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Achieving satisfactory functional outcomes in conservatively treated proximal humerus fractures: relationship between shoulder range of motion and patient-reported clinical outcome scores

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Background: Proximal humerus fractures are common osteoporotic fractures. Postinjury outcome measures include objective clinician-measured range of motion (ROM) and subjective patient-reported outcome measures (PROMs), but the relationship between both has not been established. This study aimed to determine the relationship between shoulder ROM and PROMs and establish which ROMs correlated most with PROMs.

Methods: A prospective cohort study was conducted on patients with acute proximal humerus fractures. Surgical intervention, open or pathological fractures, neurovascular compromise, polytrauma, or delayed presentations were excluded. Correlation and regression analyses between active ROM and PROMs (Quick Disabilities of Arm, Shoulder and Hand [QuickDASH] and Oxford Shoulder Score [OSS]) at 1-year postinjury were explored. ROM cutoffs predicting satisfactory PROM scores were established.

Results: Fifty-five patients were recruited. Moderate correlations were observed between PROMs and flexion, extension, and abduction, but not internal and external rotation. Multivariate analysis showed significant relationships between PROMs and flexion [QuickDASH: adjusted coefficient (AC): −0.135, $P = .013$, OSS: AC: 0.072, $P = .002$], abduction [QuickDASH: AC: −0.115, $P = .021$, OSS: AC: 0.059, $P = .005$], and extension [QuickDASH: AC: −0.304, $P = .020$] adjusting for age, gender, Neer classification, injury on dominant side, and employment. Achieving 130° flexion, 59° extension, and 124° abduction were correlated with satisfactory OSS/QuickDASH scores, respectively.

Conclusion: Overall, holistic assessment of outcomes with both subjective and objective outcomes are necessary, as shoulder flexion, extension, and abduction are only moderately correlated with PROMs. Attaining 130° flexion, 59° extension, and 124° abduction corresponded with satisfactory functional outcomes measured by OSS/QuickDASH and can guide rehabilitation.

Proximal humerus fractures are common osteoporotic fractures[18] frequently seen in the elderly,[26] accounting for 5% of adult fractures.[8] With an aging population worldwide, the incidence of osteoporotic fractures is expected to increase,[17] and these fractures can result in significant disability.[20] As such, appropriate intervention and rehabilitation are important in restoring function, maintaining functional independence,[16] and preventing future fractures.

However, it has been traditionally difficult to predict good outcomes postfracture, with many factors,[6] e.g., clinical, social, and functional coming into play. To evaluate the disease process and progress in recovery, both patient- and physician-generated outcomes provide important information. In orthopedics, both objective outcome measures, e.g., range of motion (ROM) and radiological findings, and subjective markers, e.g., patient-reported outcome measures (PROMs), are vital in assessing the outcome and

This study has been approved by National Healthcare Group (NHG) Domain Specific Review Board (DSRB) (2016/01241).

Ethics approval and institutional review board approval were obtained, and all patients consented to participation in the study.

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evaluating the impact of management, both complementing each other in the clinical setting.[4]

The positive relationship between objective markers and subjective patient reported measures has been demonstrated on elbow dislocation,[1] total ankle replacement[10] and total knee replacement,[7] with positive correlation between clinically measured absolute ROM and improvement in functional outcomes measured by PROM scores. However, there has been a paucity of evidence for shoulder conditions, in particular proximal humerus fractures. A study on patients who underwent a reverse shoulder arthroplasty was only able to demonstrate a moderate correlation between active forward flexion and PROM scores.[13]

In order to investigate the relationship between objectively measured ROM and patient-reported PROMs in nonoperatively managed proximal humerus fractures, the aim of the study was to determine (i) the relationship between the active ROM of the affected arm after proximal humerus fracture and the corresponding PROM scores, (ii) which active ROM had the greatest correlation with PROMs, and (iii) what cutoffs for active ROMs predicted a satisfactory PROM score.

