Multimodal Assessment of Shoulder Muscle Function Following Reverse and Total Shoulder Arthroplasty

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INTRODUCTION: Understanding postoperative recovery following shoulder arthroplasty requires evaluating both muscular activity and joint kinematics. EMG and inertial measurement unit (IMU) sensors offer non-invasive, quantitative tools to assess muscle function and motion. Rather than reaffirming that healthy individuals perform better, this study focuses on differentiating recovery patterns across diagnoses and procedures, uncovering compensatory activation, and quantifying movement quality to guide personalized rehabilitation. We compared shoulder muscle activation and kinematics in patients who underwent reverse shoulder arthroplasty (RSA) for glenohumeral osteoarthritis (GHOA) or cuff tear arthropathy (CTA), total shoulder arthroplasty (TSA) for GHOA, and healthy controls. Recent evidence demonstrates that the middle deltoid becomes the functionally dominant muscle following reverse shoulder arthroplasty, highlighting the importance of muscle-specific assessments for guiding rehabilitation strategies[1]. Furthermore, studies show that many patients achieve timely return to work and sport after reverse arthroplasty, underscoring its clinical relevance in restoring functional outcomes for active populations.[2]

METHODS: In a single-center, observational prospective cohort study, 19 subjects were divided into four sub-cohorts: RSA for glenohumeral osteoarthritis (GHOA) (n=5), RSA for rotator cuff arthropathy (RCA) (n=5), TSA for GHOA (n=5), and age-matched healthy controls without any shoulder pathologies (n=4). Patients were selected based on the following criteria: ASES score greater than 90 at a minimum of two years post-operative follow-up, age under 85, and BMI less than 35 to reduce confounding factors. Each subject performed four movements: forward elevation, abduction, external rotation, and internal rotation to assess shoulder function and range of motion. EMG signals were recorded from the deltoid, pectoralis major, infraspinatus, upper trapezius, and latissimus dorsi muscles during each movement. EMG Sensor data were normalized to control data, and inertial measurements were used to compute RMS jerk as a marker of neuromuscular control. Group differences were assessed using Kruskal-Wallis tests and post-hoc Dunn's tests with Bonferroni-Holm correction.

RESULTS SECTION: Distinct patterns in muscle activation and movement smoothness were observed among the four cohorts. RSA-CTA patients demonstrated significantly lower activation of the trapezius and deltoid muscles during abduction compared to healthy controls ($p < 0.05$). TSA-GHOA patients showed relatively higher activation of the pectoralis major and infraspinatus muscles during flexion-extension and external rotation, respectively. Analysis of IMU data revealed reduced movement smoothness in both RSA and TSA groups, as indicated by lower root mean square (RMS) values of estimated jerk, particularly in the trapezius and deltoid sensors. These differences suggest altered neuromuscular control post-surgery and are illustrated in Figure 1, which compares the average RMS of the estimated jerk across cohorts. Although statistical comparisons between surgical groups did not reach significance, trends indicated distinct compensatory muscle recruitment. Notably, RSA-GHOA patients exhibited elevated latissimus dorsi activity, while RSA-CTA patients showed increased reliance on the pectoralis major, highlighting diagnosis-specific biomechanical adaptations, as detailed in Table 1.

DISCUSSION: Multimodal sensor analysis reveals that shoulder arthroplasty impacts muscle activation and kinematics in diagnosis- and procedure-specific ways. By identifying compensatory patterns, quantifying movement quality, and enabling early risk stratification, these data support the development of predictive models to personalize rehabilitation. This approach also informs surgical planning and post-operative care, improving outcomes through targeted, data-driven interventions. Future work with larger cohorts and inclusion of gyroscope data may enable development of machine learning models to predict functional recovery and optimize patient-specific rehabilitation.

SIGNIFICANCE/CLINICAL RELEVANCE: This study addresses a critical clinical gap by providing quantitative insights into how different arthroplasty procedures and underlying pathologies uniquely affect shoulder muscle activation and movement quality. These findings have significant clinical relevance as they can guide personalized rehabilitation strategies, inform surgical decision-making, and ultimately improve long-term functional outcomes for patients.

REFERENCES:

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Table 1 Results (p-values) of the Kruskal-Wallis Statistical Analysis (significant for $p < 0.05$)

	Axis	Abduction		Flexion-Extension	
		KW-Test	Dunn's Test post-hoc	KW-Test	Dunn's Test post-hoc
S1: Trapezius	X	**0.0190**	RSA-OA vs. Healthy, p = 0.0145	**0.0280**	RSA-OA vs. Healthy, p = 0.0166
	Y	**0.0244**	TSA-OA vs. Healthy, p = 0.0274	**0.0233**	RSA-OA vs. Healthy and TSA-OA vs. Healthy, p = 0.0338
	Z	**0.0087**	TSA-OA vs. Healthy, p = 0.0046	**0.0198**	RSA-OA vs. Healthy, p = 0.0205
S2: Infraspinatus	X	**0.0454**	None	**0.0441**	None
	Y	0.0525	N/A	**0.0130**	RSA-OA vs. Healthy and TSA-OA vs. Healthy, p = 0.0484
	Z	0.1471	N/A	0.0726	N/A
S3: Pectoralis Major	X	**0.0273**	RSA-CTA vs. Healthy, p = 0.0411	**0.0402**	RSA-OA vs. Healthy, p = 0.0484
	Y	0.2044	N/A	0.0621	N/A
	Z	**0.0249**	TSA-OA vs. Healthy, p = 0.0273	0.2230	N/A
S4: Deltoid	X	**0.0271**	RSA-CTA vs. Healthy, p = 0.0380	**0.0263**	RSA-OA vs. Healthy and TSA-OA vs. Healthy, p = 0.0448
	Y	**0.0287**	None	**0.0272**	RSA-OA vs. Healthy, p = 0.0382
	Z	**0.0478**	TSA-OA vs. Healthy, p = 0.0429	**0.0206**	RSA-OA vs. Healthy, p = 0.0166

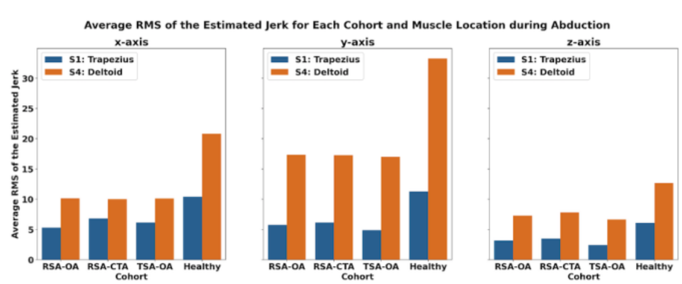

Figure 1 Comparison of the Average RMS of the Estimated Jerk for each cohort