EFFECT OF SEAT POSITION MODIFICATIONS ON UPPER EXTREMITY MECHANICAL LOADING DURING MANUAL WHEELCHAIR PROPELLATION

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INTRODUCTION
Repetitive mechanical loading of the shoulder during manual wheelchair (WC) propulsion has been associated with disabling shoulder pain that can significantly affect health and active community participation [1,2]. Because individuals with spinal cord injury (SCI) are dependent on the upper extremity during most of their activities of daily living, shoulder pain developed as a result of an acute incident or overuse is difficult to resolve.

Past efforts to reduce the mechanical demand on the upper extremity of manual WC users have focused on WC design and the interface with the WC user. For example, introducing modifications in materials and WC construction can significantly reduce the mass of the WC (e.g. >35% reduction between standard and ultralight chair), thereby reducing the magnitude of the tangential component of the reaction force (RF) needed to maintain WC speed. Incorporating WC components that are adjustable provides multiple solutions for achieving a desired elbow extension angle between 100-120 degrees when the wrist is at top-dead-center of the handrim [2]. Load exposure is affected by pushing frequency and the mechanical load experience during each propulsive cycle. Increasing the duration of hand contact may increase the duration of hand contact and reduce the average force, but not necessarily peak reaction forces during the impact or propulsive phases [5].

Identification of prospective preventative strategies for preserving shoulder function is imperative for manual WC users with SCI. Previous research indicates modifications in WC fitting can affect joint kinetics as well as muscle activation patterns during manual WC propulsion [2-4]. Our working hypothesis is that custom fitting of the WC to the individual WC user can create a functional workspace conducive for maintaining mobility and mitigating detrimental mechanical loading of the shoulder. Our purpose here is to show how modifications in seat position can alter upper extremity mechanical loading during manual WC propulsion. Modifications in axle position relative to the shoulder, arising from adjustments to seat position, orientation, and cushioning (Figure 1) are expected to affect segment kinematics and as a result upper extremity joint kinetics during manual WC propulsion [5,6].

METHODS
An experimental-based modeling approach was used to assess the sensitivity of shoulder net joint moments (NJM) and net joint forces (NJV) to changes in shoulder horizontal and vertical position relative to the rear wheel axle (Figure 2). Individuals with paraplegia volunteered to participate in accordance with the Institutional Review Board at the Rancho Los Amigos National Rehabilitation Center, Downey, CA. Kinematics, reaction forces at the hand-rim interface, and muscle activation patterns were quantified as participants propelled the WC using their self-selected free, fast and graded conditions[3,4,7]. Reflective markers were used to monitor the 3D motion of the hand, forearm, upper arm, trunk, and wheel segments (VICON, 50 Hz) and pushrim force was collected (SmartWheel 2500 Hz. The markers and upper extremity model to estimate wrist, elbow, and shoulder joint centers followed methods described in [7]. Foot-rest height was adjusted to each subject’s preferences and anthropometry.

An experimentally validated 2D inverse dynamic model, incorporating subject-specific experimental tangential force, body segment parameters, and kinematic data, was used to determine the sensitivity of UE loading to modifications in shoulder/axis distance for an individual WC user [6]. Configuration of the forearm and upper arm body segments at an instant was determined using the law of Cosines and shoulder-axle distance and
wrist angle under each seating condition (Figure 3). Mechanical loading during WC propulsion at the time of peak push was characterized by determining the elbow net joint moment (NJM) and shoulder NJM over a range of RF directions. Experimentally WC speed was maintained by preserving the tangential component of the RF and varying the magnitude of the radial component of the RF.

RESULTS AND DISCUSSION
Modifications in shoulder-axle distance and wrist location relative to the rim was found to influence how RF redirection distributes mechanical loading across the shoulder and elbow (Figure 4. Our simulation studies indicate that the effect of force redirection on elbow and shoulder NJMs depends on the seat configurations at specific times within the push phase. Simulated solution spaces at the time of peak RF during propulsion illustrate how redirection of the reaction force relative to the upper extremity segments is an effective means for shifting mechanical load (NJM, NJF) away from regions commonly experiencing pain during WCP (shoulder). If RF direction is constrained (due to friction, grip strength, etc.) solutions for redistributing the load will shift within the solution space.

CONCLUSIONS
By using an experimental-based subject-specific dynamic model, we can prospectively determine how multiple factors interact and affect mechanical loading under different seating conditions. Prospective determination of feasible solutions for an individual WC user will assist in preserving shoulder function by avoiding seat modifications that inadvertently contribute to detrimental mechanical loading of the shoulder.

REFERENCES

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