Materials and methods

Study design

A single-center prospective cohort study of patients with proximal humerus fractures at a Level 1 trauma center was conducted to determine the relationship between shoulder ROM and PROMs at 1 year. Data on the maximum active ROM (flexion, extension, internal and external rotation, and abduction) and scores for the Quick Disabilities of Arm, Shoulder and Hand (QuickDASH) and Oxford Shoulder Score (OSS) questionnaires were collected. Results were reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

Inclusion and exclusion criteria

Patients over the age of 21 who sustained a proximal humerus fracture between August 2017 and April 2019 were screened for inclusion in the study. Patients were included if they were more than 21 years of age, presented within 3 weeks of the injury, and completed a 1-year follow-up. They were excluded if (i) surgical intervention was performed, (ii) injury was an open fracture, (iii) not mentally competent, (iv) severe soft-tissue compromise, (v) neurovascular injury, (vi) multiple injuries, (vii) pathological fractures, or (viii) pregnant at time of injury. All patients undergoing a standardized progressive rehabilitation program (refer to Supplementary Appendix S1) guided by an occupational therapist.

Baseline characteristics and outcomes measures

Baseline characteristics on patient demographics (age, gender, hand dominance, body mass index, employment status) and data on the fracture (side of injury, Neer classification, type of intervention) were collected. Outcomes at 1 year postinjury included active ROM in the affected arm for shoulder forward flexion, extension, abduction, and internal and external rotation, and were performed in a standardized manner by the occupational therapist. Internal and external rotation were measured with the shoulder abducted and elbow flexed. QuickDASH and OSS scores were used as the PROMs.

Statistical analysis

Data was analyzed using IBM SPSS version 19.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to present the characteristics of patients. The correlation between ROM and PROMs (QuickDASH and OSS) were explored using the Spearman correlation test. The relationships were further tested using multiple linear regression adjusting for age, gender, Neers classification, injury in dominant side, and employment status. Multicollinearity and interaction were checked, while heteroscedasticity was tested using the Breusch-Pagan/Cook-Weisberg test. Statistical significance was denoted as $P < .05$. A complete case analysis was performed.

ROMs with significant correlation with both QuickDASH and OSS were then analyzed using receiver operating characteristic analysis to explore their perforce in classifying satisfactory outcomes (defined as QuickDASH$\leq$15 and OSS$\geq$40[2]). The optimal cutoffs were defined using the predictive modeling approach with higher precision compared to the conventional receiver operating characteristic approach.[27] The sensitivity, specificity, positive predictive value, and negative predictive value of the defined cutoffs were determined and compared with the minimum ROM needed in activities of daily living (ADLs) described by Namdari et al.[22]

Table I
Baseline characteristics at time of injury.

Patient characteristics	n	Values
Age in years	55	68.36 ± 10.26
Gender		
Male	55	11 (20.0)
Female		44 (80.0)
BMI in kg/m^2		24.33 ± 4.68
Hand dominance		
Left	55	2 (3.6)
Right		53 (96.4)
Employment status		
Employed	55	25 (45.5)
Homemaker		8 (14.5)
Retired		22 (40.0)
Fracture characteristics		
Side of injury		
Left	55	27 (49.1)
Right		28 (50.9)
Injury on the dominant hand		
No	55	27 (49.1)
Yes		28 (50.9)
Neer classification		
1	54	11 (20.4)
2		18 (33.3)
3		21 (38.2)
4		4 (7.3)

BMI, body mass index.
A total of 55 patients were included, with 20.0% male and 80.0% female, and majority being right-hand dominant (96.4%).

Results

Baseline characteristics

A total of 55 patients (20.0% male and 80.0% female) were recruited and completed a 1-year follow-up. The mean age was 68.4 years old (SD = 10.3). Baseline characteristics are summarized in Table I.

Outcome measures

The mean active ROM and PROM scores at 1 year postinjury are given in Table II. Mean flexion was 133.6° (SD = 28.0), extension was 62.4° (SD = 11.8), abduction was 126.4° (SD = 29.5), external rotation was 60.1° (SD = 13.1), and internal rotation was 70.4° (SD = 9.9). For PROMs, mean QuickDASH score was 8.49 (SD = 12.2) and OSS was 43.8 (SD = 7.8).

