

Robotic upper-limb neurorehabilitation in chronic stroke patients

Leah R. MacClellan, MSPH; Douglas D. Bradham, DrPH;
Jill Whittall, PhD; Bruce Volpe, MD;
P. David Wilson, PhD; Jill Ohlhoff, BA;
Christine Meister, OTR; Neville Hogan, PhD;
Hermano I. Krebs, PhD; Christopher T. Bever Jr, MD

Purpose of the Work. A robotic exercise device has been developed (MIT-Manus) and shown in a research setting to be capable of providing therapy to the arm of patients with weakness due to stroke, which simulates a conventional therapy known as skateboard therapy. We evaluated whether this robot-assisted task-specific therapy could also improve motor function in stroke patients with continuous, stable arm impairment. **Subjects and Procedures.** In a pilot intervention study conducted at the Baltimore Department of Veterans Affairs (VA) Medical Center without controls, we enrolled subjects with stable shoulder and elbow deficits due to stroke, stroke onset at least 6 months before enrollment, and a Motor Power Assessment (MPA) grade of 3 or less. We delivered 18 sessions of robot-assisted task-oriented therapy over 3 weeks. Primary outcome measures included the MPA, the upper-limb Fugl-Meyer (FM) Assessment Test, the Wolf Motor Function Arm Test, and the Motor Status Score for shoulder and elbow. We used the Wilcoxon Signed Test for paired data to assess pre- and posttreatment outcomes. **Results.** Statistically significant improvements were observed for the severely impaired group when we compared baseline and postintervention outcomes measured with the FM Assessment Test (mean increase of 1.5, $p = 0.003$), and the MPA (mean increase of 4.3, $p = 0.006$). Trends of improvement were observed but not significant among subjects who were moderately impaired. **Relevance to the Veteran Population.** Upper-limb dysfunction due to weakness and spasticity is a leading cause of chronic disability in veterans with stroke. This is a particular problem in more severely disabled, nonambulatory patients where loss of fine motor coordination, proximal limb weakness, and spasticity can interfere with activities of daily living. These more disabled patients are overrepresented in the VA population and therefore are particularly important to the VA. Our findings indicate that improvement in upper-limb motor function is not only for those with moderate impairments, as previously held, but is also for chronic stroke patients with severe impairments as

well. Upper-limb neurorehabilitation has the potential to improve the VA systems delivery of care in several ways. First, if evidence from a controlled trial indicates that the robot-assisted therapy is equal in efficacy to traditional exercises for stroke patients with chronic upper-limb impairment, then having one therapist oversee several robotic workstations at one time would be possible, thereby potentially lowering costs. In addition, as the per-unit cost of the robot decreases, placement of remotely monitored units in the field for home therapy may be possible. If the robot were significantly more effective in improving function than the current standard of care, then adoption of robotic therapy would improve care. Finally, robotic therapy may reduce long-term costs of care, such as nursing home and hospital readmissions. These opportunities for improved VA services exist, but underlying evidence of efficacy begins with this study.

Leah R. MacClellan, MSPH

Response to upper-limb robotics and functional neuromuscular stimulation following stroke

Janis J. Daly, PhD, MS; Neville Hogan, PhD;
Elizabeth M. Perepezko, PhD; Hermano I. Krebs, PhD;
Jean M. Rogers, PhD; Kanu S. Goyal, PhD;
Mark E. Dohring, PhD; Eric Fredrickson, MD;
Joan Nethery, PhD; Robert L. Ruff, MD, PhD

Purpose of the Work. Many stroke survivors are unable to use one arm and hand. **Subjects and Procedures.** In chronic stroke survivors, we tested two treatments: robotics and motor learning (ROB-ML) and functional neuromuscular stimulation and motor learning (FNS-ML). All participants had treatment 5 h/d, 5 d/wk, for 12 wk. During each daily session, the ROB-ML group had 1.5 h of robotics for shoulder/elbow movement training; FNS-ML had 1.5 h FNS for wrist/hand movement training. For the remaining 3.5 h/d, both groups had task practice. **Results.** Results showed that ROB-ML group had gains in a test of functional tasks, as well as gains in accuracy and smoothness of movement. FNS-ML group had gains in upper-limb coordination and hand/wrist functional task components. **Relevance to the Veteran Population.** The study supports the use of ROB-ML and FNS-ML in rehabilitation for stroke survivors.

