"The Quest for New Knowledge…"

Dear Colleagues:

Welcome to the 2nd Annual VA Rehabilitation Research and Development National Meeting. For this meeting, we chose the theme "The Next Generation" not only because the rehabilitation research community is actively engaged in training a new generation of investigators, but because, indeed, the field of rehabilitation is in the midst of moving into a new generation of care.

We are fortunate in this very young field to be able to learn from the pioneers of rehabilitation who not too long ago advocated that activity impairments did not translate into an institutionalized life. These investigators made it their business to assure that clinicians were armed with the best of adaptive strategies and technology to assist their patients realize optimal function. And thus, the rehabilitation field was born. VA is very fortunate to have those very same intrepid investigators working on behalf of veterans. We are even more fortunate that these same professionals are taking on the task of mentoring young researchers. And so, this meeting celebrates this next generation to whom we look to take advantage of the growing body of new knowledge that promises even more optimal rehabilitative care for veterans and for all persons with disabilities.

In passing on traditions, we cannot overlook the tradition of VA rehabilitation research to never accept the status quo; to always believe that we can achieve even better. Advances in medicine have ushered in a new era for rehabilitation researchers and we must be diligent in turning new knowledge into best clinical practices. For instance, we now know that in addition to adaptive strategies, it is possible to realize genuine recovery after traumatic incident. As we teach the next generation, it is also incumbent on all of us to point these investigators towards the unexplored path is of the next generation or rehabilitation research. We must energize new researchers to go on the quest for new knowledge that will bring our patients a realm of function thought impossible not more than a decade ago.

It is my hope that you will take advantage of this meeting by sharing with colleagues across disciplines, across disease states, and across geographic locals. Through this interaction, you may find ever new perspectives on disability and its sequelae, and through these new perspectives, work together to bring about the next generation or rehabilitative research.

Finally, I would like to thank all those who worked very hard to bring this year's meeting to fruition, especially Dr. Joseph Ouslander, Director of the Atlanta Rehabilitation Research and Development Center for Geriatric Rehabilitation. Dr. Ouslander and all of his team in Atlanta graciously agreed to host this year's meeting and have been diligently laboring away throughout the last year to put together what I believe will be a dynamic and inspiring meeting.

Enjoy!

Mindy L. Aisen, MD
Director, Rehabilitation Research and Development Service

Dear Colleagues,

Welcome to the 2nd National VA Rehabilitation Research and Development Service National Conference! I hope you have an enjoyable and productive time. Please use the meeting to meet new colleagues, learn about their work, and develop ideas for collaborative activities.

The staff of the Atlanta VA Center of Excellence in Geriatric Rehabilitation has greatly appreciated the opportunity and challenges of coordinating this second national meeting. We are especially thankful for the excellent assistance that we received from Bob Potts in VAHQ, who took on the task of coordinating the meeting logistics. Several individuals on our Center staff have worked especially hard on different aspects of the meeting, including: Zerry West (who processed and created a database of all the abstracts); Ron Cebulski (who fielded numerous calls and coordinated our efforts with VAHQ); Bettye Rose Connell (who helped develop the registration materials); and Bruce Blasch and Ted Denny (who put together the proceedings).

We have been fortunate to learn from the efforts of the coordinators of the first meeting, Hunter Peckham and Felix Zajac. They successfully took on the task of creating the 1st National Meeting without any precedents. Our attempts to build upon their efforts have highlighted the critical importance of two fundamental principles of rehabilitation: Teamwork and Continuous Quality Improvement (CQI).

Putting together a national meeting requires a team effort, and I thank Mindy Aisen, Bob Potts and their staff in VAHQ for their teamwork in collaboration with our Center. I hope that we have used the principles of CQI to successfully build upon the 1st meeting, and created infrastructure and procedures that can be used by Art Sherwood and the staff of the Houston Center, as well as others in the future for the 3rd National Meeting and beyond.

Enjoy the meeting, learn, and meet some new colleagues! Collaborative efforts will be critical as we move into the next century of research to improve the care of the Veteran population.

Joseph G. Ouslander, M.D.
Director, Center for Geriatric Rehabilitation, Atlanta VAMC

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Second National
Department of Veterans Affairs
Rehabilitation Research and Development
Conference:
"The Next Generation"

AGENDA

Sunday Night
February 20, 2000

6:00p – 9:00p
CONVENTION REGISTRATION

Registration/Exhibit and Poster Set-up

Monday
February 21, 2000

7:00a – 8:00a
ASSEMBLY AREA

Breakfast

8:00a – 9:00a
SALON I & II

WELCOMING REMARKS

Secretary of Veterans Affairs
The Honorable Togo West

Undersecretary for Health (Acting)
Thomas Garthwaite, MD

Chief Research and Development Officer
John R. Feussner, MD

Director, Rehabilitation Research and Development Service
Mindy L. Aisen, MD

9:00a – 9:45a
SALON I & II

PANEL DISCUSSION
"Ingredients for Success in VA Rehab R&D Career Development"

Marguerite T. Hays, MD
Career Development Review Board Chairperson

Steven Gard, PhD
Career Development Awardee

A.M. Erika Scremin, M.D.
Career Development Mentor

9:45a – 11:00a
SALON I & II

PLENARY SCIENTIFIC SESSION
Career Development Awardee Presentations

Awardee	Abstract No.
Anne Strouse Carter	C-46
Eileen Collins	A-8
Graham Creasey	S-110
Carolynn Patten	S-147
Lisa Riolo	A-28

