

Changes in EMG–Angle Relationships Following Reverse Total Shoulder Arthroplasty

Hugo Francalanci^a, Nicolas Holzer^b, Yosra Cherni^{c, d, e},
Florent Moissenet^{a, f*}

Received date: 14/01/2026

Accepted date: 16/03/2026

Publication date: 02/06/2026

a Biomechanics and Translational Research in Surgery Research Group, Department of Surgery, University of Geneva, Geneva, Switzerland

b Orthopedic Surgery and Musculoskeletal Trauma Care Division, Department of Surgery, Geneva University Hospitals, Geneva, Switzerland

c Laboratoire de neurobiomécanique et neuroréadaptation de la locomotion, Centre de recherche Azrieli du CHU Sainte Justine, Montréal, Canada

d Ecole de kinésiologie et sciences de l'activité physique, Université de Montréal, Montréal, Canada

e Institut de génie biomédical, Université de Montréal, Montréal, Canada

f Kinesiology Laboratory, Geneva University Hospitals and University of Geneva, Geneva, Switzerland

* Corresponding author: florent.moissenet@unige.ch

Keywords: reverse total shoulder arthroplasty, rotator cuff tear, motor control, kinematics, electromyography

© 2026 The Authors

Licence CC-BY 4.0

Published by Société de Biomécanique

1. Introduction

Restoring shoulder function in patients with massive rotator cuff tears (MRCT) partly relies on the motor system's ability to reorganise muscle activation. Reverse total shoulder arthroplasty (rTSA) stabilises the glenohumeral centre, enabling the deltoid to compensate for cuff deficiency, but also induces significant neuromuscular adaptations (Smith et al., 2020). Understanding recovery after rTSA requires more than kinematic analysis alone, as muscle activation patterns reflect compensatory strategies. However, the interaction between shoulder kinematics and electromyography (EMG) remains poorly documented.

This study investigates the change in the relationship between thoracohumeral (TH) elevation and shoulder muscle activations before and after rTSA in comparison to asymptomatic shoulders. We hypothesised that postoperative kinematic improvements would be accompanied by a more stable and functional EMG–angle relationship, indicating a shift towards efficient coordination strategies.

2. Methods

2.1 Data acquisition and preprocessing

Retrospective data were collected from asymptomatic ($n = 20$; 71.7 ± 9.7 years) and symptomatic ($n = 20$;

71.8 ± 10.3 years) shoulders assessed preoperatively and 12 months following rTSA. All participants provided written informed consent, and the study was approved by the local ethics committee (CER 2025-00773). Data acquisition was performed during four functional tasks: hand to mouth, hand to head, maximal overhead reach, and hand behind the back, each repeated three times.

EMG signals from the deltoid (DELTA, DELTM, DELTP), trapezius (TRAPM, TRAPS), and serratus (SERRA) were processed using: band-pass filtering (15–475 Hz), full-wave rectification, root mean square (RMS) smoothing (250 ms), and normalisation to sub-maximal tasks. For each subject and muscle, three cycles per task were time normalised and averaged to obtain a representative EMG cycle.

TH joint elevation angle was computed for the same cycles using a Y-X-Y Euler sequence decomposition (Wu et al., 2005) and averaged similarly. The resulting mean EMG and TH cycles were aligned to allow the analysis of the relationships. All data processing was performed using MATLAB (R2024b, The MathWorks, USA).

2.2 EMG–angle relationships

EMG–angle relationships were quantified at the subject level over the movement cycle using linear regressions,

