Shoulder Joint Load during Lever Wheelchair Propulsion in Individuals with SCI

Philip Requejo PhD[2,3] ; Sharon Eun J. Lee[3] ; Lisa Haubert MPT[3] ; Ernest Bontrager MS[3] ; Sara Mulroy PhD, PT[1,3]

Department of [1]Biokinesiology and Physical Therapy, & [2]Kinesiology, USC, Los Angeles, CA

[3]Pathokinesiology Laboratory, Rancho Los Amigos National Rehabilitation Center, Downey, CA

RANCHO

PATHOKINESIOLOGY LABORATORY

Introduction

Wheelchair (WC) propulsion places an added burden on the upper extremities. The highly repetitive and weight-bearing nature of WC propulsion often has been associated with development of upper limb pain in persons with SCI. Using a lever-propelled WC has been suggested to be more efficient and less physically demanding than a pushrim-propelled WC. Propelling with a lever mechanism also is thought to provide a more effective transfer of power by increasing mechanical advantage and placing the arms in a more natural segmental position and orientation [1].

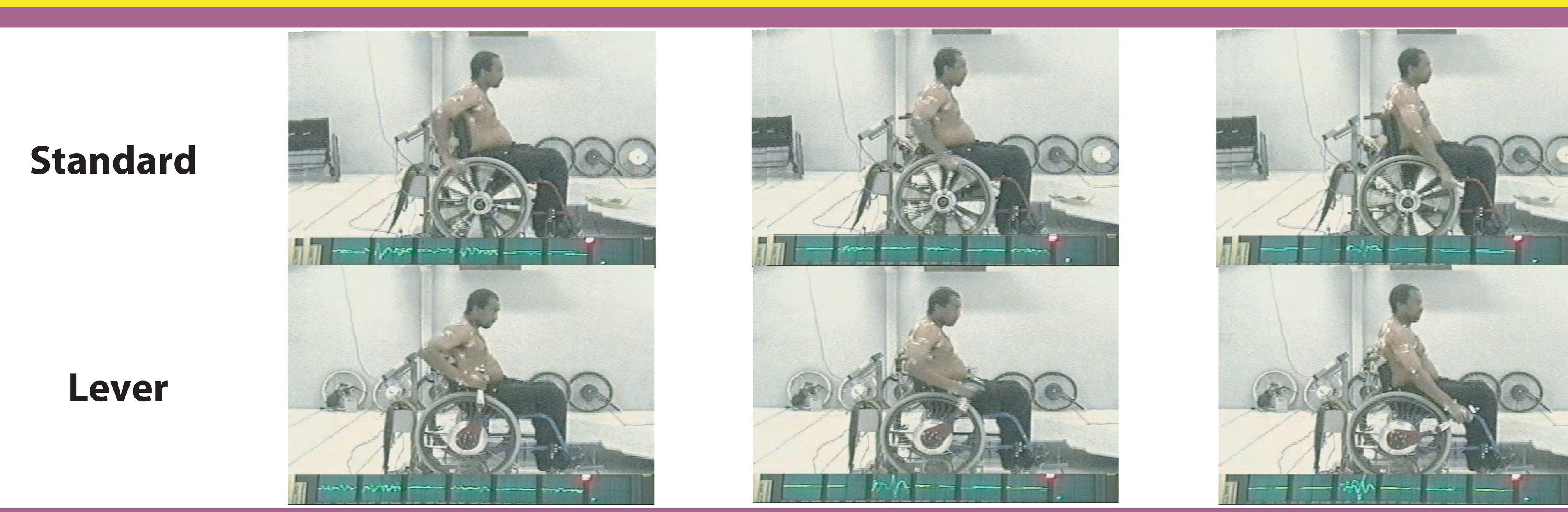
Purpose

To compare the shoulder joint kinematics and kinetics recorded during standard pushrim wheelchair propulsion (Standard) and lever propulsion (Lever). We hypothesized that Lever propulsion will shift the shoulder joint load by redistributing the glenohumeral joint forces while changing the orientation and range of upper arm motion.

