The Effect of Total Shoulder Arthroplasty on Glenohumeral Kinematics during Activities of Daily Living (ADLs)

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INTRODUCTION: Glenohumeral osteoarthritis (GOA) has been implicated with significant pain and disability when performing activities of daily living (ADLs). Total shoulder arthroplasty (TSA) reliably assists in restoring shoulder range of motion (ROM), but current subjective outcome metrics to assess ROM such as ASES may not provide enough objective data for clinicians to assess basic function or disability when performing ADLs. Furthermore, there is no consensus within the literature as to how objectively track a patient's restoration of ROM or ability to perform ADLs after TSA. Therefore, the purpose of this study is to objectively track restoration of shoulder ROM and ability to perform ADLs after TSA using motion capture system.

METHODS: 26 patients who underwent TSA for GOA performed multiple ADLs including hygiene, drinking, overhead reach and hairbrush (Figure 1) tasks using both the surgical and asymptomatic upper extremity (control) for direct comparison pre-operatively and up to three months post-operatively. Patients underwent a standard post-operative physical therapy protocol. A motion capture system used eight infra-red cameras (Vicon, Oxford, UK) sampling at 100 Hz to capture both a patient's peak shoulder angle and total degrees of ROM achieved during ADLs. Shoulder flexion, adduction, and rotation were all employed to provide three planes of motion for 3D motion capture. Unadjusted descriptives were compared using Kruskal-Wallis and chi-squared tests for continuous and categorical variables, respectively (Stata 16.1, StataCorp, CollegeStation, TX).

RESULTS:

Demographic and patient reported outcome scores are reported in Table One. Patients demonstrated significant pre-operative ROM deficits and lower peak kinematic angles while performing ADLs in the diseased extremity compared to controls ($p < 0.05$, Table 2). By 3 months, though statistically significant ($p< 0.05$), patients were clinically within 5 degrees of ROM in all three planes for hygiene and drinking tasks. Overhead reach remained significantly limited at 3 months (flexion 78.02° vs 103.75°, $p < 0.001$; adduction 31.98° vs 46.89°, $p <0.001$); rotation 42.69° vs 71.13°, $p < 0.001$). Overall patients demonstrated significant improvements in at least two planes during ADL performance compared to pre-operative values ($p < 0.05$).

Though peak kinematic angle was restored for hair brushing at 3 months, patients still demonstrated some deficits in all planes for the remaining ADLs (Table 3). Flexion during overhead reach (67.64° vs 80.44°, $p = 0.005$), and rotation during hygiene (19.30° vs 36.99°, $p < 0.001$) were the most notable, though other planes for these tasks were within 10° to the asymptomatic side. Except for flexion, adduction (14.19° vs 10.04°, $p < 0.001$) and rotation (21.58° vs 19.30°, $p < 0.001$) during hygiene did not recover to pre-operative values.

DISCUSSION AND CONCLUSION:

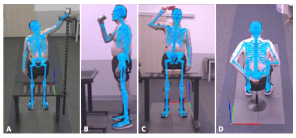
Our findings provide objective evidence that TSA for GOA significantly reduces multi-plane disability that hampers performance of ADLs with the use a motion capture system. Apart from overheard reach, patients demonstrated sufficient ROM to perform self-hygiene, drinking, and hairbrush tasks using the operative extremity three months after surgery. Patients can expect restoration of peak kinematic angle to pre-operative values at 3 months for almost all tasks but may require more time to achieve comparable results to their asymptomatic side. Our objective measurements coincided with subjective reported functional improvement and reduced pain post-operatively. Not only do our findings help clinicians possibly council patients on post-operative expectations, but use of motion capture provides a more efficient and cost-effective mean of tracking a patient's post-surgical recovery and ability to perform ADLs.

Figure 1: Demonstration of ADLs. A: Overhead reach. B: Drinking. C: Hairbrushing. D: Hygiene.

Table 1. Demographics and Patient Reported Outcomes. * $p<0.050$, † $p<0.010$, ‡ $p< 0.001$; PROMIS: Patient-Reported Outcomes Measurement Information System. SD = Standard Deviation.

Table 2. Shoulder Total Kinematic Degrees of Range of Motion During Four ADL Tasks. * $p<0.050$ (orange), † $p<0.010$ (yellow), ‡ $p< 0.001$ (green). Values reported as Mean (Standard Deviation).

Table 3. Shoulder Kinematic Peak Angle During Four ADL Tasks. * $p<0.050$ (orange), † $p<0.010$ (yellow), ‡ $p< 0.001$ (green). Values reported as Mean (Standard Deviation).



