Elbow Joint Reaction Forces and Prosthesis Failure: A Musculoskeletal Analysis of Functional Movement

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Summary

Total elbow arthroplasty (TEA) is a surgical intervention, which has relatively high failure rates due to overloading. To understand loading during daily tasks and potentially extend prosthesis life after TEA, we analyzed a door-opening task, where net joint moments around the elbow were calculated and joint reaction forces were estimated. We explored the relationship between elbow flexion-extension (FE) angle and joint loads in six healthy participants. Elbow joint loads were the FE moment, varus-valgus (VV) moment, and ulnar-humeral joint reaction force (UH JRF). Cross-correlation analyses showed strong correlations between elbow FE angle and UH JRF (0.73 ± 0.07), with UH JRFs peaking near full elbow extension. These findings underscore the importance of posture and movement execution in managing joint stresses to prevent overloading, particularly in contexts relevant to prosthetic design and rehabilitation.

Introduction

Total elbow arthroplasty (TEA) is a surgical intervention for various elbow pathologies. Overloading of the elbow joint is the primary cause of failure [1]. VV joint moments and UH JRF are key contributors to this overloading [2]. However, current postoperative loading instructions fail to effectively reduce joint loads, compromising prosthesis longevity. Literature suggests JRF peaks early in flexion due to poor mechanical advantage of primary flexor muscles [3]. This study investigates the relationship between upper extremity movement and elbow joint loading during an activity of daily living (ADL), focusing on the correlation between elbow FE angle and joint load (VV moment, FE moment, and JRF).

Methods

Six healthy participants performed a door-opening and closing task. 3D motion capture and external force data were collected. The data were analyzed using an upper extremity model in OpenSim 4.5 to determine elbow joint angles, moments, and joint reaction forces (JRFs) through inverse dynamics and static optimization. Cross-correlation analyses (MATLAB R2022b) were performed to evaluate the relationships between elbow flexion-extension (FE) angle and joint loads.))

Results and Discussion

UH JRFs ranged from 18.2 to 61.4 N. Cross-correlation coefficients of FE angle were highest for UH JRF (0.73 ± 0.07). For VV moment and FE moment, these were 0.70 ± 0.1 and 0.67 ± 0.1, respectively (Table 1).

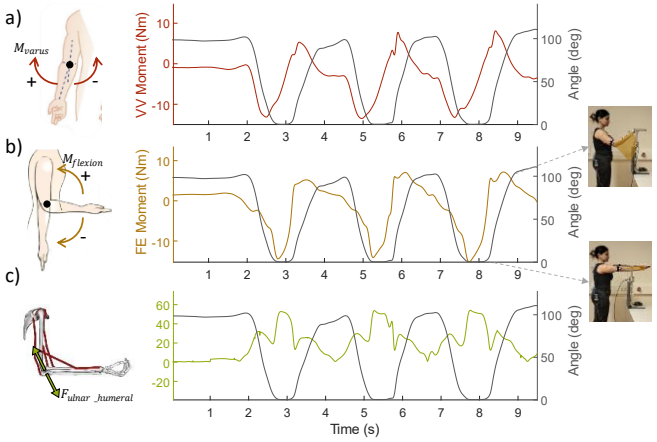

Figure 1: Opening and closing a door: Elbow flexion-extension angle and elbow joint loads, VV moment (a), FE moment (b), and ulnar-humeral joint reaction forces(c).

Conclusions

This study highlights the interaction between kinematics and joint load, relevant for developing postoperative instructions to extend prosthesis survival. To prevent elbow overloading, highly demanding ADL activities involving full extension should be avoided.

References

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Table 1: Peak elbow joint load and cross correlation values (n=6) during opening and closing a door

	VV moment (Nm)	FE moment (Nm)	UH JRF (n)
Peaks joint load (mean±sd)	9.7±2.2	14.0±5.6	44.1±18.6
Xcor Elbow FE-angle (lag)	0.70±0.1 (2.55s)	0.67±0.1 (1.44s)	-0.73±0.07 (1.15s)
Xcor Shoulder elevation angle (lag)	-0.67±0.1 (0.66s)	-0.61±0.1 (-0.61s)	0.87±0.07(-0.27s)