COMPARISON OF TEMPORAL SPATIAL CHARACTERISTICS AND SHOULDER KINEMATICS AND KINETICS DURING REVERSE AND CONVENTIONAL MANUAL WHEELCHAIR PROPULSION IN PERSONS WITH PARAPLEGIA

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INTRODUCTION

Shoulder pain after spinal cord injury (SCI) is attributed to a shift in mobility demands to the upper limbs and negatively impacts independence, participation and quality of life[1, 2].

CLINICAL SIGNIFICANCE

Repetitive superior and posterior shoulder joint forces produced during wheelchair (WC) propulsion can result in impingement of subacromial structures if unopposed, owing to fatigue or weakness[3]. Further, these forces increase with fast and inclined propulsion. RoWheels® (RW), geared rear wheels that produce forward WC movement with backward rim pulling, have the potential to reverse these shoulder joint forces and utilize the larger posterior shoulder and scapular muscles to protect the shoulder joint and preserve mobility.

METHODS

Ten men with paraplegia from SCI (AIS A, B) who pushed traditional manual WCs and were free of shoulder pain (Wheelchair User's Shoulder Pain Index (WUSPI) < 12) or pathology participated. Right upper extremity/trunk kinematics and kinetics were collected during three conditions of ergometer propulsion[4] sitting on their own seat cushion in a rigid, lightweight WC frame adjusted to match the participant's own WC: self-selected free speed reverse propulsion (pulling back on the rim) with RW, and matched-speed reverse (rSW) and forward (fSW) propulsion with standard instrumented pushrim wheels (Smartwheels (SW) using an analog display of propulsion speed. Right 3-D pushrim kinetics were collected on the right at 200 Hz using SW. Three-dimensional trunk, right upper extremity, and wheel kinematics were collected at 200 Hz using a Qualisys motion capture system (10 cameras). Kinematic and kinetic data were low-pass filtered with a fourth-order zero-lag Butterworth filter with cutoff frequencies of 8 Hz and 10 Hz, respectively, using Visual3D (C-Motion, Inc., Germantown, MD).

Temporal-spatial, kinematics and kinetics variables were compared across the three conditions (RW, fSW and rSW) with a repeated-measures Analysis of Variance.

RESULTS

Mean age of participants was 39.6 years and duration of SCI was 14.5 years. Free propulsion velocity and cadence were similar during RW and rSW compared to fSW, although push distance was mildly reduced in rSW vs. RW and fSW (Table 1).

At the forward-most hand contact position (initial contact during RW and rSW, and end contact during fSW), shoulder flexion, abduction and internal rotation were similar in all three conditions. At the backward-most hand position (end contact during RW and rSW and beginning contact during fSW propulsion) shoulder extension was significantly lower in both RW and rSW vs. fSW propulsion. Shoulder abduction and internal rotation in the backward-most hand position was similar in all three conditions.

Anteriorly and inferiorly directed forces on the pushrim were significantly greater during fSW than in rSW propulsion. In contrast, posteriorly and superiorly directed forces on the pushrim were significantly greater during rSW than in fSW. Medial and lateral forces on the pushrim were similar between the two conditions.

Superior (upward) force at the shoulder joint was significantly higher during fSW than during rSW propulsion. Posterior shoulder force was also greater during fSW than rSW. Inferior force tended to be higher during rSW than fSW. Anterior and medial shoulder forces were similar between fSW and rSW conditions.

Peak flexor, adductor, and external rotation moments during the contact phase (forward or reverse) were significantly higher during fSW propulsion than during rSW. Shoulder moments during the contact phase were otherwise similar during fSW and rSW propulsion.

Table 1. Temporal-spatial, kinematics and kinetics data for RW, rSW and fSW.

	RW	**rSW**	**fSW**
Velocity (meters/minute)	70.1 ± 10.9	70.3 ± 6.9	72.0 ± 7.8
Cadence (pushes/minute)	67.4 ± 26.1	68.1 ± 14.1	61.5 ± 17.1
Push Distance (meters)	1.16 ± 0.35	*1.06 ± 0.17	1.23 ± 0.27
Shldr EXT (°)**, backward hand position**	25.5 ± 10.3	25.6 ± 16.9	*41.2 ± 9.9
Pushrim Forces (Newtons(N))**, Anterior**	-	5.2 ± 7.8	*33.6 ± 4.3
Pushrim Forces (N)**, Inferior**	-	25.0 ±16.6	*44.6 ± 11.7
Pushrim Forces (N)**, Posterior**	-	*35.9 ± 13.8	3.3 ± 4.3
Pushrim Forces (N)**, Superior**	-	*22.5 ± 21.8	0.6 ±0.7
Shldr Forces (N)**, Superior**	-	-3.2 ± 15.4	*12.7 ± 10.7
Shldr Forces (N)**, Posterior**	-	13.0 ± 8.9	*41.7 ± 7.7
Shldr Forces (N)**, Inferior**	-	**56.7 ± 7.7	48.4 ± 10.2
Shldr Flexion Moment (Newton·meters/kg (Nm/kg))	-	5.0 ± 3.9	*14.1 ± 2.4
Shldr Adduction Moment (Nm/kg)	-	4.5 ± 2.0	*9.8 ± 2.5
Shldr External Rotation Moment (Nm/kg)	-	3.1 ± 1.8	*8.7 ± 2.3

*$p<0.05$; **$0.05>p>0.10$

DISCUSSION

These results demonstrate that reverse propulsion requires an upward force applied to the pushrim which, combined with the weight of the arm, translates to a distraction force at the shoulder. In contrast, forward propulsion incorporates a downward pushrim force leading to a superior, potentially impinging shoulder joint force. Moreover, the overall demands on shoulder muscle groups are lower during the contact phase of pulling compared to forward pushing. Reverse propulsion may protect the subacromial structures and thereby prevent injury and pain and preserve mobility, independence, and participation for individuals living with paraplegia.

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DISCLOSURE STATEMENT

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