11:00a – Noon
SALON III & IV

View Posters

SALON V & VI	View Exhibits
11:30a *ASSEMBLY AREA*	Buffet Lunch Available *(Please take your lunch to your workshop. Workshops start promptly at noon.)*
Noon – 2:00p	**WORKSHOPS**
SALON G&F	1. **Common Pitfalls in Grant Proposals and Opportunities for Funding** Coordinator: S. Fausti, Ph.D.
SALON H	2. **Rehabilitation Outcomes Research** Coordinator: D. Reker, Ph.D., R.N.
SALON J	3. **Technology Transfer in Rehabilitation Research** Coordinator: S. Sheredos
SALON K	4. **Measurement of Gait, Balance, and Falls** Coordinator: S. Wolf, Ph.D.
2:00p – 2:30p *ASSEMBLY AREA*	Break
2:30p – 3:30p	**PLENARY SESSION**
SALON I & II	**Keynote Speaker: Christopher Reeve**
	Presentation of Paul B. Magnuson Award
3:30p – 5:00p	
SALON III & IV	View Posters
SALON V & VI	View Exhibits
5:00p – 6:30p	**SPECIAL INTEREST GROUPS**
SALON F&G	Aging
SALON H	Prosthetics, Robotics and Functional Electrical Stimulation
SALON I	Sensory and Communication
SALON J	Tissue Engineering and Guided Regeneration
7:00p	**DINNER**
SALON I & II	**Keynote Speaker** **Edward Taub, Ph.D.: "*CI Therapy – A New Family of Treatments in Rehabilitation Based on Mass Practice*"**

Tuesday
February 22, 2000

7:00a – 8:30a *ASSEMBLY AREA* *SALON I & II*	Breakfast / Town Hall Meeting / Award Presentations	
8:30a – 10:00a *SALON III & IV*	View Posters	
SALON V & VI	View Exhibits	
10:00a – 11:30a	**PLENARY SCIENTIFIC SESSION**	
SALON I & II	**Awardee**	**Abstract No.**

	S. Lai *(Aging)*	A-20
	T. Bell *(Communication, Sensory and Cognitive Aids)*	C-44
	A. Patwardhan *(Prosthetics, Amputation, and Orthotics)*	P-93
	A.M. Erika Scremin *(Spinal Cord and Related Neurological Disorders)*	S-154
	R. Ruff *(Other)*	**O-191**

11:30a
ASSEMBLY AREA

Buffet Lunch Available
(Please take your lunch to your workshop. Workshops start promptly at noon.)

Noon – 2:00p

WORKSHOPS (Repeat of Monday)

SALON G&F

1. **Common Pitfalls in Grant Proposals and Opportunities for Funding**
   Coordinator: S. Fausti, Ph.D.

SALON H

2. **Rehabilitation Outcomes Research**
   Coordinator: D. Reker, Ph.D., R.N.

SALON J

3. **Technology Transfer in Rehabilitation Research**
   Coordinator: S. Sheredos

SALON K

4. **Measurement of Gait, Balance, and Falls**
   Coordinator: S. Wolf, Ph.D.

2:00p

Meeting Adjourns

CAREER DEVELOPMENT AWARDEES

Anne Strouse Carter, Ph.D.

James H. Quillen VA Medical Center

Eileen Collins, Ph.D.

Hines VA Hospital

Graham Creasey, M.D.

Louis Stokes DVA Medical Center

Margot S. Damaser, Ph.D.

Hines VA Hospital

Steven A. Gard, Ph.D.

VA Chicago Health Care System

Margaret Nield, Ph.D., R.N.

VA Greater Los Angeles Healthcare System

Carolynn Patten, Ph.D., P.T.

Rehab R&D Center of Excellence on Mobility, VA Palo Alto Health Care System

Karen L. Perell, Ph.D.

Departments of PM&R[1] and Research[2], Greater Los Angeles Healthcare System

Lisa Riolo, Ph.D., P.T.

Rehab R&D Center, Atlanta VAMC

Richard F. Weir, Ph.D.

Northwestern University Prosthetic Research Laboratory

C-46

LEXICAL EFFECTS ON DICHOTIC WORD RECOGNITION IN YOUNG AND ELDERLY LISTENERS

Anne Strouse Carter and Richard H. Wilson
James H. Quillen VA Medical Center, Mountain Home, Tennessee

Objectives: The Neighborhood Activation Model (NAM) of spoken word recognition assumes that words are recognized in the context of other similar sounding patterns in memory. Investigators have demonstrated that both the speed and accuracy of processing spoken words differ as a function of the lexical properties of the words. Moreover, the lexical properties have differential effects on word recognition performance in older and younger adults, suggesting that age-related changes in cognitive capacities might reduce the efficiency of accessing words in memory and thus contribute to the poorer word recognition ability characteristic of older listeners. This study was designed to examine the effects of age and hearing loss on dichotic word recognition within the framework of the NAM.

Method: Monosyllabic word pairs differing in the lexical properties of *neighborhood frequency* and *neighborhood density* formed the following dichotic pairings: (1) an EASY word with a HARD word, (2) a HARD word with an EASY word, (3) an EASY word with EASY word, and (4) a HARD word with HARD word. The words were presented at 70-dB HL to 24 young adults with normal hearing, 24 elderly adults with normal hearing, and 24 elderly adults with mild-to-moderate sensorineural hearing loss.