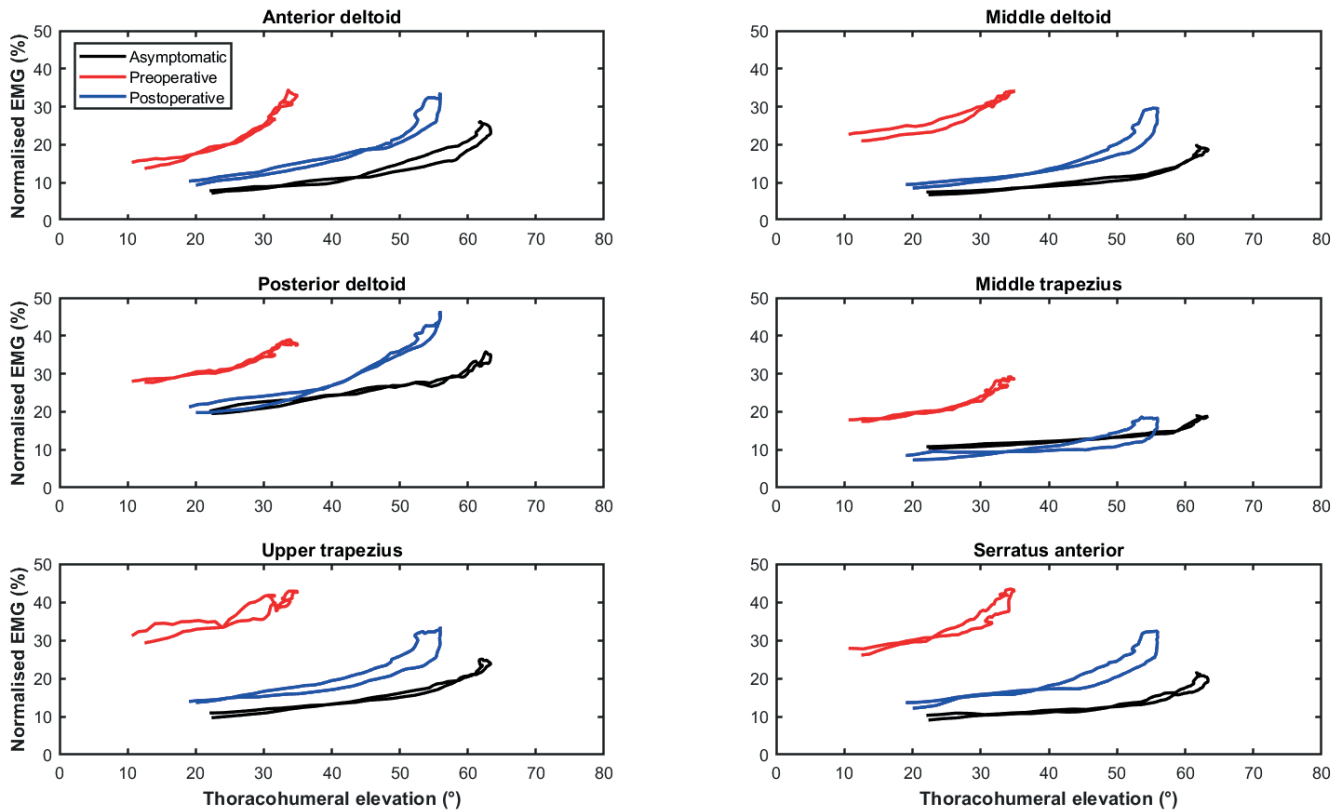


Figure 1. Comparison of normalised shoulder muscle EMG activity across thoracohumeral elevation angles between groups during combined functional tasks. Each plot displays the linear relationship between EMG activity and elevation angle for a single muscle.

Credit: Francalanci.

and metrics were compared across groups. The regression slope indexed muscle activation relative to TH elevation, while the RMS deviation (RMSD) from the group-averaged EMG–angle curve quantified intra-group variability and EMG–angle coupling consistency.

2.3 Statistical analysis

Two-way ANOVAs (Group×Muscle) were performed for regression slopes and RMSD values. When a significant Group×Muscle interaction was detected, separate one-way ANOVAs were conducted for each muscle, followed by post-hoc pairwise t-tests. When no significant interaction was present, post-hoc tests were performed globally across all muscles. Significance was set at $p < 0.05$.

3. Results and discussion

3.1 EMG–angle relationships

Regression slope analysis revealed that changes in EMG–angle relationships (Fig. 1) were primarily driven by clinical status rather than muscle-specific effects

(Table 1), indicating a global reorganisation of motor control.

Preoperatively, altered DELTA recruitment was associated with rotator cuff deficiency and pseudoparalysis (Bauer et al., 2022), reflected by reduced TH elevation amplitude compared with asymptomatic shoulders (24.4° vs 43.6°). After rTSA, the EMG–angle relationship of DELTM remained altered, suggesting a modified functional role in restoring elevation (Pietroski et al., 2025), consistent with postoperative recovery of TH elevation (41° vs 43.6°). Differences in DELTP slopes between asymptomatic and postoperative groups indicate an increased contribution of this muscle to postoperative shoulder coordination.

The TRAPM fibres showed altered EMG–angle coupling only preoperatively, consistent with impaired scapular stabilisation in MRCT, with recovery observed after surgery. In contrast, SERRA coupling remained altered postoperatively, suggesting incomplete restoration of coordination or persistent compensatory strategies following rTSA.