Methods

Fourteen males with complete (ASIA-A) spinal cord injury (SCI) participated. Subjects represented 2 groups of SCI level: paraplegia (n=6) and tetraplegia (n=8). Upper extremity reaction forces were recorded using an instrumented pushrim (SmartWheel) and instrumented lever during Standard and Lever propulsion, respectively. Upper extremity kinematics were recorded with a 6-camera VICON system. Reaction forces and kinematics were recorded while subjects propelled a wheelchair mounted to a stationary ergometer [2]. Data were recorded at self-selected free (FR) and fast (FT) speeds and at a simulated 8% grade (GR). Speed in Lever was matched with Standard in each test condition. Shoulder net joint forces, moments, and kinematics were determined using an inverse dynamics algorithm in Visual3D.

Methods cont.



Results

Propulsion Characteristics: Subjects with paraplegia had significantly greater speed, less push duration and greater superior shoulder forces than subjects with tetraplegia.

	FREE				FAST				GRADED			
	Velocity (m/min)	Push Duration (% of cycle)	Cadence (cycles/min)	Cycle Length (m)	Velocity (m/min)	Push Duration (% of cycle)	Cadence (cycles/min)	Cycle Length (m)	Velocity (m/min)	Push Duration (% of cycle)	Cadence (cycles/min)	Cycle Length (m)
PARA	74.7 ± 20	0.3 ± 0.1	1.03 ± 0.17	1.24 ± 0.42	143 ± 45.3	0.17 ± 0.05	1.61 ± 0.35	1.52 ± 0.51	62.9 ± 20.3	0.44 ± 0.11	1.25 ± 0.2	0.85 ± 0.26
TETRA	53.2 ± 13.6	0.45 ± 0.14	0.98 ± 0.34	0.96 ± 0.31	81.4 ± 18.2	0.29 ± 0.07	1.32 ± 0.25	1.04 ± 0.24	29.2 ± 9.3	0.79 ± 0.24	0.88 ± 0.19	0.56 ± 0.16