Results/Conclusions: The data for young adult listeners indicate that EASY words are recognized correctly more often than HARD words in all listening conditions. More importantly, the lexical characteristics of words have an effect on the way words are recognized dichotically. With HARD words to the left ear, and EASY words to the right ear, there is a significant right-ear advantage. With EASY words to the left ear and HARD words to the right ear, the right-ear advantage is minimal (non-significant). It is hypothesized that the differences in ear advantage may be a result of the processing of stimuli from the left ear. Data on half of the elderly subjects have been collected and indicate a similar ear pattern as well as reduced word recognition ability as compared to the young adult group and poorer word recognition for elderly listeners with mild-to-moderate SNHL as compared to those with normal hearing. Data collection and statistical analysis will be completed by December 1999.

Funding Acknowledgement: The first author is on a Career Development Award sponsored by the Rehabilitation, Research and Development Service.

Clinical Relevance: Explanations for age-related deficits in word recognition that are based on cognitive factors (i.e. the NAM), rather than the more traditional sensory factors, have important consequences when choosing rehabilitation strategies. The use of hearing aids has been the primary intervention for improving speech perception. Although this approach is successful in many cases, research focusing on more cognitive-based explanations for difficulties with word recognition suggests that a focus on sensory factors alone may have only limited clinical utility. An integrated approach incorporating both cognitive and sensory actors is likely to be of greatest benefit in designing strategies for improving speech perception in older adults.

A-8

EFFECT OF VENTILATION-FEEDBACK TRAINING ON EXERCISE PERFORMANCE IN COPD

Eileen Collins, W. Edwin Langbein, Linda Fehr, Franco Laghi, Christine Maloney, Lonnie Edwards, Eileen Hagarty, Domenic Reda, Martin Tobin

Objectives: The primary purpose of this pilot study was to begin evaluating the efficacy and feasibility of a unique program of ventilation-feedback training combined with leg-cycle, walking, and upper body strength exercise to improve exertional tolerance, perceived dyspnea and quality of life in persons with COPD.

Methodology: Four male subjects 66±8 yr of age completed the study. Average pulmonary function values were FEV_1 1.0±0.32 L, MVV 41.3±11 L/min, and FEV_1/FVC 35.2±3.6%. All participants completed symptom limited leg cycle and treadmill tests at baseline, six and 12 weeks post-training, respectively. After baseline testing each subject began a six-week interval-training program combined with ventilation-feedback on a leg-cycle ergometer followed by an additional six-weeks on a treadmill. Upper body strength training using elastic Therabands® and dumbbells was completed during the last 15 min of each session. Exercise intensity was ~85% of the individual's peak oxygen uptake. Ventilation-feedback was provided in the form of a computerized incentive system driven by inspiratory and expiratory flows. As subjects inspired and expired, they moved a horizontal bar across a computer screen hitting specified targets.

Results: Subjects' exercise duration improved by 88% and 163% on the CWR leg-cycle and treadmill tests, respectively. Similar improvements of 44% and 81% were realized with the incremental maximal cycle and treadmill tests. The Borg ratio scale was used to measure perceived dyspnea during e testing. Linear regression procedures were used to determine the slopes for the relationship between ratings of perceived dyspnea and exercise time during the CWR cycle tests for each participant. The mean dyspnea slope pre-training was 0.58 ± 0.44 and decreased to 0.23 ± 0.19 post-training ($P < 0.05$, Wilcoxon). Similarly, a 57% decrease in perceived dyspnea slope was found during CWR treadmill test (dyspnea slope pre-training 1.31 ± 1.18; and post-training 0.44 ± 0.22). Breathing frequency declined from 23.0±4.5 breaths/min at baseline to 13.8±4.4 after six-weeks of training (40% decline) and VT increased from 1.3±0.3 L to 1.9±0.6 L at six-weeks (42% increase) for the same absolute workload. The Dyspnea subscale of the CRQ showed moderate improvement (effect size = 0.78) in the three subjects (3.53±0.95 baseline; 4.27±1.17 six weeks after training).

Conclusion: In these subjects, ventilation-feedback combined with exercise training was a clinically effective method of pulmonary rehabilitation. Moreover, the improvements in exercise tolerance seen in these subjects were markedly greater than those previously reported in the literature. A randomized clinical trial is now necessary to verify the efficacy of this new innovative approach to pulmonary rehabilitation.

Clinical Relevance: Ventilation-feedback combined with exercise training may be a clinically effective method of pulmonary rehabilitation.

Funding: Rehabilitation Research & Development Career Development Award, #D1003CD

S-110

RESTORATION OF BLADDER AND BOWEL FUNCTION USING ELECTRICAL STIMULATION AFTER SPINAL CORD INJURY

Graham H. Creasey, [1]Donald R. Bodner,[1] Yoshiro Takaoka[2]
[1]Louis Stokes DVA Medical Center, Cleveland, Ohio
[2]MetroHealth Medical Center, Cleveland, Ohio

Objectives: To evaluate the effects of sacral nerve stimulation and posterior sacral rhizotomy on bladder and bowel function in human subjects with spinal cord injury.

Methods: In patients with suprasacral spinal cord injury, electrodes were implanted surgically on the sacral nerves and connected to a stimulator implanted under the skin of the chest or abdomen. The stimulator was powered and controlled by radio transmission from an external controller operated by the user. Rhizotomy of the posterior sacral nerve roots was carried out intradurally on the same occasion in all but two subjects. Bladder and bowel function were evaluated pre-operatively and at 3, 6 and 12 months follow-up, using subjects as their own controls. Micturition was evaluated urodynamically and urinary continence was evaluated by a one-month diary which also documented the occurrence, duration and techniques used for bowel evacuation. Medications, appliances, complications, costs and user satisfaction were also documented.

