

The biomechanics of wheelchair propulsion in individuals with and without upper-limb impairment

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Purpose of the Work. This study compared the propulsion biomechanics of manual wheelchair users with and without upper-limb impairment. **Subjects and Procedures.** Forty-seven manual wheelchair users (15 with upper-limb impairment and 32 without upper-limb impairment) propelled an instrumented wheelchair ergometer while a 3D motion analysis system was used to collect joint kinematic and temporal data, as well as hand rim and joint kinetics. Measures were compared between groups. **Results.** The group with upper-limb impairment propelled with a higher stroke frequency and reduced contact time; with smaller peak joint angles of the wrist, elbow, and shoulder during the contact phase; with reduced power output; and with reduced hand rim propulsive and resultant forces, moments, and joint compressive forces. **Relevance to the Veteran Population.** More than 175,000 veterans use manual wheelchairs for mobility, with 44,000 manual wheelchairs distributed annually, according to the Department of Veterans Affairs (VA) Prosthetics National Database. Manual wheelchair users with upper-limb impairment adopt strategies to remain independent, and some of these strategies may protect them from the development of secondary upper-limb pathologies.

Margaret A. Finley, PhD, PT

Prevalence and identification of shoulder pathology in athletic and nonathletic wheelchair users with shoulder pain: A pilot study

Margaret A. Finley, PhD, PT; Mary M. Rodgers, PhD, PT

Purpose of the Work. This study investigated the prevalence and identity of shoulder pathology in athletic and nonathletic manual wheelchair users. **Subjects.** Fifty-two manual wheelchair users (26 athletes, 26 nonathletes) participated in this study. **Procedures.** Each subject completed a survey regarding the nature of his or her injury, sports involvement, history, and presence of current and/or past shoulder pathology. Subjects currently experiencing shoulder pain underwent a clinical examination of both shoulders. Analysis of variance (ANOVA) ($p \leq 0.05$) determined if differences existed between the groups in demographic variables, history of shoulder pain, and clinical evaluation

measures in those with shoulder pain. Chi-squared ($p \leq 0.05$) analysis determined the frequency distribution and association by groups and involved limbs for the clinical shoulder test measures. **Results.** No difference was found in the incidence of shoulder pain, past or present, between athletes and nonathletes. Collectively, 61.5% (32/52) of the subjects reported experiencing shoulder pain, with 29% reporting shoulder pain at the present time. Years since onset of disability ($p = 0.01$) and duration of wheelchair use ($p = 0.01$) were found to be greater in individuals who reported a history of shoulder pain. Of the painful shoulders tested, 44% revealed clinical signs and symptoms of rotator cuff impingement, while 50% revealed signs of biceps tendonitis. Instability was found in 28% of the painful shoulders. **Relevance to the Veteran Population.** More than 175,000 veterans use manual wheelchairs for mobility, with 44,000 manual wheelchairs distributed annually, according to the Department of Veterans Affairs National Prosthetics Database. These findings indicate that involvement in athletics does not increase or decrease the risk of shoulder pain in the manual wheelchair population. Identification of impingement syndrome as the most common pathology may provide insight into development of prevention and treatment.

Margaret A. Finley, PhD, PT

The effect of seat position on wheelchair propulsion biomechanics

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Purpose of the Work. This study furthered our knowledge of the interface between wheelchair and user by refining our understanding of the effect of seat position on handrim biomechanics. **Subjects and Procedures.** Thirteen experienced users participated in the study. Information on handrim forces and motion were collected in a motion analysis laboratory while subjects propelled a wheelchair over a smooth level floor at a self-selected speed. We changed the axle position to examine the effect that seat position has on wheelchair propulsion biomechanics. **Results.** A seat unit that is positioned behind the drive wheels resulted in improvement of some wheelchair timing variables. No effect on effectiveness of force production at the rim was observed. **Relevance to the Veteran Population.** Wheelchair timing measures can be improved by altering wheelchair fit.

