MANUAL WHEELCHAIR PROPULSION BIOMECHANICS AND UPPER LIMB PAIN, EXPLORING INJURY MECHANISMS AND PREVENTATIVE STRATEGIES

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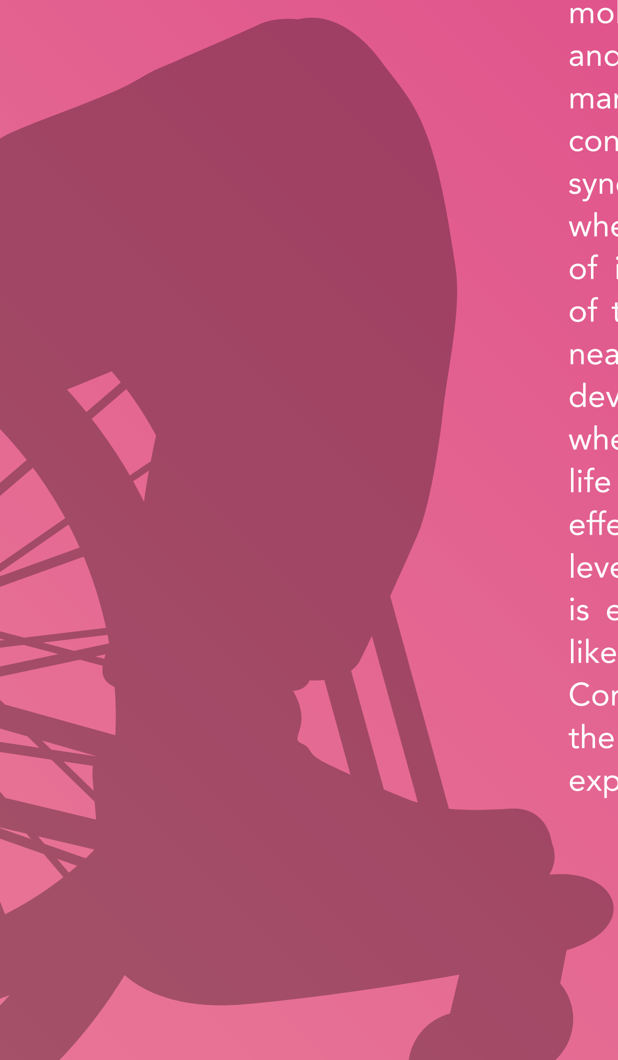
PAIN & INJURY

Individuals with mobility limitations are shown to have reduced opportunity for participation in social and community activities compared to their ambulatory peers. Although many will utilize mobility technologies like manual wheelchairs, large health and participation disparities remain. For example, although manual wheelchair propulsion offers numerous benefits[1,2] it often contributes to upper extremity pain and injury[3-6]. Carpal tunnel syndrome has been observed in up to 73 percent of manual wheelchair users, while pain has been reported in up to 59 percent of individuals with spinal cord injury (SCI). Because a majority of these individuals are reliant on their upper limbs to perform nearly all activities of daily living, the emergence of pain can have devastating consequences. For instance, pain and injury in manual wheelchair users has been shown to adversely impact quality of life and dramatically increase health care costs[7]. The far reaching effects have been compared to sustaining a second SCI at a higher level, both functionally and economically[8]. Furthermore, there is evidence that once upper extremity pain occurs, treatments like surgery are extremely disruptive and minimally effective. Consequently, researchers have made great efforts to understand the underlying causes of upper limb pain and injury as well as exploring strategies to prevent their occurrence all together[9].



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WHEELCHAIR PROPULSION TECHNIQUE AND INJURY?

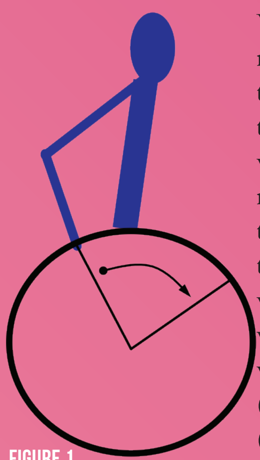


FIGURE 1
CONTACT ANGLE (CA) - maximizing CA can help improve biomechanics and reduce pain & injury

Wheelchair propulsion and transferring are inherently repetitive activities, having the potential to overwhelm the upper limbs both acutely and over time[10]. In fact, the average wheelchair user takes one stroke per second which far exceeds what the literature considers to be a repetitive task. Even more striking, it has been estimated that merely 16 minutes of propulsion a day exceeds the number of repetitions experienced by a factory worker performing a high frequency task in an 8-hour work day[11]. Not surprisingly, the literature specific to wheelchair propulsion indicates: 1) stroke frequency (cadence); 2) high forces; and 3) rate of loading (impact), all relate to injury development and should be minimized when possible[4]. For example, a wheelchair user misjudging his or her hand speed relative to the rotational speed of the wheel can impart large nonproductive forces that exacerbate all three parameters. In contrast, a more ideal stroke is one in which a wheelchair user lets the hands drift below the pushrim during the recovery phase of propulsion, allowing gravity to assist the arms swinging back in preparation for contact. Referred to as a semicircular pattern, this technique allows a wheelchair user to take less strokes and spend more time in propulsion relative to recovery[12]. In basic terms, it is ideal for a wheelchair user to minimize forces, taking as few strokes as possible to maintain a given speed, using as much of the handrim as possible (maximizing contact angle, see figure 1). Factors like body mass, wheelchair fit and configuration, disability type, and education can profoundly influence propulsion technique and overall mobility independence. Although we can't reverse most disabilities, a vast majority of the factors influencing propulsion technique are modifiable[13,14].