Results: The majority of subjects use the stimulation system routinely at home for producing micturition on demand with low residual volumes of urine and reduced urinary tract infection, and also use the system to assist with bowel evacuation. Subjects report significant reductions in urinary incontinence, autonomic dysreflexia, usage of anticholinergic medication, and usage of catheters and other appliances. Upper urinary tracts have been well preserved and complication rates have been low. Subjects use fewer suppositories, laxatives and stool softeners and the time taken for bowel care is reduced. Subjects report reduced costs of bladder and bowel care and improved satisfaction and quality of life.

The stimulation system has now received FDA approval for producing micturition on demand with reduced residual volumes of urine and for assisting with bowel function in patients with complete suprasacral spinal cord injury.

Conclusions: Electrical stimulation of the sacral nerves using an implanted neural prosthesis is a safe and effective method of producing micturition and assisting defecation in patients with suprasacral spinal cord injury. Posterior sacral rhizotomy is effective in reducing detrusor hyper-reflexia and its complications. The combination of the two techniques is projected to reduce significantly the costs of bladder and bowel care after spinal cord injury.

Funding: Rehabilitation Research and Development Service of the Department of Veterans Affairs

S-147

MOTOR UNIT FIRING PATTERNS IN POST-STROKE HEMIPARESIS

Carolynn Patten, Mark Gardner, Kevin C. McGill, Felix E. Zajac, III
Rehab R&D Center of Excellence on Mobility
VA Palo Alto Health Care System

Objectives: Stroke and resultant hemiparesis involves over 500,000 new cases in America each year and is a frequently encountered clinical problem in the VA Health Care System. A prominent characteristic of post-stroke hemiparesis is weakness. Consequently, a primary focus of rehabilitation is improvement of muscular strength and task dependent control of muscular force. To date, no particular therapeutic approach has produced superior functional outcomes. Importantly, the neuromuscular mechanisms impaired in post-stroke hemiparesis have not been well characterized. Thus, a sound, scientific basis for effective rehabilitation approaches is lacking. In an effort to develop more effective rehabilitation interventions, the aim of this research is to characterize the physiologic basis of impaired muscle function in persons with post-stroke hemiparesis.

Methods: Leg extension force and motor unit (MU) discharge activity are simultaneously measured from the vastus medialis during isometric (ISO) contractions to 40% of maximal voluntary force and during isometric contractions facilitated with either flexion (FF) or extension (FE) of the contralateral leg. Two groups of hemiparetic subjects demonstrating near complete (Brunnstrom 5-6, CVA-I) and moderate recovery (Brunnstrom 3-4, CVA-II) from hemiparesis are compared with young control subjects. Forces are obtained using strain gauge force transducers. Motor unit discharge activity is obtained using a quadrifilar needle electrode and identified using custom-written spike recognition software. MU discharge rates (MUDR) are measured and instances of recruitment and derecruitment identified

Results: For isometric contractions, CVA-II subjects demonstrate significantly higher MUDRs than control and CVA-I subjects (20 pps vs. 10 pps, $p < .05$). With contralateral flexion, control and CVA-I subjects increase ipsilateral force, primarily by recruiting additional MUs. In contrast, CVA-II subjects reduce ipsilateral force, primarily by reducing MUDR. With contralateral extension, control and CVA-I subjects reduce ipsilateral force, primarily by reducing MUDR. CVA-II subjects also reduce ipsilateral force and MUDR, but with a longer latency.

Conclusions: Results to date demonstrate remarkable impairment in force regulation mechanisms in hemiparetic individuals attributable to both supraspinal and spinal segmental levels of the neuraxis. These data will serve to identify impaired physiologic mechanisms to be targeted in future studies developing more effective rehabilitation interventions.

Acknowledgements: Department. of Veteran's Affairs – Rehab R&D Career Development Award, Foundation for Physical Therapy – NIFTI Fellowship

A-28

REDUCED USEFUL FIELD OF VIEW IN OLDER ADULTS IS EXPLAINED USING PHYSICAL PERFORMANCE MEASURES

Riolo, L. Atlanta Veterans Affairs Rehabilitation Research and Development Center, Decatur, GA 30033. Funded by VA Rehabilitation R&D C2140R and D0912.

Purpose: The purpose of this project was to determine group differences in physical performance measures to describe the contribution of visual attention as measured by useful field of view (UFOV) to mobility in older adults.

Subjects: Seventy-seven community-dwelling elders aged 70 to 89 (76 +/- 4.8) participated in the study. Each subject had a history of falling in the previous year.

Methods: Two physical measures that have been related to dependence in mobility and increased fall risk were recorded. Timed Up and Go (TUG) is the time to stand from an armchair, walk 3 meters, return to the chair, and sit. Functional Reach (FR) is the distance one is able to reach forward while standing without taking a step. UFOV was measured using the UFOV attention analyzer to describe UFOV as a percent reduction.

Analyses: Independent t-tests were performed and a Bonferroni correction was applied. A significant p value with Bonferroni correction is 0.025.

Results: Forty subjects had UFOV scores greater than 50% (70.8 +/- 12.4) and 37 subjects scored less than a 50% reduction (38.7 +/- 7.6). The two groups differed on TUG (t=2.8, 75 df, p=.006) and FR (t=-4.23, 75 df, p=.0001).