Table II
ROM and PROM outcomes at 1 y postfracture.

Assessments	n	Mean ± SD	Median (IQR)	Range
Range of motion				
Flexion	55	133.60 ± 27.97	140 (115, 150)	40-180
Extension	54	62.37 ± 11.83	60 (59, 70)	30-100
Abduction	55	126.42 ± 29.45	130 (110, 150)	50-180
Rotation				
Internal	55	70.36 ± 9.85	70 (65, 80)	45-90
External	55	60.09 ± 13.14	60 (50, 70)	20-90
Patient-reported outcome measures				
QuickDASH	55	8.49 ± 12.21	2.5 (0.0, 13.6)	0-59
OSS	55	43.75 ± 5.76	46 (41, 48)	20-48

IQR, interquartile range; *ROM*, range of motion; *PROM*, patient-reported outcome measure; *OSS*, Oxford Shoulder Score; *QuickDASH*, Quick Disabilities of Arm, Shoulder and Hand.

Table III
Correlation between ROM and PROM at 1 y.

ROM	n	QuickDASH		n	OSS	
		Coefficient	*P* value		Coefficient	*P* value
Flexion	55	−0.396	**.007**	55	0.318	**.031**
Extension	54	−0.424	**.004**	54	0.301	**.045**
Abduction	55	−0.414	**.004**	55	0.365	**.013**
Rotation						
Internal	55	0.091	.549	55	−0.121	.423
External	55	−0.070	.642	55	0.126	.403

ROM, range of motion; *PROM*, patient-reported outcome measure; *OSS*, Oxford Shoulder Score; *QuickDASH*, Quick Disabilities of Arm, Shoulder and Hand.
$P < .5$ for flexion, extension, abduction for both QuickDASH and OSS. Spearman Correlation was used, adjusted for age, gender, Neer classification, injury on the dominant hand and employment status.
The values in bold represent $P < .05$.

Significant correlations were observed between PROMs with flexion, extension, and abduction of the shoulder with $P < .05$ (Table III) for both QuickDASH and OSS. External and internal rotation did not show a significant correlation with QuickDASH ($P = .642$ and .549, respectively) and OSS ($P = .403$ and .423).

The associations were further tested using linear regression adjusting for age, gender, Neer classification, injury on the dominant side, and employment status. It was found that the relationships between flexion, extension, and abduction and PROMs remained significant (Table IV) for QuickDASH, flexion, and abduction with OSS.

The area under the curve for flexion, extension, and abduction in relation to a favorable QuickDASH score (QuickDASH $\leq$15) were 0.704, 0.820, and 0.649; and 0.856, 0.831, and 0.798 in relation to a favorable OSS score (OSS $\geq$40), respectively (Figs. 1 and 2). These were considered acceptable with an area under the curve $\geq$0.65 despite the fact that diagnostic ability is not perfect.

Flexion, extension, and abduction were used for further analysis as they were significantly correlated with both QuickDASH and OSS. Cutoffs for the various ROMs were determined for OSS and QuickDASH scores with the larger ROM value between the two being used as the minimum ROM target, and the sensitivity and specificity of the determined cutoffs were compared with the minimum functional ROM proposed by Namdari et al (Table V).

Discussion

The main aims of this study were threefold: to determine (i) the relationship between the active ROM of the affected arm after proximal humerus fracture and the corresponding PROM scores; (ii) which active ROM had the greatest correlation with PROMs; and (iii) what cutoffs for active ROMs correlated with a satisfactory PROM score.