Table 1. Statistical comparison of EMG–angle relationships (slopes) and intra-group variability (RMSD) between groups during combined functional tasks [Credit: Francalanci]

			One-way ANOVA Group	Two-way ANOVA Group×Muscle	Post-hoc Asymptomatic vs Preoperative	Post-hoc Asymptomatic vs Postoperative	Post-hoc Preoperative vs Postoperative
EMG-angle relationships (slopes)	Main effects	Group	—	<0.001*	—	—	—
		Muscle	—	0.081	—	—	—
	Interaction effect	Group×Muscle	—	0.421	—	—	—
	Muscles	DELTA	—	—	0.017*	0.066	0.244
		DELTM	—	—	0.011*	0.049*	0.515
		DELTP	—	—	0.057	0.026*	0.259
		TRAPM	—	—	0.021*	0.912	0.057
		TRAPS	—	—	0.443	0.055	0.597
SERRA		—	—	0.082	0.006*	0.731	
Intra-group variability (RMSD)	Main effects	Group	—	<0.001*	—	—	—
		Muscle	—	<0.001*			
		Interaction effect	Group×Muscle	—			
	Muscles	DELTA	0.252	—	—	—	—
		DELTM	0.159	—	—	—	—
		DELTP	0.154	—	—	—	—
		TRAPM	0.404	—	—	—	—
		TRAPS	<0.001*	—	<0.001*	0.581	<0.001*
SERRA		<0.001*	—	<0.001*	0.263	0.005*	

DELTA: anterior deltoid; DELTM: middle deltoid; DELTP: posterior deltoid; TRAPM: middle trapezius; TRAPS: upper trapezius; SERRA: serratus anterior; *: $p < 0.05$.

3.2 Intra-group variability and coupling consistency

RMSD analysis demonstrated that EMG–angle variability reflected both global motor control changes and muscle-specific behaviour (Table 1). No group differences were observed for the deltoid portions or TRAPM, whereas TRAPS and SERRA showed higher variability preoperatively compared with asymptomatic and postoperative shoulders. This indicates reduced coupling consistency before surgery and a postoperative return towards asymptomatic patterns.

These findings highlight the sensitivity of scapular stabilisers to MRCT-related dysfunction (Hawkes et al., 2012) and their responsiveness to rTSA. Interpretation should be cautious given the limited muscle set and task selection.

4. Conclusions

Clinical status primarily drives global motor control adaptations. Preoperative subjects showed altered recruitment patterns and high variability, particularly in the anterior deltoid and scapular stabilisers, whereas postoperative subjects exhibited more consistent EMG–angle coupling and a reorganisation of coordination strategies, with all three deltoid portions emerging as primary contributors to restoring thoracohumeral elevation, reflecting a shift towards efficient coordination strategies.

Conflict of Interest Statement

None.

Contributor Roles

HF: Conceptualisation, Formal analysis, Methodology, Visualisation, Writing – original draft. NH: Conceptualisation, Writing – review & editing. YC: Conceptualisation, Methodology, Software, Visualisation, Supervision, Writing – review & editing. FM: Conceptualisation, Data collection, Methodology, Visualisation, Supervision, Writing – review & editing.

Funding

No funding was received by the authors for this study.

Data, software, code availability

Code is available at the following GitHub repository: <https://github.com/HugoFrancalanci/Changes-in-EMG-angle-relationships-following-reverse-total-shoulder-arthroplasty.git>. Data are available upon request to the corresponding author.

References

- Bauer, S., Okamoto, T., Babic, S. M., Coward, J. C., Coron, C. M. P. L., & Blakeney, W. G. (2022). Understanding shoulder pseudoparalysis: Part I: Definition to diagnosis. *EFORT Open Reviews*, 7(3), 214–226. <https://doi.org/10.1530/EOR-21-0069>
- Hawkes, D. H., Alizadehkhayyat, O., Kemp, G. J., Fisher, A. C., Roebuck, M. M., & Frostick, S. P. (2012). Shoulder muscle activation and coordination in patients with a massive rotator cuff tear: an electromyographic study. *Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society*, 30(7), 1140–1146. <https://doi.org/10.1002/JOR.22051>
- Pietroski, A., Zhou, Y., Kasto, J., Obinero, C., Zhu, K., Mazeh, M., Chen, C., & Muh, S. (2025). Surface electromyography reveals middle deltoid as the functionally dominant shoulder muscle after reverse total shoulder arthroplasty. *Cureus*, 17(3). <https://doi.org/10.7759/CUREUS.80229>
- Smith, R. A., Woolley, K., Mazzocca, A., Feinn, R., Cote, M., Gomlinski, G., Garbalosa, J., & Myrick, K. M. (2020). Kinematics and EMG activity in reverse total shoulder arthroplasty. *Journal of Orthopaedics*, 22, 165–169. <https://doi.org/10.1016/J.JOR.2020.04.017>
- Wu, G., van der Helm, F. C. T., Veeger, H. E. J., Makhsous, M., van Roy, P., Anglin, C., Nagels, J.,

Karduna, A. R., McQuade, K., Wang, X., Werner, F. W., & Buchholz, B. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand. *Journal of Biomechanics*, 38(5), 981–992. <https://doi.org/10.1016/J.JBIOMECH.2004.05.042>