Conclusion: UFOV is a measure of visual attention comprised of a composite score of perceptual speed, divided attention, and selective attention. Ball and colleagues report that greater than 50% UFOV reduction predicts car crashes in older individuals. However, the relationship between UFOV and mobility remains unclear. The results suggest that individuals with reduced UFOV scores have limitations in mobility as measured by TUG and FR, validating UFOV as related to physical mobility.

Revelance: The interaction between cognitive processes and physical performance is important to consider in the rehabilitation of older adults with mobility limitations. Future studies will investigate using UFOV to predict falls and immobility in older individuals and the effects of UFOV training on physical performance, mobility, and fall risk.

OUTSTANDING PRESENTATION AWARDEES

S. Lai, Ph.D.

Center on Aging - University of Kansas Medical Center

(Aging)

T. Bell, Ph.D.

James H. Quillen VA Medical Center

(Communication, Sensory and Cognitive Aids)

A. Patwardhan, Ph.D.

Hines VA Hospital

(Prosthetics, Amputation, and Orthotics)

A.M. Erika Scremin, M.D.

Departments of PM&R and Research, Greater Los Angeles Healthcare System

(Spinal Cord and Related Neurological Disorders)

R. Ruff, M.D.

VA RR&D Brain Rehabilitation Center

(Other)

A-20

DEPRESSION AND STROKE RECOVERY

Sue-Min Lai, Ph.D., MBA, MS, Pamela W. Duncan Ph.D., FAPTA
John Keighley MS.
[1]Center on Aging - University of Kansas Medical Center, Kansas City, KS; [2]Center on Aging - University of Kansas Medical Center, Kansas City, KS, Department of Veteran's Administration, Kansas City, MO; [3]Department of Preventative Medicine, University of Kansas Medical Center, Kansas City, KS

Objectives: The present study was to investigate prevalence of depression after stroke and examined its effect on independence of basic and instrumental ADLs.

Methods: The Kansas City Stroke Study enrolled 459 stroke patients and prospectively assessed their stroke impact and recovery at baseline, 1, 3, and 6 months after stroke. Baseline data were evaluated within 2 weeks of stroke onset. Stroke severity was assessed by the Orpington Prognostic Scale. Depression was defined as present (Geriatric Depression Score of 6 to 15) and absent (GDS 0 to 5). Outcomes are dependency of BADL (Barthel index < 60), independence of BADL (Barthel index > 90), complete independence in preparation of meals (MEAL), getting to places (PLACE), and taking medications (MED). Logistic regression was used to examine the relationship between depression and associated outcomes.

Results: The prevalence of depression was 33% at baseline, 35%, 33 %, and 30% at 1-, 3-, and 6-month after stroke, respectively. Depression was also associated with stroke severity ($P < 0.05$). Percentages of patients that were dependent in BADL, independent in BADL, independent in PLACE, MEAL, and MED were 18%, 49%, 27%, 51%, and 50%, respectively. Patients with depression were shown to be more likely to be dependent in BADL (OR = 2.6; $p < 0.01$) and less likely to be independent in BADL (OR = 0.2; $p < 0.001$) compared to patients without depression after controlling for stroke severity. Similarly, after controlling for stroke severity, odds ratios associated with depression for independence in PLACE, MEAL, and MED were 0.2 ($p < 0.001$), 0.4 ($p < 0.001$), and 0.6 ($p = 0.03$), respectively.

Conclusions: Depression was common among stroke survivors and its occurrence did not decrease at 3-or 6-month follow-up. Depression affected both ADL and IADL recovery.

Funding and support for this research has been provided through the Rehabilitation Research and Development, Office of Research and Development, Veterans Health Administration, Department of Veterans Affairs.

C-44

RELIABILITY OF THE VETERAN AFFAIRS SENTENCE TEST (VAST)

Bell, TS[2] & Wilson, RH[1]
[1] James H. Quillen VA Medical Center Mountain Home
[2] California State University, Los Angeles

Objectives: (1) To select an appropriate presentation level (dB HL) on which to begin threshold testing using the VAST, and to evaluate the efficiency of the VAST, that is, the minimum number of trials or sentences required to maintain accuracy and reliability. (2) To assess the test-retest reliability and to determine the homogeneity of the various versions and sub-lists of the VAST protocol in terms of the obtained SRT scores. (3) To examine the effects of lexical variables, word expectancy and confusibility, on observed intelligibility. (4) To assess the influence of audiometric characteristics of the listener and linguistic background.

Methods: All sublists of the VAST were compared in a test-retest format with a one-week delay. Testing was performed in a quiet environment. Subjects ranged in age from 22 to 65 years, were native speakers of English, and all had normal hearing as defined by ≤0 dB HL from 250-4000 Hz, normal immittance measures, reflex thresholds <95 dB HL. An adaptive procedure was employed to track VAST thresholds for thirty-six subjects.

Results: Reliable speech reception thresholds can be obtained with the VAST protocol within 10 to 12 sentence presentations, with a test-retest difference of less than 3 dB-HL. Further, no significant difference across sublists of the VAST were found when lexical characteristics were controlled. Previous studies, demonstrating significant ($p < .001$) differences attributable to word usage frequency and word confusibility were replicated. High-usage words were more intelligible than low-usage words, and words in sparse neighborhoods were more intelligible than words in dense neighborhoods when overall RMS levels were equated. Additional data are currently being collected to assess the reliability of the VAST for non-native speakers of English.

Conclusion: These sentences will form the basis for a new speech recognition test that isolates significant non-acoustic sources of variation using sentence materials. The protocol will greatly improve the evaluation of speech communication in any environment, through a more efficient, reliable, and valid method.