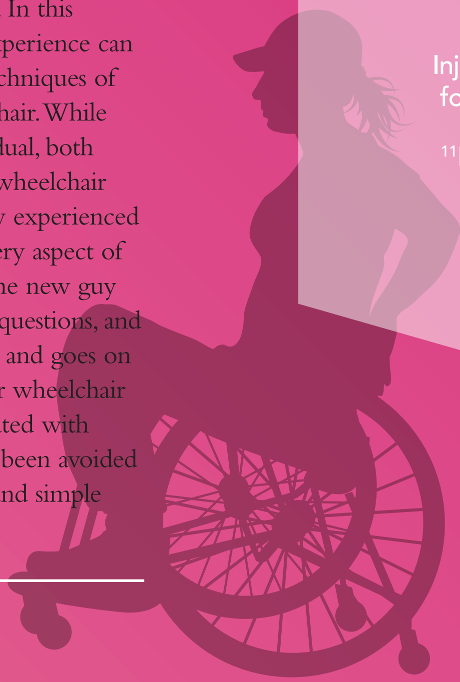
WHEELCHAIR FIT AND CONFIGURATION

FIGURE 2 REAR AXLE POSITION (RAP) - Moving RAP up and forward relative to shoulder can improve propulsion biomechanics

While exotic frame materials like titanium, carbon fiber, and magnesium can be seductive to active wheelchair users, the benefits of proper match, fit and configuration far exceed those anticipated by a wheelchair selected for its weight or materials alone. Although a wheelchair should be as light as possible, an improperly configured ultra-lightweight adjustable chair can easily be configured to perform as poorly as a hospital/ depot wheelchair. Not surprisingly, the literature has reported numerous aspects of wheelchair configuration to improve mobility and reduce upper limb stress. In essence, a properly configured wheelchair allows the user to more easily achieve ideal stroke technique. For example the rear axle position (RAP) of the user's wheel relative to their shoulder has profound effects on ease of propulsion[1,15]. A forward axle position (more tippy chair), reduces rolling resistance, and lends to improvements in stroke frequency, stroke time, rate of loading, contact angle and mechanical efficiency(see figure 2)[16–18]. A more aggressively configured or tippy chair also offers less caster flutter, decreased turning radius, and decreased downhill turning tendency than a chair set up for rearward stability[1]. These benefits must, however, be weighed against a stable chair that will tip less but may facilitate the development of repetitive strain injuries and eventually lead to a more sedentary lifestyle. Clearly rear axle placement should be balanced with an individual's functional abilities, access to training, use environment, and desired goals. Other wheelchair factors like tire pressure, back angle, seat drop, and castor wheel diameter (just to name a few), are well represented in the literature and influence propulsion biomechanics. It is important to note, however, that many wheelchair users receive little education regarding chair maintenance or configuration and commonly propel with axle positions directly under or behind the shoulder (out of the box configuration) even when the chair is easily adjustable.

CHALLENGES AND HOPE

With Medicare and other insurance companies interpreting regulations for wheelchair eligibility more strictly, individuals increasingly receive deficient technologies, such as less adjustable, heavier manual wheelchairs that are simply inappropriate for long-term use. Furthermore, manufacturers are often forced to reduce their product lines, removing once great technologies and building wheelchairs based on what insurance companies will pay for rather than on performance. Compounding the problem, individuals with traumatic injuries are spending far less time in rehabilitation, receiving less training and being discharged before receiving a wheelchair. Needless to say, few will ever receive formal wheelchair training in propulsion, skills, or equipment. Ultimately, many will experience a downward spiral of diminishing activity and deconditioning, threatening quality of life. Consequently, motivation and the need to self-educate becomes imperative. For many, adapted athletics and wheelchair sports can fill the gap. In this context, those with newer injuries or who have less experience can witness persons with disabilities who have mastered techniques of efficient body movement both in and out of a wheelchair. While the formula for success may differ based on the individual, both technology and training are critical components. As a wheelchair athlete myself for more than 20 years, I have personally experienced the benefits of wheelchair sports trickling down to every aspect of life. Similarly, I have had the opportunity to witness "the new guy or girl" timidly roll in to watch a practice, start asking questions, and not long after become a wheelchair user who "gets it" and goes on to save the next person. It's also common to encounter wheelchair users who have drifted from sport and become devastated with health problems associated with aging that could have been avoided had they been aware of readily available technologies and simple adaptive behaviors. Prevention is key!!



THE FOLLOWING ARE EXCELLENT RESOURCES FOR MORE DETAILED INFORMATION ON THESE TOPICS:

Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) Position on the Application of Ultralight Manual Wheelchairs, 2012

[14]Preservation of Upper Limb Function Following Spinal Cord Injury: A Clinical Practice Guideline for Healthcare Professionals, 2005

[11]Pushrim biomechanics and injury prevention in spinal cord injury: Recommendations based on CULP-SCI investigations, 2005

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