ROBUSTNESS OF A WRIST JOINT COORDINATE SYSTEM TO FOREARM PRONATION-SUPINATION

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INTRODUCTION

The long-term goal of the kinematic wrist joint coupling project is to study complex, dynamic motions like throwing without imposing limitations on the motion. As the majority of functional tasks *(vocational, recreational, and daily living activities)* occur between neutral and full pronation of the forearm; one prerequisite is to establish a wrist joint coordinate system (WJCS) that is robust over a range of forearm pronation-supination positions. Our original WJCS was based upon the ISB recommended standards [1] and was reported at the past ISB meeting [2]. In this system, global wrist motion was based upon a floating axis solution between the 3rd metacarpal (MC) and radius.

METHODS

A more advanced WJCS was developed which expressed global wrist motion between 3rd MC and forearm segment

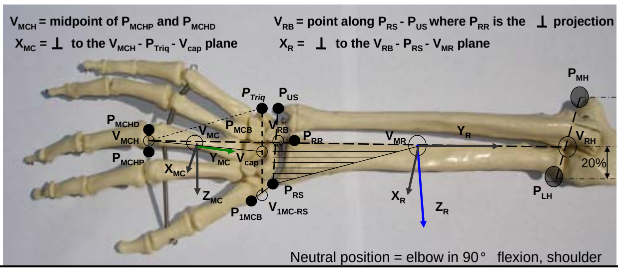

Figure 1: Advanced Wrist Joint Coordinate System.

coordinate systems (Figure 1). A functional axis method was applied with the goal of finding the 'true' flexion-extension axis [3]. To assess appropriate wrist motion with all variations of the WJCS, we tested their ability to identify an isolated arc of pure flexion-extension in various degrees of forearm pronation and supination. Two triads of 9mm retro-reflective markers were affixed to the 3rd MC and distal forearm (or radius) of one healthy subject. Other anatomical landmarks were identified with a 3D digital pointer. 3D wrist movements were captured with a 12 camera Motion Analysis Corp system with each WJCS implemented in Visual 3D.

RESULTS AND DISCUSSION

The coupling ratio *(flexion-extension ROM/radial-ulnar deviation ROM)* was plotted versus forearm pronation-supination position while the subject performed isolated wrist flexion-extension (Figure 2). The subject was instructed to perform isolated flexion-extension arc without radial-ulnar deviation, a task that would yield an infinite coupling ratio. Several variations of the WJCS were examined: Distal Forearm Axis (yellow); Radial Axis (light blue); Functional Methods acquired at 45° of Pronation (purple), Functional Method acquired at Full Pronation (red), and Functional Method acquired at Neutral Position (green).

As shown in Figure 2, the functional joint method, when modeled with the forearm in either neutral or 45° of pronation, resulted in the highest coupling ratios over the most common range of forearm positions. In pronated positions, the anatomical radius-based WJCS, tracked with a

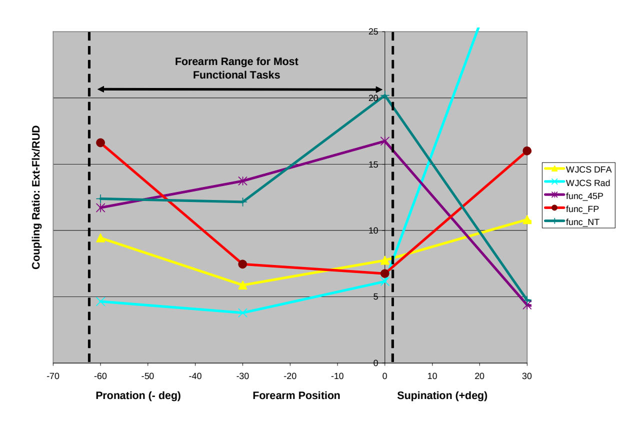

Figure 2: Coupling ratio for isolated flexion-extension at different forearm pronation and supination positions.

cluster placed directly on the radius, could not effectively produce isolated motion. This finding was explained by the fact that the mathematical axis *(tracked by the radial cluster*) and the true flexion-extension axis did not coincide. Closer examination revealed that the radial tracking cluster did not accurately represent the motion of the radius. As the forearm position shifted from full pronation to full supination the cluster would slide over the radius in the volar direction. This lack of fidelity caused the radial axis to be tilted in the transverse plane, resulting in apparent coupled motion. Placing the tracking cluster centrally on the dorsal aspect of the distal forearm minimized the cluster's movement due to skin motion. Our WJCS proximal tracking cluster is now *distal forearm based*, as opposed to ISB-recommended radius based, to ensure more robust performance over forearm pronation – supination positions.

CONCLUSIONS

The hybrid anatomical (3rd metacarpal) - functional (flexion-extension) axis model when trained at neutral or 45° of pronation performed most robustly over the pronated forearm positions.

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