Funding Acknowledgement: This project is supported by a Merit Review from Rehabilitation, Research and Development Service, Department of Veteran Affairs.

Clinical Relevance: These test materials are easily adaptable to an audiology environment in which precise measures of speech intelligibility are required for both aided and unaided measures of speech recognition.

P-93

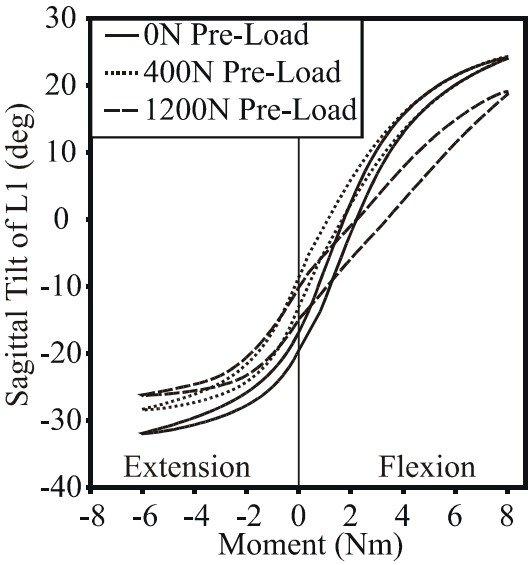
LUMBAR SPINE MOBILITY UNDER IN VIVO COMPRESSIVE LOADS

A. Patwardhan, R. Havey, A. Ghanayem, K. Meade,
G. Carandang, L. Voronov, T. Lim, VAH, Hines, Illinois

Objectives: *In vivo* compressive loads on the human lumbar spine reach 1000 N during standing and walking and exceed that level in lifting activities. In the absence of muscles, the ligamentous lumbar spine cannot support vertical compressive loads of physiologic magnitude. This has been a limiting factor in *ex vivo* testing of the whole lumbar spine under compressive pre-loads of physiologic magnitude. Patwardhan, et al. (1) showed that if the compressive load is applied along the follower load path (the path that approximates the tangent to the spinal curve), the segmental bending moments and shear forces on the mid-transverse plane of the discs are minimized. This allows the lumbar spine to support large compressive follower loads without hypermobility in a given posture. In this study we asked: "Is the increased stability of the lumbar spine under a follower load achieved at the cost of mobility?" The hypothesis was that a compressive follower pre-load does not affect the neutral zone and range of motion of the lumbar spine in flexion and extension.

Methods: The neutral zone (NZ), range of motion (ROM), and stiffness of healthy human lumbar spines (L1-sacrum) were determined in flexion-extension under compressive follower pre-loads of up to 1200 N which covers a significant portion of the physiologic compressive pre-load on the lumbar spine. A compressive follower pre-load was applied to the specimen bilaterally using cables and dead weights. The cables were attached to L1 and passed through cable guides secured to L2-S1. The specimen was tested first under zero follower pre-load by applying three complete cycles of flexion-extension moments (0-8 Nm flx-0-6 Nm ext-0). The change in L1-S1 sagittal angle was continuously recorded. This protocol was repeated with follower pre-loads of up to 1200 N.

Results: The load-displacement curve underwent a gradual change from a nonlinear to a linear curve with increasing follower pre-load magnitude. The flexion/extension stiffness of the spine increased as the compressive follower pre-load increased. The range of motion decreased with increasing follower pre-load magnitude. However, at 1,200 N follower pre-load the ROM decreased by only 24%; from a mean of 52 degrees to 39 degrees. The neutral zone was not significantly affected at 1200 N follower pre-load magnitude.



Conclusions: We believe the follower load path represents the overall effect of muscles that stabilize the spine and allow it to support compressive loads of physiologic magnitude throughout the range of motion in a dynamic task. This is in sharp contrast to previous studies that noted nearly 90% decrease in the segmental ROM and NZ under simulated actions of selected muscles. This study provides an explanation of how muscles can stabilize the lumbar spine in lifting tasks that induce large compressive loads while bending forward. It offers a new experimental technique to test the effects of spinal implants on the response of the lumbar spine under realistic *in vivo* loads.

References: Patwardhan et al., Spine 1999; 24:1003-1009.

Acknowledgment: VA RR&D Grants A2219RA and A2259RA.

S-154

FUNCTIONAL ELECTRICAL STIMULATION INDUCED CYCLING DECREASES THE AMPLITUDE OF THE TIBIAL H-REFLEX

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Objectives: This Study tested the hypothesis that functional electrical stimulation induced lower extremity cycling (FESILEC) could attenuate the tibial H-Reflex, an index of spasticity.

Research Plan: H-Reflex waves amplitude and duration were measured under standardized conditions in six men with chronic spasticity of moderate to severe degree (Ashworth scale= 2-4) resulting from a traumatic spinal cord injury. Measurements were performed just before and within 1 hr after a FESILEC session of 30 min duration and on a control condition consisting of subjects seating on the ergometer with stimulating electrodes and bracing in place but without actual stimulation. Measurements were taken on three sessions over eight week intervals.

Methods: FESILEC was performed on a REGYS I computer-controlled FES cycle ergometer (Advanced Technologies Inc.). H-Reflex was recorded from electrodes placed over the soleus muscle, midpoint between the popliteal crease and the rostral flare of the medial malleolus. Stimulating electrodes were placed over the popliteal crease overlying the tibial nerve (cathode) and 2 cm proximal to it (anode). Skin temperature of the popliteal fossa was measured with a hand-held infrared temperature scanner. Means of base to peak (BP), peak to peak (PP) and through to peak (TP) amplitudes of the H-reflex waveform were calculated for the conditions before and after FESILEC. Analysis of variance and contrasts between means (Student's test, 2 tailed) were performed. Statistical significance was declared for $P<0.05$.