Limited ability of active ROMs in predicting PROMs

From our results, we have observed that PROM scores were only moderately correlated with some but not all ROM tested in patients with proximal humerus fractures. While objective markers such as ROM and radiographic measures[15] often form the basis of routine patient assessment in busy clinical practice, it may not fully reflect the needs and function of the patient postproximal humerus fracture, which are often better measured through the use of PROMs.[5]

It has been established that full ROM is not necessary for daily ADL.[19,22] It is noted that shoulder ROM decreases with age[21] with no associated decrease in functional ability,[25] particularly in more sedentary individuals with lower functional demands. For many elderly patients with proximal humerus fractures, regaining the ability to perform ADLs (ie, independent living) and its social and emotional implications, which are best measured using PROMs, are often more important than regaining maximal ROM and strength.[5] Scores like the Constant Score, which incorporate both an objective clinician measure and subjective patient-reported elements may be helpful in giving a more holistic clinical picture.[2]

Rehabilitation targets for satisfactory function in elderly postfracture patients

To achieve acceptable functional outcomes, participation in postfracture rehabilitation is important with the aim of safely mobilizing the affected shoulder early, reducing pain and edema, and restoring function. Common protocols include early passive and active ranging,[14,16] with eventual movement in all planes and strengthening. We propose the targets of 130° flexion, 59° extension, and 124° abduction, which have been shown to achieve satisfactory functional outcomes when OSS and QuickDASH were used, respectively, with a more balanced sensitivity and satisfactory positive predictive value and negative predictive value in postinjury rehabilitation. The proposed cutoffs were shown to have satisfactory sensitivity and specificity for OSS and QuickDASH. These targets are similar to what Namdari et al concluded were sufficient for completion of tasks of daily living and self-care. Other studies similarly show that many ADLs require some degree of flexion, extension, and abduction.[22,23]

Our study showed that flexion and abduction had the strongest correlations with PROMs, followed by extension. A systematic review by Oosterwijk et al showed that a greater proportion of ADLs required shoulder flexion and abduction compared to extension,[23] In addition, it is noted from the literature that small improvements in forward flexion lead to large increases in perceived general health.[24] We propose to prioritize achieving the aforementioned targets for abduction and flexion, followed by extension, so that rehabilitation can be more targeted toward optimizing function. These proposed targets are intended to serve as a guide with specific management and rehabilitation regimes still tailored to each patient's functional demands.

Strength and weakness of the study

This study has several strengths. Firstly, the study is a prospective cohort study from a single institution with standardized treatment and follow-up protocols used, and based on the authors' knowledge, it is one of the largest studies investigating the relationship between ROMs and PROMs in proximal humerus fractures. Secondly, outcome measures were collected in a standardized fashion by trained therapists, ensuring consistency of

Table IV
Relationship between ROM and PROMs at 1 y postfracture after multivariate analysis.

Range of motion	n	QuickDASH			n	OSS		
		Adj coeff	95% CI	*P* value		Adj coeff	95% CI	*P* value
Flexion	54	−0.135	−0.240, −0.030	**.013**	54	0.072	0.027, 0.117	**.002**
Extension	53	−0.304	−0.557, −0.050	**.020**	53	0.097	−0.013, 0.206	.081
Abduction	54	−0.115	−0.211, −0.018	**.021**	54	0.059	0.019, 0.098	**.005**
Rotation								
Internal	54	0.153	−0.101, 0.408	.232	54	−0.028	−0.147, 0.091	.635
External	54	−0.089	−0.315, 0.137	.432	54	0.053	−0.050, 0.156	.305

CI, Confidence Interval; *ROM*, range of motion; *PROMs*, patient-reported outcome measures; *OSS*, Oxford Shoulder Score; *QuickDASH*, Quick Disabilities of Arm, Shoulder and Hand.
$P < .5$ for flexion and abduction for both QuickDASH and OSS, and for extension for only QuickDASH. This was adjusted for age, gender, Neer classification, injury on the dominant hand and employment status. Multicollinearity and interaction were checked and not found.
The values in bold represent $P < .05$.