Janis J. Daly, PhD, MS

Recovery of cohesion in narrative discourse after left-hemisphere stroke

Charles Ellis, PhD; John C. Rosenbek, PhD;
Maude R. Rittman, PhD, RN; Craig A. Boylstein, PhD

Purpose of the Work. This article reports findings of the assessment of narrative discourse in veterans without diagnosed language disorders following stroke; our objective was to detect the disruptions and natural recovery of language poststroke. **Subjects and Procedures.** We evaluated the cohesiveness of narrative discourse in a cohort of individuals who had suffered a left-hemisphere stroke and had not been diagnosed with expressive language impairment. We analyzed their narrative discourse at 1, 6, and 12 months poststroke. **Results.** Our findings indicate that, while the mean number of cohesive ties in narrative discourse remained generally constant during the first year poststroke, the % correct use of cohesive ties increased significantly during the same time period. These findings suggest that subtle disruptions in expressive language can be present initially in narrative discourse and then be recovered naturally over time. **Relevance to the Veteran Population.** This research will help identify veterans who are experiencing communication difficulties and develop strategies for assisting them in continued recovery.

Charles Ellis, PhD

Quality-of-life predictors for caregivers at 1 and 6 months poststroke: Results of path analyses

Marieke Van Puymbroeck, PhD;
Maude R. Rittman, PhD, RN

Purpose of the Work. This study provides clinical relevance for veterans in that when society understands how the quality of life of caregivers of stroke survivors is affected by providing care, we can target interventions to facilitate the caregiving process. Providing care for caregivers may decrease the institutionalization rate of individuals who have had a stroke, keep more people in their homes longer, and decrease national healthcare costs. This study identifies the predictors of quality of life for the caregiver at 1 and 6 months poststroke. **Subjects and Procedures.** Ninety-two stroke survivors and their caregivers ($N = 184$) were included in this study. **Results.** We found that the most important influence in the quality of life for stroke caregivers was the coping ability, or sense of coherence. This sense of coherence is the ability of an individual to mobilize coping resources and draw needed

support to deal most effectively with the situation. **Relevance to the Veteran Population.** Stroke survivors will benefit in the long-term from understanding the caregiving process. By shedding light on what enhances the quality of life for the stroke caregiver, we may indirectly affect the quality of life for the stroke survivor.

Marieke Van Puymbroeck, PhD

Key characteristics of walking correlate with bone density in individuals with chronic stroke

Lise C. Worthen, MS; C. Maria Kim, MSc, PT;
Steven A. Kautz, PhD; Henry L. Lew, MD, PhD;
B. Jenny Kiratli, PhD; Gary S. Beaupre, PhD

Purpose of the Work. This study determined if certain gait-related parameters correlate with femoral bone mineral density (BMD) in ambulatory individuals with poststroke walking deficits. **Subjects and Procedures.** The following data from 33 volunteers with poststroke walking deficits were analyzed: demographics, functional outcome measurements, BMDs and gait-related parameters. **Results.** BMD at the proximal femur was significantly lower on the paretic relative to the nonparetic side. BMD for the paretic and nonparetic sides did not correlate with clinical motor recovery or demographic variables, but a relationship was demonstrated between BMD and a newly developed gait-related parameter, the Bone Density Index, that incorporates the number of steps per day and ground reaction force (GRF) magnitudes. **Relevance to the Veteran Population.** Our results demonstrate that increasing daily walking activity and increasing GRFs both have the potential for modulating bone loss and should therefore be considered when devising stroke rehabilitation protocols for independent ambulators with poststroke walking deficits.