Results: FESILEC induced a statistically significant decrease in all parameters of the H-reflex waveforms (mV, Mean ± S.E.); Before FESILEC: BP= 3.55±0.32, PP= 4.53±0.36, TP= 5.54±0.36; After FESILEC: BP=2.73±0.21, PP=3.13±0.22, TP= 4.39±0.36. H-Reflex latency decreased after FESILEC (Difference before-after FESILEC, = 1.29±0.13 msec, $P<0.0001$) but not after the control condition (0.07±0.069, P= n.s.). Further analysis indicated that H-Reflex latency co-varied with popliteal fossa temperature (ANCOVA F= 7.51 $P<0.01$).

Conclusions: FESILEC reduced the amplitude of the tibial H-Reflex, an index of spasticity. The decrease in reflex latency observed with FESILEC is most likely a consequence of enhanced nerve conduction velocity induced by the temperature increase in the lower extremity associated with muscle work.

Clinical Significance: FESILEC might be of help for SCI patients when spasticity is detrimental to rehabilitation. This issue is important to the VA Healthcare System due to the prevalence of spinal cord disease patients. The ability of FESILEC to reduce spasticity over longer periods of time needs to be explored.

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O-191

INTRAMUSCULAR FUNCTIONAL NEUROMUSCULAR STIMULATION (FNS-IM) TREATMENT OF IMPAIRED GAIT IN CHRONIC STROKE PATIENTS

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Background: Stroke is the third leading cause of disability for adults in the United States. There are 500,000 individuals each year who suffer a new stroke and 1,000,000 individuals in the United States are suffering with residual disabilities from strokes. To date, rehabilitation techniques have not proven sufficient to restore normal, safe, gait for many individuals with stroke. FNS-IM is an experimental rehabilitation technique that directly stimulates muscles under computer control to produce functional activity. FNS-IM has been used for 10 years for rehabilitating spinal cord injured patients, but FNS-IM has not been used extensively for gait rehabilitation of stroke patients.

Methods: We studied 8 gait-impaired patients 1 year after stroke onset, which is beyond the time when patients spontaneously recover function. Patients were treated sequentially with conventional rehabilitation (CR) followed by FNS-IM, with each technique applied until a patient achieved a maximum benefit. Patients reached a plateau for lower extremity motor function within 3 months of CR treatment. FNS-IM was applied to 8 paretic lower extremity muscles. With FNS-IM, patients reached a stable plateau within 6- 8 months. FNS electrodes were removed at the end of FNS-IM gait training. Patients were examined at 6 months after electrode removal. Outcome measures (done with FNS off) included kinematics of voluntary gait, Fugl-Meyer index and the motor subscore of the FIM (FIM-M).

Results: Patients tolerated the FNS-IM treatment well. We designed stimulation paradigms that minimized discomfort associated with electrical stimulation of a leg with preserved sensation. Monolimb stimulation, using the FNS protocols we developed, did not increase cardiac output above that of volitional activity. With CR each patient improved in some aspects of gait kinematics. In contrast, each patient improved with FNS-IM in gait kinematics beyond that attained with CR. Improvements in gait kinematics achieved with FNS-IM compared with CR include: knee flexion at toe-off increased from 15±5 to 39±4, peak-swing phase knee flexion improved from 22±7 to 49±10, ankle dorsiflexion at heel strike increased from 2±2 to 19±4, peak swing phase ankle dorsiflexion increased from 2±3 to 20±5, knee extension at heel strike decreased from 22±4 to 2±1 and knee wobble in stance phase decreased from 11±4 to 1±1 (all were $p<0.001$). The Fugl-Meyer score improved by 8.1±6.4 during conventional rehabilitation and 25.2±5.1 ($p<0.001$) during FNS-IM treatment. FIM-M improved by 5.3 ±3 during conventional therapy to 53.1 ±6.1. With FNS-IM, FIM-M further improved to 64.9 ±6.8 ($p<0.01$). Functional gains persisted after removing the FNS-IM electrodes including advancement from wheelchair use to walking from car to restaurants, malls or medical appointments (i.e., walking independently 1 block).

Conclusions: 1) FNS-IM can be used in stroke patients without discomfort or excessive increases in cardiac output. 2) FNS is a useful stroke rehabilitation technique that can restore voluntary gait function beyond that attained by spontaneous recovery and conventional rehabilitation. 3) The improved gait persists after completion of FNS-IM treatment. 4) FNS-IM is a promising rehabilitation tool for veterans with gait disorders due to stroke.

Funding Source: The Office of Research and Development, Medical Research Service of the Department of Veterans Affairs

AGING

Abstract
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A-1

MOTOR UNIT FIRING BEHAVIOR IN THE VASTUS LATERALIS MUSCLE

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Objectives: This study is part of a larger project investigating the effects of exercise on elderly individuals. That project was motivated by reports in literature suggesting that neural factors play a more significant role than hypertrophy in the strength gains that the elderly derive from exercise. Previously, we observed significant differences in the neural control of muscles in young and elderly subjects. We hypothesize that these altered neural control patterns in the elderly may be moved closer to those in the young through exercise. An investigation of the effects of exercise on muscle control in the elderly will elucidate the mechanisms involved thus enabling more enlightened prescription of rehabilitation and training regimens. We chose to investigate the Vastus Lateralis (VL) in the exercise study, since this muscle crucial to the performance of daily activities such as stair climbing or getting up from a chair.