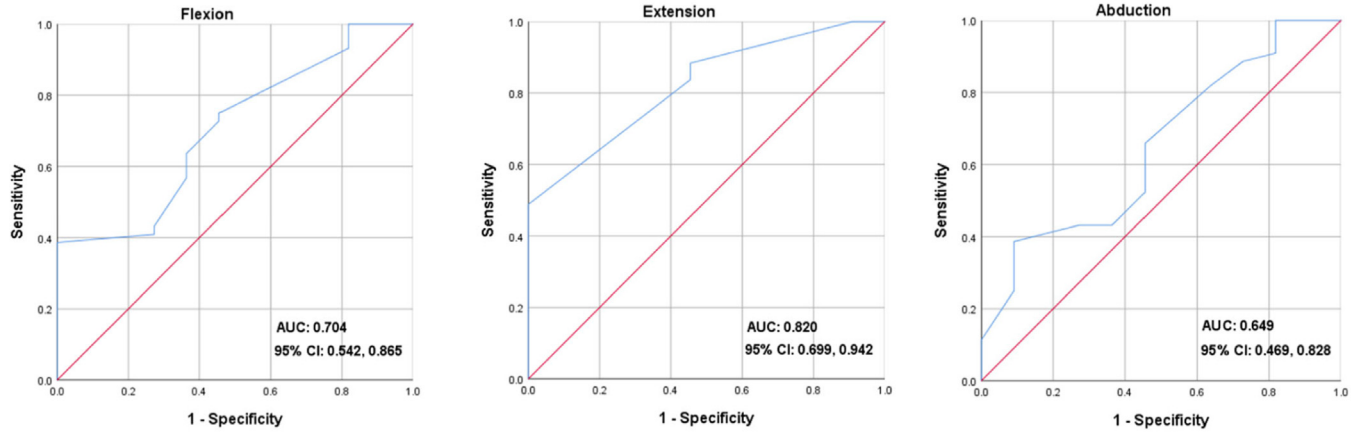

Figure 1 Receiver operating characteristic (ROC) analysis for flexion, extension, and abduction in relation to QuickDASH. *AUC*, area under the ROC curve; *CI*, confidence interval.

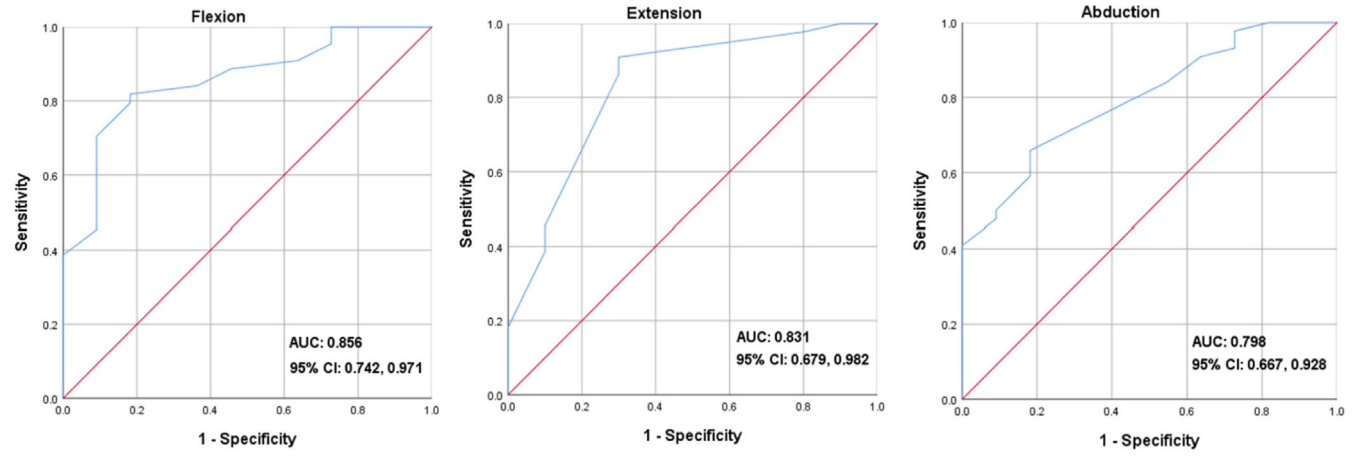

Figure 2 Receiver operating characteristic (ROC) analysis for flexion, extension, and abduction in relation to the Oxford Shoulder Score (OSS). *AUC*, area under the ROC curve; *CI*, confidence interval.

measurements. Thirdly, both OSS and QuickDASH were collected as part of the PROMs component to give a more comprehensive picture, and fourthly, in a further attempt to address possible confounders, a multivariate regression analysis was performed to control for potential factors such as age, gender, Neer classification, injury on the dominant side, and employment status. Factors like age, hand dominance, and fracture type directly affect management and outcomes,[12] while such fractures are more common in females.[3] Employment status[11] influences rehabilitation goals and contextualizes the injury to the individual.

