal rotation strength had the weakest negative correlation. Shoulder strength was investigated between age groups with males and females in the same group and in separate groups. This was done due to females being known to have weaker shoulder strength.^{3,4,15} The correlations between shoulder strength and age did not change when males and females were separated into different groups. This verified that sex would not alter the results if some age groups were predominantly female or male. The exact mechanism for decreases in shoulder strength with age is not well researched. One study by Kallman¹⁷ et al recorded the grip strength and muscle mass of 847 healthy volunteers in 1990. It was found that elderly patients with higher muscle mass were weaker than expected, while younger patients with lower muscle mass were stronger than expected. This showed that there are other physiological factors causing people to lose strength as they age.

All of the patients in the present study had no history of shoulder injury, surgery, or pain and only those who reported greater than 90% shoulder function and a 1 on a 1 to 10 pain scale were enrolled. These measures were taken to ensure that only patients with asymptomatic, healthy shoulders were selected, as any type of shoulder pathology or previous injury could affect the results. One limitation of this study is that previous medical diagnosis and comorbidities such as diabetes and obesity were not considered, but it has been shown that these can affect shoulder ROM.² We also did not have radiographic imaging of the shoulders measured, but differences in the anatomic composition of patients' shoulders appear to have a negligible impact on ROM.¹⁸

Additionally, studies vary in their method of measuring internal rotation. We used the vertebral level scoring system due to standard of care and straightforward utilization. It was first described by Flurin et al,⁹ who used it to compare differences in ROM between patients that had undergone aTSA vs. reverse TSA. Significant differences were found using the vertebral scoring system, prompting us to use it in this study. Another potential limitation may have risen in the form of patient effort during strength measurements, as it is possible that some patients exerted less force than they were capable of. In future studies, it should be ensured that patients participate to their full potential. Future work should also compare age and shoulder postoperative pathology with baseline shoulder ROM and strength controls, as this may help predict postoperative outcomes based on age.

Conclusion

After testing a total of 256 shoulders of patients with no previous history of shoulder surgery, injury, or pain, it was found that shoulder ROM and strength significantly decreased with an increase in age. These differences were most significant in the >65 age group. The correlations from this study provide useful controls for patients of various ages regarding their clinical outcomes when presenting with shoulder pathology. Since previous studies identified that preoperative ROM and strength affect postoperative ROM and strength, we can conclude age will most likely have a significant effect on postoperative ROM and strength. With variability present in current literature, this study helps verify the impact of age on shoulder ROM and strength.

Disclaimers:

Funding: No funding was disclosed by the authors.

Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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