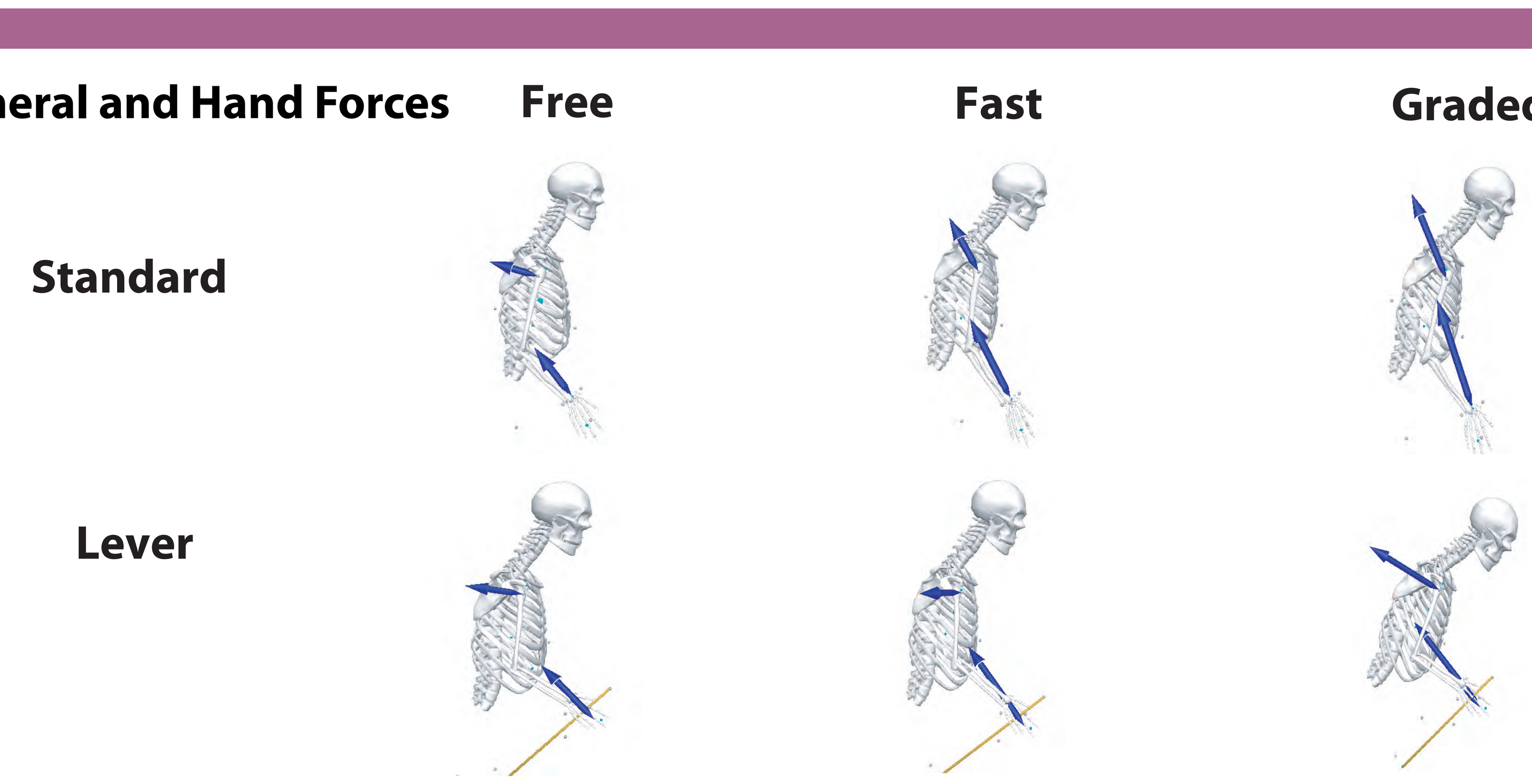
Net Joint Forces: Superior shoulder force (Z-MAX) was significantly ($p<0.05$) lower in the Lever. The posterior shoulder force (Y-MAX) was lower in Lever during FR and FT but greater during GR. (FTI: Force time integral)

		FREE				FAST				GRADED			
		Y-FTI	Y-MAX	Z-FTI	Z-MAX	Y-FTI	Y-MAX	Z-FTI	Z-MAX	Y-FTI	Y-MAX	Z-FTI	Z-MAX
FORCE	LEVER	1.6 ± 3.6	27 ± 21.4	-11.1 ± 7.0	-19.7 ± 14.3	1.5 ± 2.7	42.6 ± 26.7	-6.2 ± 3.1	-14 ± 21.5	30.8 ± 9.9	106.4 ± 59.2	-15.4 ± 11.5	6.7 ± 23.6
(N)	STD	5.0 ± 4.6	33.5 ± 17.1	-5.3 ± 3.3	4.5 ± 11.6	5.6 ± 3.4	67.6 ± 31.8	-1.9 ± 1.8	20.3 ± 17.7	26.7 ± 8.4	79.9 ± 28.9	1.3 ± 6.9	40.6 ± 22.5

Net Joint Moment: Subjects in Lever displayed lower peak adductor moment (Y-MAX) during FR, FT and GR. Peak flexor moment (X-MAX) was lower in Lever but was significant only during FT. (MTI: Moment time integral)