Brian R. Kotajarvi, MS, PT

The oxygen uptake-heart rate relationship in trained female wheelchair athletes

Victoria Goosey-Tolfrey, PhD; Keith Tolfrey, PhD

Purpose of the Work. For this study, we examined the heart rate-oxygen uptake rate (HR- $\dot{V}O_2$) relationship in female wheelchair athletes (WAs) to determine the appropriateness of using American College of Sports Medicine (ACSM) target HRs for training prescription. **Subjects and Procedures.** Ten trained WAs completed a series of submaximal incremental stages on a wheelchair ergometer. Oxygen uptake ($\dot{V}O_2$) and HR were determined. Peak $\dot{V}O_2$ was also measured with the use of a separate protocol. Linear regression equations of the percentage of peak HR versus the percentage of $\dot{V}O_2$ were calculated for each participant. Subsequently, the percent peak HR values corresponding with 40%, 60%, 80%, and 85% peak $\dot{V}O_2$ were calculated. The regression equation was % peak HR = $0.652 \times \% \dot{V}O_2 + 35.2$ (standard error of the estimate [SEE] 3.41). **Results.** The group mean of the individual correlation coefficients for the $\dot{V}O_2$ -HR relationship was $r = 0.973$. The percentage peak HRs for the WAs were slightly, though not significantly, greater than those suggested by the ACSM across the exercise intensity continuum. **Relevance to the Veteran Population.** Limited exercise prescription guidelines have been established for persons who perform wheelchair exercise, and the most recent work has been restricted to males. As we well know, exercise is important for health maintenance as well as for performance improvements. The results suggest that training programs prescribed on the basis of ACSM target HR guidelines need not be altered for trained female WAs.

Victoria L. Goosey-Tolfrey, PhD

The effects of rear-wheel camber on the mechanical parameters produced during the wheelchair sprinting of handibasketball athletes

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Purpose of the Work. This study examined the effects of different rear-wheel camber (9° , 12° , and 15°)—today used mainly in the handibasket championship—on the various kinetic and kinematic parameters of the propulsion cycle. **Subjects and Procedures.** Eight males, all players in the French handibasket championship, were asked to participate in this study. They performed three 8 s maximal sprints as measured by a wheelchair ergometer, at 9° , 12° , and 15° of rear-wheel camber. **Results.** We found residual torque increases in proportion to the increase in wheel camber. This could explain other study

results, which show a decrease in mean velocity and an increase in both power output and time of the propelling phase, in relation to the wheel camber. **Relevance to the Veteran Population.** These results should provide the information necessary for optimal wheelchair regulation.

Arnaud Faupin, BS

The Smart Wheelchair Component System

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Purpose of the Work. We are developing a Smart Wheelchair Component System (SWCS) that can be added to a variety of commercial power wheelchairs to provide independent mobility to individuals with severe physical, perceptual, or cognitive impairments. **Procedures.** This paper describes the development and evaluation of a prototype of the SWCS. The SWCS was evaluated on four different wheelchairs with an array of specific navigation tasks and a reliability test in which each wheelchair was configured to wander randomly within an enclosed area populated with obstacles. **Results.** The results of these evaluation activities indicate that the SWCS has met our initial design criteria for safety and performance on a range of wheelchairs. **Relevance to the Veteran Population.** While the needs of many individuals with disabilities can be satisfied with power wheelchairs, some veterans find it difficult or impossible to operate a standard power wheelchair.

Richard Simpson, PhD, ATP

Design features of portable wheelchair ramps and their implications for curb and vehicle access

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Purpose of the Work. This study evaluated the effectiveness of a range of portable wheelchair ramps to assess the impact of different designs and product features on ease of use when curbs are climbed or vehicles accessed. **Subjects and Procedures.** A multidisciplinary group appraised 12 portable ramps in detail, and wheelchair users and caregivers evaluated them, where possible, in standard trials using a simulated curb and test vehicle. **Results.** Participant ratings, user comments, and objective observations of simulated curb and vehicle trials revealed that the design of the ramp and the location of specific

accessories, such as carrying handles and locks, greatly influenced ease of use. Although no single ramp successfully met the needs of all wheelchair users or their caregivers, each group of participants valued different features highly and for different reasons. In general, the wheelchair users preferred the singlewide platform ramps and the caregivers preferred the channel ramps. Some ramps were delivered without instructions, others were found to move during a maneuver, and some channel ramps were too narrow to allow wheelchair casters to pass through without jamming. **Relevance to the Veteran Population.** These findings will aid wheelchair users, including veterans, their caregivers, and professional advisors to evaluate the potential benefits and limitations of different ramp designs and their implications for curb and vehicle access. The findings will also be of use to researchers who are seeking to develop new devices that will overcome the potential hazards we have uncovered and improve their compatibility with motor vehicles.

