Understanding the Mechanisms of Scapulohumeral Rhythm with the HARMONY Exoskeleton

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The coordinated movement patterns between the humerus and the shoulder girdle (i.e., the clavicle and scapula) is known as scapulohumeral rhythm (SHR). This coupling is critical to providing glenohumeral joint stability and properly aligning the shoulder muscles. This synchronicity varies significantly among individuals and tasks with different loading characteristics. The loss or alteration of this coordinated behavior has been associated with various neuromuscular pathologies, including stroke and spinal cord injuries, and leads to impaired arm function and an increased risk of shoulder impingement. Furthermore, it has been shown that patients with greater proximal arm capabilities at the onset of rehabilitation have substantially improved recovery of hand function than those with reduced shoulder mobility [1]. The ability to concurrently measure and control SHR is essential to ascertaining what factors govern SHR and how they can manipulated to produce healthier motion.

To address these questions, we have developed an upper body exoskeleton called HARMONY (Fig. 1). The kinematics of the robot closely match the physiological motions of the shoulder complex, including the elevation/depression and protraction/retraction of the shoulder girdle [2]. Its compact design supports bilateral arm movements and facilitates a wide range of motion that envelops the majority of activities of daily living. The robot's sensors and actuators allow it to simultaneously apply various loads to the upper limb and measure the user's response to these demands. We are currently conducting human subject studies with both healthy and stroke subjects to evaluate the device's capacity to alter the user's SHR.

These features allow us to thoroughly explore multiple aspects of shoulder biomechanics and control. The robot's ability to monitor and modify SHR when performing tasks will help us discern how task performance depends on this coordination. Observing how healthy subjects respond to external disruptions to SHR can provide insight into compensatory movement strategies and potential injury mechanisms. In addition, pairing HARMONY with various physiological sensors, such as EMG, can be used to study how the shoulder complex responds to perturbations. Finally, utilizing this exoskeleton as a rehabilitation device will allow us to examine the relationships between SHR, functional recovery after therapy, and shoulder impingement. These findings have the potential to improve rehabilitation techniques, enhance our understanding of neuromuscular recovery, and accelerate patient recovery.

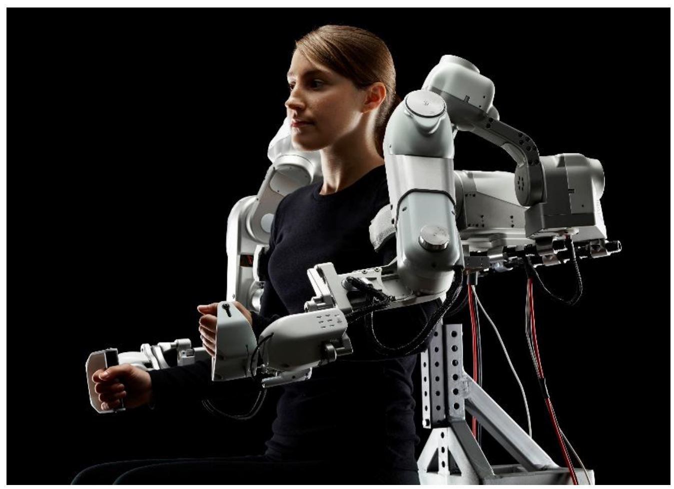

Figure 1: The HARMONY exoskeleton.

References

1. Houwink A et al. (2013) Functional recovery of the paretic upper limb after stroke: who regains hand capacity? Arch Phys Med Rehab 94 (5):839–844.
2. Kim B and Deshpande AD (2016) An Upper-Body Rehabilitation Exoskeleton with an Anatomical Shoulder Mechanism: Design, Modeling, Control, and Performance Evaluation. Manuscript submitted for publication.

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