Effect of Shoulder Girdle Movement on Upper Limb Dummy

Minjae Kim[1], Sang Hoon Kang[1]

Ulsan National Institute of Science and Technology, Ulsan, Republic of Korea,
{min9765, sanghkang}@unist.ac.kr

Abstract. This study investigates the effect of shoulder girdle movement on muscle moment arms and joint torque vectors. Comparing scenarios with fixed versus posture-adjusted muscle origins revealed significant differences in moment arm magnitudes and torque vector angles. The Deltoid posterior's moment arm varied by up to 38%, while the Triceps long showed a 42.52° difference in torque vector angles. These findings highlight the importance of considering posture-dependent muscle origins in dummy models to better replicate human mechanical impedance.

Keywords: mechanical impedance, shoulder girdle, moment arm

1 Introduction

Accurate mechanical impedance measurements are essential for human-robot interaction in rehabilitation and other applications. A 3D upper limb dummy[1], based on the OpenSim model[2], aims to replicate human mechanical impedance but may be inaccurate with fixed muscle origins. This study investigates the effects of posture-dependent changes in muscle origins to improve dummy design.

2 Method

Mechanical impedance includes mass, damping and stiffness. The magnitude of the muscle moment arm and direction of torque vector affect both the size and shape of the mechanical impedance[3]. This study compares the fixed(neutral posture) versus moving effects of the shoulder girdle on muscle moment arms and torque vector directions using arm postures of shoulder flexion at 60°, shoulder abduction at 20°, shoulder external rotation at -80°, and elbow flexion at 60°.

3 Result

The Deltoid posterior showed a 38% variation in moment arm magnitude, and the Triceps long showed a 42.52° difference in torque vector angles. These findings highlight the need for posture-dependent muscle origins in dummy models to accurately reflect human mechanical impedance.

Table 1. Moment arm and angle between two torque vectors

Muscle	Magnitude of moment arm				Angle
	Moving shoulder girdle (mm)	Fixed shoulder girdle (mm)	Error (mm)	Percent error (%)	(degree)
Deltoid anterior	52.53	42.59	-9.94	18.93	2.03
Deltoid posterior	32.37	20.07	-12.30	38.00	6.13
Supraspinatus	22.85	23.44	0.59	2.58	25.91
Infraspinatus	24.59	23.07	-1.52	6.19	23.98
Subscapularis	18.94	20.47	1.53	8.08	8.73
Pectoralis major-clavicular	40.26	38.96	-1.30	3.22	5.04
Triceps long	26.10	19.27	-6.83	26.18	42.52
Biceps long	16.04	20.42	4.38	27.29	8.12
Biceps short	40.46	39.39	-1.08	2.66	1.17

Acknowledgments This study was supported in part by the Translational Research Program for Rehabilitation Robots(#NRCTR-EX23009), National Rehabilitation Center, Ministry of Health and Welfare, Korea, in part by the Korea Medical Device Development Fund grant funded by the Korea government (the Ministry of Science and ICT, the Ministry of Trade, Industry and Energy, the Ministry of Health & Welfare, the Ministry of Food and Drug Safety) (Project Number: 1711174372 , RS-2020-KD000165), in part by the Korea Medical Device Development Fund grant funded by the Korea government (the Ministry of Science and ICT, the Ministry of Trade, Industry and Energy, the Ministry of Health & Welfare, the Ministry of Food and Drug Safety) (Project Number: 1711196704, RS-2023-00252859), in part by the National Research Foundation of Korea(NRF) grant funded by the Korea government(Ministry of Science and ICT) (RS-2024-00417959), and in part by the Translational Research Center for Rehabilitation Robots(#NRCTR-EX24006), National Rehabilitation Center, Ministry of Health and Welfare, Korea.

References

1. Kim, J.: Exploring 3 DOF upper limb dummy design method for upper limb impedance analysis. Ulsan : Graduate School of UNIST, Ulsan (2020)
2. Saul, K.R., Hu, X., Goehler, C.M., Vidt, M.E., Daly, M., Velisar, A., Murray, W.M.: Benchmarking of dynamic simulation predictions in two software platforms using an upper limb musculoskeletal model. Computer Methods in Biomechanics and Biomedical Engineering 18, 1445-1458 (2015)
3. Hu, X., Murray, W.M., Perreault, E.J.: Muscle short-range stiffness can be used to estimate the endpoint stiffness of the human arm. Journal of Neurophysiology 105, 1633-1641 (2011)