Tim Storr, BSc, MSc

Health practices of veterans with unilateral lower-limb loss: Identifying correlates

Susan Robinson-Whelen, PhD; Carol Bodenheimer, MD

Purpose of the Work. This study described the extent to which veterans with a nontraumatic, unilateral lower-limb amputation engage in two health-related behaviors, foot care and smoking, and determined the extent to which health beliefs (severity, susceptibility, benefits, barriers, self-efficacy) and psychological well-being (life satisfaction, depression) are related to those health behaviors. **Subjects and Procedures.** Veterans who were between 6 months and 3 years postamputation participated in a brief telephone survey. **Results.** Although most participants reported practicing good foot care, a small percentage did not. In addition, nearly a third still smoked. A belief in one's ability to engage in good foot care and the belief that good foot care reduces the risk of future foot problems were significantly correlated with daily foot care practices. In addition, psychological well-being (life satisfaction) was significantly related to foot care and smoking status. **Relevance to the Veteran Population.** Veterans with a nontraumatic lower-limb amputation are at high risk of losing their contralateral limb in the years postamputation. Research is needed to better understand their health practices and to better identify determinants of those practices to direct intervention efforts to improve self-care and ultimately improve the long-term health outcomes of veterans with lower-limb loss.

Susan Robinson-Whelen, PhD

Simulated neuroprosthesis state activation and hand-position control using myoelectric signals from wrist muscles

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Purpose of the Work. This study investigated the use of myoelectric signals (MES) from wrist muscles as control signals for a hand-grasp neuroprosthesis. **Subjects and Procedures.** MES from the wrist flexor and extensor muscles were recorded in five able-bodied subjects and two individuals with C7 spinal cord injury. The MES data were used to customize a control algorithm. We evaluated the subjects' ability to use muscle contractions to activate target neuroprosthesis states and control the opening and closing of a computer-simulated hand. **Results.** Every subject was able to activate at least 99% of the target states for at least 1 continuous second. Every subject was also able to control the position of the computer-simulated hand with enough proficiency to match at least 87% of the target hand positions for at least 2 continuous seconds. Most of the errors made in controlling the position of the simulated hand were of small magnitude and are expected to have minimal consequences during actual hand control. **Relevance to the Veteran Population.** The hand-grasp neuroprosthesis restores grasp-release hand function to individuals with cervical spinal cord injury. The use of MES for neuroprosthesis control will enhance the existing neuroprosthesis by providing an invisible and potentially more natural means for opening and closing the hand.

Jayme S. Knutson, MS

The influence of voluntary tonic EMG level on the vestibular-evoked myogenic potential

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Purpose of the Work. Vestibular-evoked myogenic potentials (VEMPs) have been proposed as a reliable clinical test that may supplement the current vestibular test battery by providing diagnostic information about saccular and/or inferior vestibular nerve function. VEMPs are short-latency electromyograms (EMGs) evoked by high-level acoustic stimuli recorded from surface electrodes over the tonically contracted sternocleidomastoid muscle (SCM m.). Controlling the level of tonic EMG is a prerequisite for the accurate interpretation of interaural VEMP amplitude differences, because VEMP amplitude is influenced by the EMG level. This study determined the ability of subjects to achieve the EMG target levels over a range of target levels typically used during VEMP recording. In addition, the influence of