Variable					
Total Patients, N	26				
Age, Mean (SD)	67.6 (8.5)				
Gender, N (% Female)	25 (50.0)				
Height, Mean (SD)	1.67 (0.1)				
Weight, Mean (SD)	92.1 (24.3)				
BMI, Mean (SD)	33.0 (8.1)			P-Value	
Patient Reported Outcomes	Pre-Operative	Post 6 weeks	Post 3 months	Pre vs Post-Operative 6 Weeks	Pre vs Post-Operative 3 months
ADLIER, Mean (SD)	24.3 (6.1)	27.7 (7.7)	31.0 (4.4)	0.191	0.127
ASES, Mean (SD)	39.1 (15.0)	63.8 (21.3)	74.8 (16.7)	<0.001‡	<0.001‡
Tampa Scale of Kinesiophobia, Mean (SD)	40.0 (6.9)	37.8 (5.6)	35.2 (6.5)	0.012*	0.002†
PROMIS Mood, Mean (SD)	48.8 (10.8)	43.6 (8.2)	40.6 (7.7)	0.029*	0.003†
PROMIS Pain Interference, Mean (SD)	63.85 (5.8)	56.6 (6.5)	53.8 (8.3)	<0.001‡	<0.001‡
PROMIS Physical Function, Mean (SD)	38.1 (7.5)	39.6 (7.0)	43.9 (9.1)	0.360	0.009†

Overhead Reach

Variable	Symptomatic			Asymptomatic	P-Value				
Angle	Pre-Op	Post-Op 6 weeks	Post-Op 3 months	Pre-Op	Pre vs Post-Op 6 weeks	Pre vs Post-Op 3 months	Pre-Symptomatic vs Asymptomatic	Asymptomatic vs Post-Op 6 weeks	Asymptomatic vs Post-Op 3 Months
Shoulder Flexion	60.18 (54.55, 65.81)	54.43 (48.17, 60.69)	78.02 (72.03, 84.02)	103.75 (98.07, 109.42)	0.079	<0.001‡	<0.001‡	<0.001‡	<0.001‡
Shoulder Adduction	25.87 (22.73, 29.00)	27.01 (23.41, 30.61)	31.98 (28.56, 35.39)	46.89 (43.73, 50.05)	0.459	<0.001‡	<0.001‡	<0.001‡	<0.001‡
Shoulder Rotation	34.70 (29.23, 40.18)	30.09 (24.07, 36.12)	42.69 (36.89, 48.48)	71.13 (65.61, 76.64)	0.121	0.001†	<0.001‡	<0.001‡	<0.001‡

Personal Hygiene

	Symptomatic			Asymptomatic	P-Value				
Angle	Pre-Op	Post-Op 6 weeks	Post-Op 3 months	Pre-Op	Pre vs Post-Op 6 weeks	Pre vs Post-Op 3 months	Pre-Symptomatic vs Asymptomatic	Asymptomatic vs Post-Op 6 weeks	Asymptomatic vs Post-Op 3 Months
Shoulder Flexion	44.81 (42.00, 47.63)	47.15 (44.08, 50.22)	55.65 (52.67, 58.62)	60.02 (57.20, 62.84)	0.075	<0.001‡	<0.001‡	<0.001‡	<0.001‡
Shoulder Adduction	17.27 (15.74, 18.80)	18.63 (16.89, 20.38)	22.16 (20.50, 23.83)	24.03 (22.50, 25.57)	0.136	<0.001‡	<0.001‡	<0.001‡	<0.001‡
Shoulder Rotation	23.14 (20.95, 25.33)	24.37 (21.86, 26.89)	25.17 (22.77, 27.56)	28.69 (26.49, 30.89)	0.361	0.117	<0.001‡	<0.001‡	<0.001‡

Hairbrushing

	Symptomatic			Asymptomatic	P-Value				
Angle	Pre-Op	Post-Op 6 weeks	Post-Op 3 months	Pre-Op	Pre vs Post-Op 6 weeks	Pre vs Post-Op 3 months	Pre-Symptomatic vs Asymptomatic	Asymptomatic vs Post-Op 6 weeks	Asymptomatic vs Post-Op 3 Months
Shoulder Flexion	34.07 (29.92, 38.23)	26.02 (21.39, 30.65)	40.93 (36.46, 45.41)	47.65 (43.45, 51.84)	<0.001‡	0.001†	<0.001‡	<0.001‡	<0.001‡
Shoulder Adduction	22.39 (20.41, 24.38)	24.06 (21.81, 26.32)	22.58 (20.41, 24.74)	21.64 (19.63, 23.64)	0.151	0.870	0.533	0.200	0.893
Shoulder Rotation	48.45 (43.19, 53.71)	39.62 (33.77, 45.46)	56.57 (50.92, 62.22)	71.99 (66.68, 77.30)	0.001†	0.002†	<0.001‡	<0.001‡	<0.001‡

Drinking

	Symptomatic			Asymptomatic	P-Value				
Angle	Pre-Op	Post-Op 6 weeks	Post-Op 3 months	Pre-Op	Pre vs Post-Op 6 weeks	Pre vs Post-Op 3 months	Pre-Symptomatic vs Asymptomatic	Asymptomatic vs Post-Op 6 weeks	Asymptomatic vs Post-Op 3 Months
Shoulder Flexion	34.75 (32.51, 36.98)	34.61 (32.05, 37.17)	39.67 (37.21, 42.14)	36.94 (34.68, 39.20)	0.917	<0.001‡	0.049	<0.001‡	0.664
Shoulder Adduction	9.54 (8.11, 10.96)	8.53 (6.89, 10.17)	10.75 (9.18, 12.33)	9.81 (8.37, 11.25)	0.249	0.151	0.668	<0.001‡	0.211
Shoulder Rotation	10.87 (9.21, 12.53)	12.16 (10.23, 14.09)	13.46 (11.62, 15.31)	11.27 (9.59, 12.94)	0.223	0.011*	0.669	0.323	0.012

