

Alternative Modes of Manual Wheelchair Propulsion

By Philip Requejo, Ph.D.

Over the past thirty years people with spinal cord injuries (SCI) have enjoyed longer, more active lives. Many improvements in the design and function of manual wheelchairs have resulted in lighter, better fitting, and more functional mobility tools. But these gains in life expectancy and technology have also created new challenges.

Studies have shown that repetitive movement associated with propelling a manual wheelchair creates two major problems that hinder quality of life: pain and loss of function. Frequent complaints include shoulder pain due to rotator cuff degeneration and loss of hand function due to carpal tunnel syndrome. Generalized fatigue is another common complaint. As a result, some individuals -- particularly those with quadriplegia and/or long-duration SCI -- may lose some or all capacity to effectively push a manual wheelchair.

To address these challenges, the Rehabilitation Engineering Research Center on Spinal Cord Injury (RERC on SCI) at Ranchos Los Amigos Research and Education Institute (LAREI) in Downey, California is finding ways to preserve the upper extremities of manual wheelchair users. Currently, they are conducting a study to evaluate and refine alternative wheelchair propulsion designs that can be easier and more efficient to propel than a conventional pushrim wheelchair.

One example is a lever-activated gear system designed to provide increased mechanical advantage by virtue of a lever arm attached to a roller mechanism of each hub. The lever shifts between forward and reverse through a shifter located on the top of the lever arm. To move forward, the gear is activated by pushing the lever forward. In reverse, the gear is activated by pulling the lever backward. Braking is activated by pulling the lever inward. And based upon the strength, ability, and needs of an individual user, a gear ratio ranging from 1:1 (easiest) to 5:1 (hardest) can be installed. The lever-activated gear system adds about six pounds to the wheelchair and the existing rear wheels can be easily replaced by virtue of a quick disconnect.

Another alternative propulsion design uses a power-assist unit designed to reduce the actual physical exertion required to propel the wheelchair. This design uses a set of springs in the handrim that can be read by the wheelchair's assist system. Then a micro-controller makes decisions about how much power to send to each wheel through the motors. The amount of physical exertion required to travel a given distance is reduced thanks to the amplification of the push force by the motors. The amplification factor ranges from 1.5 (less assist) to 3 (more assist) and can be chosen according to the individual's ability and needs. This design also features quick disconnect wheels, but the total additional weight is about 37 pounds divided into the two wheels and battery, the heaviest of which is 17.5 pounds.

A third design lowers the impact forces experienced by the wheelchair user during propulsion by replacing the rigid connections between the wheelchair wheel and the handrim with flexible attachments. When an impact load is applied to the hand from the handrim during pushing, the handrim is able to flex relative to the wheel, absorbing impact stresses that can cause upper extremity injuries. The flexible interface also provides additional friction to the hand, improving grip during pushing, and so eliminates the need to touch the tires. This design also features a quick disconnect with negligible added weight.

The RERC on SCI study provides evidence to product designers and clinical practitioners, helping them better serve the needs of manual wheelchair users. These new designs can be an alternative to using a power wheelchair, which, while reducing arm use, leads to some loss of independence owing to the difficulty of transporting these much heavier chairs, and their limits in maneuvering certain environmental barriers. Use of an alternative manual wheelchair propulsion design has the potential to preserve the shoulders of people at risk for overuse, and yet maintain a more optimal level of activity and independence.

LAREI is able to combine biomechanical testing conducted at Pathokinesiology Laboratory with computer simulation studies from the RERC to learn as much as possible about the demands associated with pushing each of these designs. They will also assess the attributes and abilities of wheelchair users, including but not limited to age, gender, time since injury, and level of SCI. Other factors to consider include appearance, size, and weight, and barriers encountered during everyday activities. Based on these findings, it is possible to recommend improvements to the current designs.

This is not merely a matter of designing a better wheelchair. While preliminary studies show that wheelchairs with power-assist units may reduce the shoulder demands when wheeling over ramps and grass, such features also bring a higher price tag. Therefore, clear evidence of the need for these wheelchairs is going to be required to convince health insurance providers that new coverage guidelines may be needed.

Dr. Requejo is a biomechanical engineer at Pathokinesiology Laboratory and LAREI of Rancho Los Amigos National Rehabilitation Center. He is co-investigator with the project entitled: Engineering Solutions for a Shoulder Preserving Wheelchair, “funded by the National Institute of Rehabilitation Research (H133E020732) Rehabilitation Engineering Research Center (RERC) grant entitled “Keep Moving: RERC on Technologies to Enhance Mobility and Function for Individuals with Spinal Cord Injury (SCI)”.