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Effect of increased load on scapular kinematics during manual wheelchair propulsion in individuals with paraplegia and tetraplegia

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ABSTRACT

Repetitive loading of the upper extremity musculature during activities like wheelchair propulsion can lead to fatigue of surrounding musculature causing irregular segment kinematics. The goal of this study was to determine the effect of increase in load on the kinematics of the scapula in users with paraplegia and tetraplegia. Data were collected on 18 participants (11 with paraplegia and 7 with tetraplegia) using an electromagnetic motion tracking system (100 Hz) and force sensing pushrim (200 Hz). The participants propelled under no load and loaded conditions at their customary propulsion velocity. On average a 60 N increase in force was elicited with the experimental protocol. Users with tetraplegia showed significant increases ($p < .05$) in the rate of change of scapular angles in the upward/downward rotation and the retraction/protraction direction under the loaded conditions, whereas users with paraplegia only showed difference in the retraction/protraction rotation direction. Overall both user populations moved towards position of increased downward rotation, anterior tilt and protraction with increase in load hence increasing the risk of impingement. This experiment adds depth to our understanding of dynamic scapular kinematics during wheelchair

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propulsion under different loading conditions and differences in scapular control between users with paraplegia and tetraplegia.

1. Introduction

Individuals dependent upon the use of a wheelchair for locomotion repeatedly expose the shoulder joint and shoulder girdle to mechanical loading as part of their activities of daily living (ADL). The repetitive nature and mechanical demand imposed on the shoulder joint during ADL is often associated with acute and overuse injuries that contribute to a loss of independence and a decrease in quality of life, particularly in manual wheelchair users with spinal cord injury (SCI) (Ballinger, Rintala, & Hart, 2000). Mechanical load experienced by the shoulder joint is high in transfers and lifts, only moderate but highly repetitive in wheelchair propulsion (van Drongelen et al., 2006). Repetitive mechanical loading during these physically demanding activities can cause fatigue and subsequent decrease in muscular control associated with irregular scapular motion pattern (McCully, Suprak, Kosek, & Karduna, 2006), injury, and secondary disabilities.

Control of the upper extremity during ADL depends upon active and passive soft tissue to stabilize and control rotation of the shoulder joint and shoulder girdle. Muscles actively controlling the shoulder girdle, comprised of the scapula and clavicle, are involved in stabilizing the humeral head within the glenoid fossa of the scapula (e.g., rotator cuff) and controlling the relative motion between the shoulder girdle and the trunk (Kendall, McCreary, & Provance, 2005). Muscles controlling the shoulder joint are involved in joint stabilization and 3D rotation of the humerus relative to the scapula. Motion of the scapula in relation to the humerus (scapulohumeral rhythm) requires coordinated muscle activation of thoraco-humeral, thoraco-scapular and scapulo-humeral muscle groups particularly during movements involving flexion/extension or ab/adduction of the shoulder joint. Strength or control deficits in one or more muscles of the shoulder complex can lead to arrhythmic motion of scapula and humerus and potentially compression of supraspinatus tendon, bicipital tendon and the subacromial bursae in the subacromial space also termed impingement.

Manual wheelchair users with tetraplegia (TP: C6–C8 SCI injury) are reported to have a higher incidence of shoulder pain associated with upper extremity ADL than those with paraplegia (PP: T1 SCI injury and below) (Curtis et al., 1999). Wheelchair users with tetraplegia (TP) experience a loss of strength and control due to partial or complete loss of innervations of muscles involved in wheelchair propulsion. As a result, the remaining shoulder muscles may compensate (McCully, Suprak, Kosek, & Karduna, 2007; van Drongelen et al., 2006) to satisfy stabilization and rotation requirements of shoulder function. Anatomically, a wheelchair user with a SCI C6 injury may have partial loss of innervations in muscles that stabilize the shoulder joint (e.g., subscapularis), control the elbow (e.g., triceps), and control the scapula (e.g., pectoralis minor, serratus anterior). A reduction in scapular control by the serratus anterior may result in less scapular stabilization, particularly when large net joint forces (NJF) are transmitted proximally during hand contact with the rim. Likewise, a reduction in scapular control by the pectoralis minor can contribute to more pronounced upward rotation and posterior tilt of the scapula. A reduction of shoulder joint stabilization (e.g., reduced innervation of subscapularis) can lead to a reduction in subacromial space and potential impingement of the supraspinatus with upward motion of the humerus in the glenoid cavity. With the deficits in neuromuscular control, the scapular-humeral motion is expected to be different between wheelchair users with TP and PP, particularly when exposed to increases in mechanical loading during wheelchair propulsion.

Kinematic-based consequences arising from neural deficits (e.g., SCI) have been associated with shoulder impingement (Ludewig & Cook, 2000; Nawoczenski et al., 2003) and soft tissue pain. Attempts to quantify relative motion between the humerus and scapula during dynamic ADL involving the upper extremity are few and often limited by the scope of the experiment and the measurement tools available (Ludewig & Cook, 2000; Nawoczenski et al., 2003; Sheikhzadeh, Yoon, Pinto, & Kwon, 2008). Individuals with impingement were found to have decreased levels of serratus anterior activity