target EMG level on the latency and amplitude of the click-and tone-evoked VEMP was examined. **Subjects and Procedures.** By rotating the head to one side, 11 individuals (mean age = 25.3 years) with normal hearing unilaterally activated the SCM m. An acoustic stimulus was delivered to the ear ipsilateral to the activated SCM m., and the tonic EMG level and evoked potential recording (VEMP) were simultaneously recorded from the activated side. Responses to each click and 500 Hz tone burst stimulus were obtained at rectified EMG root-mean-square target levels of 0, 30, 50, 70, and 90 μ V. **Results.** The VEMP amplitude increased as a function of EMG target level, and the latency remained constant. The subjects were able to achieve the EMG target levels during unilateral activation of the SCM m., and EMG amplitude increased as a function of target level. EMG target levels ranging from 30 to 50 μ V are suggested for clinical application of the VEMP. **Relevance to the Veteran Population.** Conventional vestibular assessment (caloric and rotational testing) is limited to the evaluation of the horizontal semicircular canal, which is one of the five vestibular end organs. VEMPs have been proposed as a reliable clinical test that may supplement the current vestibular test battery by providing diagnostic information about saccular and/or inferior vestibular nerve function. The saccule—one of two vestibular organs that senses linear acceleration, such as the force of gravity—contributes to postural stability. Patients with postural instability are at increased risk of falls. Vestibular rehabilitation therapy (VRT) exercises are typically based on principles of vestibular adaptation of semicircular canal input. If otolith organ involvement is identified, then VRT exercises designed to stimulate otolithic adaptation may be more effective for managing a patient's symptoms. An improvement in the postural stability of elderly people should reduce the risk of falls. The estimated cost of morbidity and mortality of fall injuries associated with dizziness is substantial. Thus, assessment and management of balance disorders in the elderly population are critical for the VA population as well as VA health-care policy.

Faith W. Akin, PhD

Telerehabilitation for veterans with a lower-limb amputation or ulcer: Technical acceptability of data

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Purpose of the Work. This study determined the technical acceptability of information available via a customized telerehabilitation system regarding patients with lower-limb

ulcers or recent lower-limb amputations receiving care at a Veterans Affairs Medical Center. **Subjects and Procedures.** Among the 54 participants, 57 wounds (38 ulcers, 19 amputation incisions) were evaluated by means of still photographs and skin temperature data sent via ordinary telephone lines. Three experienced clinicians were raters. Intrarater agreements and McNemar χ^2 tests were assessed between decisions made after telerehabilitation sessions and decisions made by the same rater after in-person sessions. **Results.** Interrater agreements and κ coefficients were assessed between two raters for both telerehabilitation and in-person sessions. The intrarater agreement on 57 wounds for the primary rater was 93%, and the McNemar test indicated no significant difference in the ratings ($p < 0.63$). Interrater agreement on 18 wounds was 78% ($\kappa = 0.55$, $p < 0.02$) for the telerehabilitation sessions and 89% ($\kappa = 0.77$, $p < 0.001$) for the in-person sessions. Most qualitative comments by three clinicians on picture quality (54/63 = 86%) and temperature data (39/44 = 88%) were favorable (good to excellent). **Relevance to the Veteran Population.** The information found provides evidence that the telerehabilitation system has the potential to present sufficient information to experienced clinicians so they can make informed decisions regarding wound management. If future findings provide evidence that using telerehabilitation facilitates healing of wounds and prevents additional wounds or amputations, then veterans who develop wounds or who are at risk for developing wounds and have access to telerehabilitation will have better health and easier access to healthcare. These patients may need to make fewer trips to the medical center, thus saving energy and resources that may be in short supply.

Diana H. Rintala, PhD

Comparative study between patellar-tendon-bearing and pressure cast prosthetic sockets

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Purpose of the Work. This study presents a simple method of fabricating prosthetic socket with the use of a pressure cast (PCast) technique. **Subjects and Procedures.** Four unilateral transtibial amputees volunteered for this study. All subjects were male and had a unilateral amputation at least 5 years before this study. Each subject was required to adopt a normal standing position, while placing his residual limb in a pressure chamber for socket casting. We performed biomechanical evaluation on four

unilateral amputees fitted with both patellar-tendon-bearing (PTB) and PCast sockets. Using a specially built strain gauge-type pressure transducer, we recorded residual limb and socket pressure profiles for each subject wearing the two types of sockets during standing and walking. Similar pressure profiles were observed. **Results.** The PCast sockets were fabricated without rectification. Subjects found the PCast sockets to be acceptable. Some subjects exhibited similar anterior-posterior or medial-lateral pressure

profiles for both prostheses, especially during push-off; other subjects exhibited high pressure distally in the PCast socket or higher-pressure concentration at the proximal region in the PTB socket. **Relevance to the Veteran Population.** The simplicity and potentially rapid fabrication of the PCast system makes it a useful alternative in prosthetic socket production.

James Cho Hong Goh, PhD