Overhead Reach

Variable	Symptomatic			Asymptomatic	P-Value				
Angle	Pre-Op	Post-Op 6 weeks	Post-Op 3 months	Pre-Op	Pre vs Post-Op 6 weeks	Pre vs Post-Op 3 months	Pre-Symptomatic vs Asymptomatic	Asymptomatic vs Post-Op 6 weeks	Asymptomatic vs Post-Op 3 Months
Shoulder Flexion	55.38 (46.57, 64.19)	42.68 (32.20, 53.15)	67.64 (57.80, 77.48)	80.44 (71.53, 89.34)	0.032*	0.030*	<0.001‡	<0.001‡	0.005
Shoulder Adduction	29.38 (27.05, 31.72)	30.92 (28.21, 33.63)	32.92 (30.35, 35.49)	36.85 (34.49, 39.21)	0.282	0.009†	<0.001‡	<0.001‡	0.003
Shoulder Rotation	34.50 (29.23, 39.77)	25.47 (19.09, 31.85)	38.80 (32.84, 44.75)	48.18 (42.85, 53.52)	0.017*	0.236	<0.001‡	<0.001‡	<0.001‡

Personal Hygiene

	Symptomatic			Asymptomatic	P-Value				
Angle	Pre-Op	Post-Op 6 weeks	Post-Op 3 months	Pre-Op	Pre vs Post-Op 6 weeks	Pre vs Post-Op 3 months	Pre-Symptomatic vs Asymptomatic	Asymptomatic vs Post-Op 6 weeks	Asymptomatic vs Post-Op 3 Months
Shoulder Flexion	-32.66 (-34.85, -30.47)	-34.30 (-36.64, -31.96)	-42.20 (-44.48, -39.91)	-44.16 (-46.35, -41.97)	0.060	<0.001‡	<0.001‡	<0.001‡	<0.001‡
Shoulder Adduction	14.19 (12.57, 15.80)	9.62 (7.85, 11.39)	10.04 (8.33, 11.76)	16.04 (14.42, 17.66)	<0.001‡	<0.001‡	0.005	<0.001‡	<0.001‡
Shoulder Rotation	21.58 (18.35, 24.81)	17.45 (13.81, 21.09)	19.30 (15.81, 22.79)	36.99 (33.74, 40.24)	0.022*	0.186	<0.001‡	<0.001‡	<0.001‡

Hairbrushing

	Symptomatic			Asymptomatic	P-Value				
Angle	Pre-Op	Post-Op 6 weeks	Post-Op 3 months	Pre-Op	Pre vs Post-Op 6 weeks	Pre vs Post-Op 3 months	Pre-Symptomatic vs Asymptomatic	Asymptomatic vs Post-Op 6 weeks	Asymptomatic vs Post-Op 3 Months
Shoulder Flexion	50.15 (45.05, 55.24)	42.36 (36.68, 48.03)	61.47 (55.99, 66.94)	64.32 (59.20, 69.44)	0.004†	<0.001‡	<0.001‡	<0.001‡	0.138
Shoulder Adduction	37.70 (34.71, 40.68)	34.85 (31.51, 38.20)	38.61 (35.40, 41.83)	37.88 (34.89, 40.88)	0.081	0.558	0.902	0.256	0.341
Shoulder Rotation	-18.66 (-24.59, -12.73)	-10.97 (-17.63, -4.31)	-33.61 (-40.02, -27.21)	-37.77 (-43.72, -31.82)	0.019*	<0.001‡	<0.001‡	<0.001‡	0.052

Drinking

	Symptomatic			Asymptomatic	P-Value				
Angle	Pre-Op	Post-Op 6 weeks	Post-Op 3 months	Pre-Op	Pre vs Post-Op 6 weeks	Pre vs Post-Op 3 months	Pre-Symptomatic vs Asymptomatic	Asymptomatic vs Post-Op 6 weeks	Asymptomatic vs Post-Op 3 Months
Shoulder Flexion	26.96 (24.27, 29.64)	20.50 (17.60, 23.39)	22.13 (19.30, 24.96)	30.23 (27.52, 32.93)	<0.001‡	<0.001‡	<0.001‡	<0.001‡	<0.001‡
Shoulder Adduction	12.80 (11.42, 14.17)	13.13 (11.55, 14.70)	13.72 (12.20, 15.23)	10.04 (8.65, 11.43)	0.688	0.245	<0.001‡	0.033	<0.001‡
Shoulder Rotation	29.95 (27.46, 32.43)	27.08 (24.23, 29.94)	26.42 (23.68, 29.16)	34.08 (31.57, 36.60)	0.056	0.014*	0.001	0.004	<0.001‡