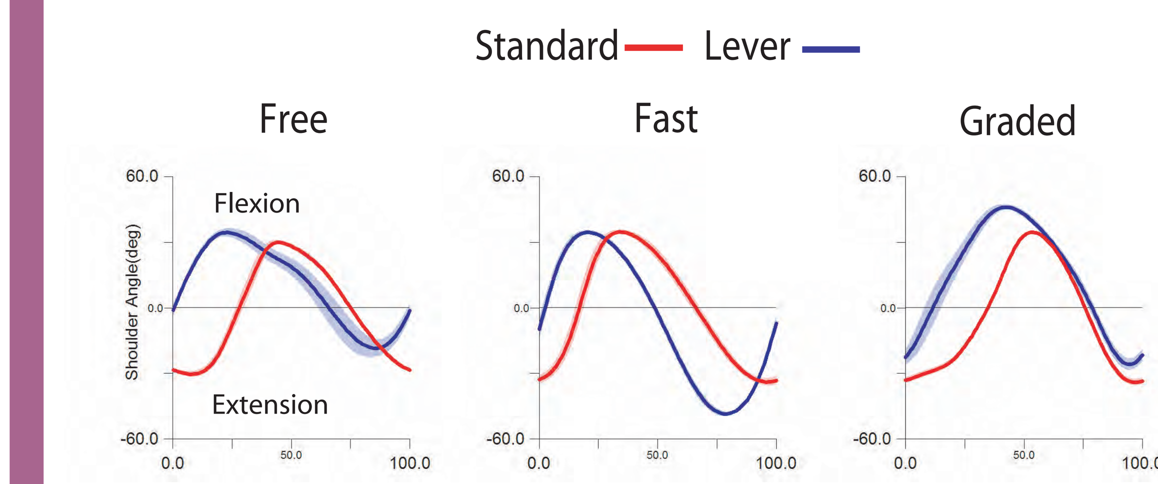
		FREE				FAST				GRADED			
		X-MTI	X-MAX	Y-MTI	Y-MAX	X-MTI	X-MAX	Y-MTI	Y-MAX	X-MTI	X-MAX	Y-MTI	Y-MAX
MOMENT	LEVER	1.4 ± 1.1	7.7 ± 4.4	-1.4 ± 1.1	-2.4 ± 1.8	0.7 ± 0.8	10.9 ± 6.8	-0.8 ± 0.7	-1.3 ± 2.6	7.1 ± 3.0	23.1 ± 8.8	3.3 ± 1.8	1.9 ± 1.9
(Nm)	STD	1.7 ± 1.7	12.3 ± 7.3	-0.2 ± 0.4	2.6 ± 2.5	1.8 ± 1.1	23.3 ±10.5	0.1 ± 0.3	6.1 ± 4.9	8.1 ± 3.6	26.7 ± 10.4	1.0 ± 1.3	8.4 ± 5.0

Glenohumeral and Hand Forces



GH MOTION: During push, peak flexion position was 10° to 13° greater, adduction excursion was 7° to 9° greater, and internal rotation was 9° to 14° greater in Lever compared to Standard.

SAGITTAL PLANE MOTION



Discussion

Lever propulsion shifted the shoulder joint load by decreasing the superior glenohumeral force. This decrease shows less potential for impingement in the shoulder joint in Lever propulsion. In addition, subjects in Lever showed lower posterior shoulder force during FT.

Lever propulsion significantly decreased adductor moment during all propulsion conditions, reflecting reduced demands on the shoulder abductor muscles.

Subjects with paraplegia performed faster in both STD and Lever WC than those with tetraplegia who had weaker muscles. Subjects with tetraplegia showed lower rates of push per minute, and distance traveled per cycle. Yet, they tended to push WC for a greater percentage of cycle than the subjects with paraplegia. This indicates that tetraplegic subjects require a longer push effort for WC propulsion despite their slower speed.

References

1. van der Woude, L H, et al. *Am J Phys Med Rehabil*. 2001; 80:765-777.
2. Mulroy, S. J., et al. *J. of Spinal Cord Medicine*. 2005; 28(3): 214-221.

Acknowledgements

Supported by: NIDRR grant H133E020732
Suppliers: Superquad Inc. (Wijit®)
Sunrise Medical (Quickie GPV®)