Lise C. Worthen, MS

Constraint-induced movement therapy for recovery of upper-limb function following traumatic brain injury

Sharon E. Shaw, DrPH, PT; David M. Morris, PhD, PT;
Gitendra Uswatte, PhD; Staci McKay, BS;
Jay M. Meythaler, MD; Edward Taub, PhD

Purpose of the Work. We conducted this study to explore the efficacy of constraint-induced (CI) movement therapy (CI therapy) for persons with chronic traumatic brain injury (TBI). **Subjects and Procedures.**

A volunteer sample of 22 participants with chronic TBI and relative hemiplegia (onset >1 year) that revealed moderate disability of the more-affected upper limb (UL) participated in the study. CI therapy was employed for training the participants' more-affected UL for 6 h daily for 10 consecutive weekdays over a 2-week period. The protocol treatments included massed practice, shaping of the more-affected UL, behavioral contracts, and other behavioral techniques for affecting transfer to a real-world setting. **Results.** We used two laboratory motor function tests, the Wolf Motor Function Test and the Fugl-Meyer Motor Performance Assessment as well as a measure of UL use in the real-world setting, the Motor Activity Log, to measure outcomes. All outcome measures improved significantly as a result of the intervention. More-adherent participants (median split) who wore the mitt more than 57% of waking hours had more improvement compared with less-adherent participants who wore the mitt less than 57% of waking hours. **Relevance to the Veteran Population.** Each year, about 1,500,000 Americans, including veterans, sustain a TBI. As a result of these injuries, over 80,000 Americans experience the onset of long-term or lifelong disability each year. An estimated \$56 billion is spent on direct and indirect costs. Nearly two-thirds of the injured US soldiers sent from Iraq to Walter Reed Army Medical Center have been diagnosed with TBI: a percentage thought to be higher than in any other past U.S. conflict. As such, TBI leads all other Iraq war injuries. Effective rehabilitation treatments, like CI therapy, are needed to overcome disability among these veterans and those of other wars.

Sharon E. Shaw, DrPH, PT

Efficacy of multidisciplinary treatment program on long-term outcomes of individuals with Parkinson's disease

William Carne, PhD; David X. Cifu, MD;
Paul Marcinko, MHA; Mark Baron, MD;
Treven Pickett, PsyD; Abu Qutubuddin, MD;
Vincent Calabrese, MD; Peggy Roberge, RN;
Kathryn Holloway, MD; Brian Mutchler, PsyD

Purpose of the Work. In this study, we examined the benefits of a multidisciplinary model of Parkinson's disease (PD) care. **Subjects and Procedures.** We reviewed the medical records of 49 PD patients and assessed the

effect of multidisciplinary management by the Parkinson's Disease Research, Education, and Clinical Center (PADRECC) program on initial and follow-up motor scores (measured by the Part III Motor Examination subscale of the Unified Parkinson's Disease Rating Scale). **Results.** Of patients assessed at 1-year follow-up, 78% had improved and 21% had worsened. Of patients assessed at 2-year follow-up, 67% had improved and 33% had worsened. Of patients assessed at 3-year follow-up, 83% had improved and 17% had worsened. **Relevance to the Veteran Population.** An awareness of the PADRECC program by veterans with PD may greatly improve their quality of life.

William Carne, PhD

Effectiveness of muscle vibration in modulating corticospinal excitability

Lorraine Smith, MSc; Brenda Brouwer, PhD

Purpose of the Work. This study examined the importance of altering the duration of muscle vibration on enhancing motor cortical excitability. **Subjects and Procedures.** Sixteen healthy men and women participated in one or more studies involving the application of 15 or 30 min of vibration of a wrist extensor muscle (extensor carpi radialis longus) with a clinically available muscle vibrator. Suprathreshold transcranial magnetic stimuli were delivered singly over seven scalp sites overlying the motor cortex to map cortical excitability. Motor-evoked potentials (MEPs) were recorded from the vibrated muscle and the antagonist before vibration and at two time intervals after (5 and 20 min). **Results.** Fifteen minutes of vibration significantly increased the size of the MEPs and the cortical region of excitability associated with the vibrated muscle only for at least 5 min beyond the vibration period. The effects were not sustained after 20 min, and no changes were detected in relation to the antagonist muscle. Vibration for 30 min failed to produce any change in corticospinal excitability in either the wrist extensor or flexor. **Relevance to the Veteran Population.** The findings of this study provide a sound basis for exploring the effectiveness of muscle vibration in individuals with central motor disorders including stroke. The cortical actions of vibration specific to the target muscle can potentially be exploited to promote more normal muscle activation patterns, a common goal in neurorehabilitation.