In terms of weaknesses, while the sample size is small for a cohort study, it represents one of the largest studies done in this area. We were able to draw several statistically significant conclusions from the study. In addition, this cohort represents predominantly an Asian population, limiting its generalization to other populations. Cutoffs for what represents a satisfactory PROM score

Table V
Comparison of the sensitivity and specificity of different ROM cutoffs.

OSS				
	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Namdari et al.[22]				
Flexion	81.82	81.82	94.74	52.94
121°	(71.62, 92.01)	(71.62, 92.01)	(88.84, 100.00)	(39.75, 66.13)
Extension	97.73	18.18	82.69	66.67
46°	(93.79, 100.00)	(7.99, 28.38)	(72.69, 92.69)	(54.21, 79.13)
Abduction	61,36	81.82	93.10	34.62
128°	(48.50, 74.23)	(71.62, 92.01)	(86.41, 99.80)	(22.04, 47.19)
Proposed ROM				
Flexion	84.09	63.64	90.24	50.00
119°	(74.42, 93.76)	(50.92, 76.35)	(82.40, 98.09)	(36.79, 63.21)
Extension	86.36	70.00	92.68	53.85
56°	(77.21, 95.52)	(57.78, 82.22)	(85.74, 99.63)	(40.55, 67.14)
Abduction	70.45	72.73	91.18	38.10
111°	(58.40, 82.51)	(60.96, 84.50)	(83.68, 98.67)	(25.26, 50.93)
QuickDASH				
	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Namdari et al.[22]				
Flexion	75.00	54.44	86.84	35.29
121°	(63.56, 86.44)	(41.39, 67.70)	(77.91, 95.78)	(22.66, 47.92)
Extension	97.73	18.18	82.69	66.67
46°	(93.79, 100.00)	(7.99, 28.38)	(72.69, 92.69)	(54.21, 79.13)
Abduction	54.55	54.55	82.76	23.08
128°	(41.39, 67.70)	(41.39, 67.70)	(72.78, 92.74)	(11.94, 34.21)
Proposed ROM				
Flexion	63.64	63.64	87.50	30.43
130°	(50.92, 76.35)	(50.92, 76.35)	(78.76, 96.24)	(18.27, 42.60)
Extension	84.09	54.55	88.10	46.15
59°	(74.42, 93.76)	(41.39, 67.70)	(79.54, 96.65)	(32.98, 59.33)
Abduction	54.55	54.55	82.76	23.08
124°	(41.39, 67.70)	(41.39, 67.70)	(72.78, 92.74)	(11.94, 34.21)

CI, Confidence Interval; *ROM*, range of motion; *PROM*, patient-reported outcome measure; *OSS*, Oxford Shoulder Score; *QuickDASH*, Quick Disabilities of Arm, Shoulder and Hand; *NPV*, negative predictive value; *PPV*, positive predictive value.
A cutoff of 130° flexion, 59° extension and 124° abduction correlated with satisfactory PROM scores (OSS and QuickDASH, respectively).

may be subjective[9] and may vary between populations. Categories based on scores may be arbitrary, and different cutoffs would lead to different outcomes with regards to correlation with ROM. As such, the ROM targets proposed in this study serve as a guide, but management still needs to be individualized for each patient with shared decision-making.

Conclusion

Shoulder flexion, extension, and abduction demonstrated moderate correlation with PROMs. Routine clinical practice should incorporate both objective clinician-assessed and subjective patient-reported outcomes for holistic patient assessment. Particularly for the lower-demand elderly patients, we propose ROM targets for postproximal humerus fracture rehabilitation of 130° flexion, 124° abduction, and 59° extension with priority given to restoring flexion and abduction as the first key to achieve satisfactory OSS/QuickDASH outcomes, respectively.

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