UPPER EXTREMITY KINETICS DURING WHEELCHAIR LEVER PROPULSION

Philip Requejo, Ernest Bontrager, and Sara Mulroy
Pathokinesiology Laboratory, Rancho Los Amigos National Rehabilitation Center, Downey, CA, USA
email: prequejo@larei.org, web: www.larei.org

INTRODUCTION

Lever-propelled wheelchairs (WC) have been described as more efficient and less physically demanding than pushrim-propelled WC [1]. Propelling with a lever mechanism is thought to provide a more effective transfer of power by placing the arms in a more natural segmental position and orientation [2]. In particular, those with limited energy resources or those with upper extremity pain/weakness may benefit from this alternative mode of manual WC ambulation. While demand on the upper extremities during standard WC propulsion has been documented [3,4], investigation of the upper extremity forces and moments magnitude and direction is required to better understand demands during ambulation with lever-propelled WC. The objective of this work was to determine the joint forces and moments during lever propulsion using a kinematic and kinetic model and an instrumented lever.

METHODS

A set of prototype levers (Wijit®, SuperQuad) were custom fabricated and the right lever was instrumented with foil strain gauges (Micro Measurements) mounted below the handles (Figure 1A). Reflective markers were placed at the lever shaft and on the right upper extremity and trunk to define the three-dimensional motion of the lever, hand, forearm, upper arm, and trunk segments. Subjects propelled a lever-mounted Quickie GPV® WC positioned on a stationary custom WC ergometer [3]. Data were recorded at a self-selected free and fast propulsion speed (level ground simulation) and at a simulated 8% grade. Wheel torque (2500Hz, A/D Data Translation) and three-dimensional motion of the right upper extremity and lever was recorded (50Hz, Vicon®) during each 10-sec propulsion trial. Reaction force normal to the lever was determined from wheel torque and lever length. Upper extremity joint kinematics was determined from the recorded motion data using a Euler/Cardan rotation sequence. A 4-segment 3D upper extremity inverse dynamics model of the right upper extremity was implemented (Visual3D) to calculate the joint forces and moments during lever propulsion. Onset of reaction force was used to determine the push and recovery phase timing of each propulsion cycle (%CYCLE).

RESULTS AND DISCUSSION

Mean hand reaction force (Figure 1B) and glenohumeral net joint forces (Figure 2) are shown for a 41 year old subject with T12 complete paraplegia (ASIA-A) for 17 years while propelling at free, fast, and graded propulsion. Vertical dashed lines represent the mean transition from the push to recovery phase. Peak lever forces occurred in the middle of push phase in free, the end of push phase in fast, and the beginning of push phase in graded propulsion. Peak posterior joint force was seen during the push phase in the free and graded propulsion while peak force was seen during the recovery phase of fast propulsion. Medial/lateral forces were minimal. Inferior joint forces were seen in the push phase of free and fast while superior forces were seen in the push phase of graded and the recovery phase of fast, indicating the increased effects of inertial loads at high velocities and cadence. The relative difference between posterior and upward joint forces reflected a shift in upper extremity demands from vertical to horizontal direction compared to previously reported push phase forces with a standard pushrim WC [3,4]. Within-subject comparison of the upper extremities demands during lever and standard WC propulsion will be studied. The joint kinetic model allows us to investigate these demands during lever WC propulsion.

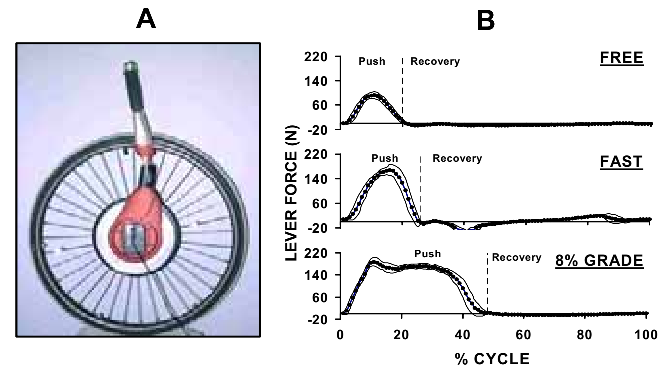

Figure 1: A) Instrumented Wijit® lever design. B) Lever reaction force during propulsion

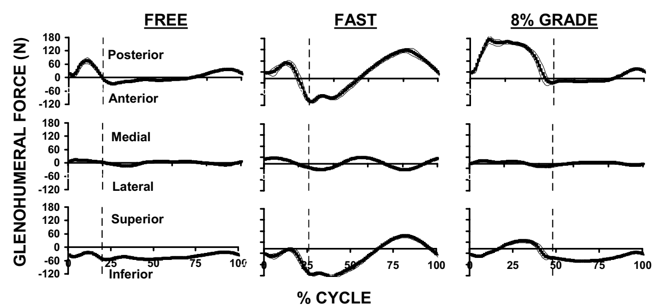

Figure 2: Glenohumeral net joint forces during lever propulsion.

REFERENCES

1. van der Woude, L. H., et al. *Am J Phys Med Rehabil* **80**(10), 765-777, 2001
2. van der Woude, L. H., et al. *J Rehabil Res Dev* **34**(3), 286-294, 1997
3. Kulig, K., et al. *Clin Orthop Rel Res,* **354**, 132-143, 1998
4. Kootz, A. M., et al. *J Rehabil Res Dev* **39**(6), 635-650, 2002

ACKNOWLEDGEMENTS

NIDRR grant H133E020732, SuperQuad®