Brenda Brouwer, PhD

Efficacy of shock-absorbing versus rigid pylons for impact reduction in transtibial amputees based on laboratory, field, and outcome metrics

Jocelyn S. Berge, MSE; Joseph M. Czerniecki, MD;
Glenn K. Klute, PhD

Purpose of the Work. Lower-limb amputees lack many natural mechanisms that attenuate the impact forces of gait, such as a heel pad and some lower-limb joint motion. This musculoskeletal change coupled with the unfortunate placement of their residual-limb soft tissue in the load path may result in tissue breakdown and localized pain. To prevent and/or ameliorate these problems, prosthetic manufacturers have designed and marketed shock-absorbing pylons (SAPs) to attenuate transmitted forces. This study compared the performance of a commonly prescribed SAP (Mercury™ Telescopic Torsion Pylon, Chas A. Blatchford & Sons, Ltd, Hampshire, England, United Kingdom) with a conventional rigid pylon through laboratory gait analysis, field measurements of activity, and subjective outcome assessments. **Subjects and Procedures.** We used a randomized cross-over design with 15 unilateral transtibial amputees to compare and contrast the two pylons. Subjects were provided a 3-week acclimation period for each pylon. We employed hypothesis testing to explore the effects of pylon type on self-selected walking speed, prosthetic-side step length, prosthetic-side loading rate and decelerative peak of the vertical ground reaction force, prosthetic-side knee angle at initial contact, peak pylon acceleration, step count per week, and responses to three questionnaires: the opinion of performance questionnaire, an adapted Chronic Pain Grade (residual-limb pain grade), and the Multidimensional Fatigue Inventory[®]. **Results.** The only statistically significant difference found was between mean prosthetic-side knee angles at initial contact, where subjects displayed, on average, 2.6° more flexion with the rigid pylon than with the SAP while walking at controlled speeds of 1.2 m/s. This result suggests that transtibial amputees are able to modulate the effective stiffness of their residual limb to accommodate changes in prosthetic component stiffness. No differences between pylons were found for any of the other kinematic, kinetic, activity level, or subjective outcome metrics. **Relevance to the Veteran Population.** The results from the laboratory, field, and outcome measurements imply that the SAP in this study is as effective an intervention as the rigid pylon for unilateral transtibial amputees.

Jocelyn S. Berge, MSE

Foot and ankle ligament morphometry

Chimba Mkandawire, PhD; William R. Ledoux, PhD;
Bruce J. Sangeorzan, MD; Randal P. Ching, PhD

Purpose of the Work. The foot has many ligaments, some of which are very small. To understand how diseases like diabetes affect these ligaments, we must test the mechanical properties of the ligaments. In this study, we determined the area and length of a cross section of foot ligaments. Future work will explore how to estimate mechanical properties based on ligament shape and thus avoid difficult mechanical tests. **Procedures.** Using digital calipers, we measured the length, width, and thickness of 121 ligaments from 26 feet. We also developed a way to measure areas by freezing, fracturing, and digitally photographing ligaments. **Results.** We measured the cross-section area of a range of foot ligaments and developed a range of ligament areas and lengths. **Relevance to the Veteran Population.** Every year, more veterans are diagnosed with diabetes. Information from this study will help researchers better understand how diabetes affects foot ligaments.

Chimba Mkandawire, PhD

Nerve conduction topography in geriatric hand assessment

Mohammed Ferdjallah, PhD; Jacqueline J. Wertsch, MD;
Mohammad A. Ahad, MS; Gulapar Phongsamart, MD;
Kevin C. McGill, PhD

Purpose of the Work. This study verified the variability of the single-site measurement of nerve conduction on the hand of elderly subjects with carpometacarpal degenerative joint disease (CMC DJD). This study illustrates the significance of topographic thenar mapping with multisite recordings and lays the foundation for the development of multichannel topographic nerve conduction studies. **Subjects and Procedures.** Twelve normal young subjects (age 32 ± 8.8) and 25 geriatric patients with clinical findings of CMC DJD (age 75 ± 3.29) participated in this study. Median motor nerve conduction studies were performed with 15 recording sites on the thenar muscle. Compound muscle action potentials (CMAPs) were recorded at each site. Amplitude, latency, and area under the curve of CMAPs were computed and analyzed. **Results.** Results showed that one electrode position registered the highest CMAP amplitude for the normal hands, whereas in the elderly subjects, multiple sites registered high amplitude. Results indicated that single-site measurements were more

variable than multisite measurements. **Relevance to the Veteran Population.** The current single-site measurement technique for the assessment of CMC DJD hands of the elderly may be misleading and lead to unnecessary hand surgery. The proposed multichannel grid electrode measurement offers a significant technical advancement for geriatric hand assessment.

Mohammed Ferdjallah, PhD

Neurocognitive enhancement therapy with work therapy: Productivity outcomes at 6- and 12-month follow-ups

Morris D. Bell, PhD; Gary J. Bryson, PsyD;
Tamasine C. Greig, PhD; Joanna M. Fiszdon, PhD;
Bruce E. Wexler, MD

Purpose of the Work. This study enhances work therapy (WT) outcomes for people with schizophrenia by adding a program of cognitive remediation to address impairments in executive function and working memory. **Subjects and Procedures.** A total of 145 outpatients with diagnoses of schizophrenia or schizoaffective disorder recruited from a Department of Veterans Affairs (VA) mental hygiene clinic and a community mental health center were randomized to 6 months of paid WT or to neurocognitive enhancement therapy and WT (NET+WT). **Results.** By 12 months from intake, subjects in NET+WT had worked significantly more hours and earned significantly more money than those in WT only, with differences emerging after rehabilitation. Results indicate that work outcomes were enhanced by NET training. Effects were greatest for NET responders. **Relevance to the Veteran Population.** Findings support efficacy of cognitive training when integrated into broader rehabilitation programs for veterans. The VA is the largest single provider of work services for people with chronic mental illness in the United States and should be a leader in developing and testing new approaches to enhance outcomes. These results are in keeping in with that mission.

Morris D. Bell, PhD

Use of 35 words for evaluation of hearing loss in signal-to-babble ratio: A clinic protocol

Richard H. Wilson, PhD; Christopher A. Burks, MS

Purpose of the Work. We developed a test that quickly measures speech understanding in background noise. An established 70-word test was reduced to 35 words, which

cut testing time in half. **Subjects and Procedures.** In Experiment 1, we measured word recognition in 72 listeners with hearing loss on two 35-word lists based on recognition performance at each signal-to-babble ratio. In Experiment 2, we measured word recognition in 48 listeners with hearing loss on two lists based only on recognition performance. **Results.** Listeners performed 0.5 dB poorer on one list than the other in Experiment 1 but performed the same on both lists in Experiment 2. We suggest that clinicians use the Experiment 2 lists and present words from highest to lowest recognition performance. **Relevance to the Veteran Population.** The most common complaint of veterans with hearing loss is difficulty understanding speech in background noise. A shorter word list will help clinicians rapidly evaluate patients' abilities and address their needs (e.g., hearing aids with directional microphones, frequency modulation technology, or digital signal-processing noise-reduction algorithms).

Richard H. Wilson, PhD

Issues in maintenance and repairs of wheelchairs: A pilot study

Shirley G. Fitzgerald, PhD; Diane M. Collins, PhD, OTR/L;
Rory A. Cooper, PhD; Michelle Tolerico, BS;
Annmarie Kelleher, MS, OTR/L, ATP; Peter Hunt, PhD,
MPH; Stephanie Martin, BS; Bradley Impink, BS;
Rosemarie Cooper, MPT, ATP

Purpose of the Work. An estimated 2.2 million Americans use wheelchairs for their daily mobility. The development of wheelchairs that are durable and meet the user's needs is crucial. This study assessed wheelchair durability and how this affects user satisfaction with the wheelchair. **Subjects and Procedures.** One hundred and ten people who used wheelchairs as their primary means of mobility completed a questionnaire about their wheelchairs (type, make, model), its maintenance and repair history, and their satisfaction. **Results.** Results showed that 26% had completed a wheelchair repair in the past 6 months, 16% had completed general wheelchair maintenance, and 27% had had tire repairs. Wheelchair age and hours of wheelchair use did not affect the occurrence of repairs or maintenance. The participants were generally satisfied with their wheelchairs. **Relevance to the Veteran Population.** The feedback of veteran wheelchair users is crucial to the improvement of wheelchairs and related assistive technology.

Shirley G. Fitzgerald, PhD