In young healthy adults the behavior of motor unit firings in small, distal limb muscles such as the First Dorsal Interosseous (FDI), have been contrasted from larger, proximal muscles such as the deltoid and the trapezius. Latter exhibit recruitment of motor units over the whole force range with relatively low firing rates, while in the FDI, recruitment tends to be completed at 50% of the maximum voluntary contraction force and motor units reach higher mean firing rates. The reduced dynamic range of firing rates in the proximal muscles may be due to stronger recurrent inhibition of the Renshaw system which has been shown to be more prominent in these muscles. Common to all these muscles is the phenomenon of common drive, the finding that firing rates of concurrently active motor units fluctuate in unison and are not controlled independently. The current study is aimed at establishing the control properties of motor units in the VL of young subjects in order to allow a baseline comparison with data from elderly subjects.

Methods: The firing patterns of motor units in the VL were studied in healthy young subjects during a voluntary isometric knee extension task. The task involved short duration contractions at several submaximal force levels. Intramuscular electromyographic (EMG) signals were detected using fine wire electrodes. Surface EMG signals and knee joint torque were also recorded. The Precision Decomposition Technique was used to identify firing times of motor units. The recruitment thresholds, mean firing rates, and the correlation among the firing rates of motor units were investigated in relation to the force output of the muscle.

Results: Preliminary results show that the mean firing rates of motor units in the VL are lower and exhibit smaller dynamic ranges when compared to the those in the FDI. Furthermore, common drive is present but less pronounced than in the small hand muscle.

Conclusions: The observation of relatively low mean firing rates agrees well with evidence of recurrent inhibition among quadriceps motor units. Motor unit firing behavior in the VL appears similar to that of a postural muscle such as the trapezius.

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A-2

TASK-SPECIFIC RESISTANCE TRAINING TO IMPROVE TRANSFERS

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Background: Difficulty in transferring, moving into and out of a bed or chair, is a common problem in older adults, affecting 6-8% of non-institutionalized and over 63% of institutionalized adults aged 65 or over. In our previous biomechanical studies, we found that key movement strategies of the arms, legs, and trunk contribute to rising from a chair. We adapted these strategies into a series of task-specific movements used to rise from a bed and chair (such as scooting to the edge of the chair), adding a resistance training component to improve chair and bed rise ability. Few controlled studies have examined transfer training.

Objective: To train mobility-impaired older adults to improve bed and chair rise ability

Hypothesis: Task-specific resistance training can improve the ability of mobility-impaired older adults to rise from a bed and from a chair, over a twelve-week intervention period.

Subjects: Independent congregate housing residents in southeastern Michigan aged ≥65 with self-reported disability (requiring assistance of a person or device) in one of four mobility-related ADL tasks (transferring, walking, toileting, or bathing) were eligible to participate. Based on a computer program, 161 eligible residents were allocated to either training or control groups in order to minimize group differences in: gender (85% female in both groups), mean age (82 years in both groups); percent with self-reported transfer difficulty (42% in both groups); and mean number of ADL disabilities (2.7 in both groups). Drop-out rate by 12 weeks was 26% for training and 20% for the controls.

Methods: *Assessments:* At baseline and at 12 weeks, subjects performed chair and bed rise tasks of graded difficulty based on varying the bed height and chair seat height, and based on the use of arms to facilitate rising. Outcomes were able or unable to rise, and if able, the time taken to rise. *Interventions:* The training group received individualized training in bed and chair rise sub-tasks (such as practicing scooting to the edge of a chair), with addition of a weighted vest, waist belt, or ankle belt. The controls underwent a chair-based flexibility program. Both groups met three times weekly for one-hour sessions for 12 weeks.

Results and Conclusions: Results from performance on four tasks are discussed below: supine to sit at the edge of the bed with head of bed flat (SSEFLAT); sitting up in bed without use of hands with head of bed at 30 degrees (SSNH30); rising from a chair with the seat at 100% of floor to knee height while using hands on the armrests (100%H) or without use of hands (100%NH). No disproportionate group differences over 12-weeks were seen in rise ability across all four tasks. Mean (sd) time to complete the four tasks appears below:

	Baseline	12 weeks		Baseline	12 weeks
SSEFLAT			*100%H*		
Training	6.7 (3.9)	7.7 (10.2)	Training	3.6 (4.2)	2.1 (1.1)[a]
Controls	6.7 (3.5)	6.7 (3.1)	Controls	3.6 (2.6)	3.3 (1.7)
SSNH30			*100%NH*		
Training	3.0 (2.2)	2.2 (1.2)[a]	Training	4.5 (3.1)	4.3 (3.5)[b]
Controls	2.6 (1.3)	2.5 (1.0)	Controls	4.3 (3.5)	4.8 (4.5)

Controlling for baseline and using log time for analysis, a greater reduction in rise time was seen in training versus controls ([a]$p<0.003$, [b]$p<0.03$). We conclude that task-specific training can improve the ability of mobility-impaired older adults to rise from a bed and chair, specifically in time taken to rise. Task-specific training may be adapted to enhance transfers in other disabled older adult populations. *Supported by DVA Rehab R&D and NIA AG08808.*

A-3

MECHANOBIOLOGY IN THE REPAIR AND REHABILITATION OF ARTICULAR CARTILAGE DEFECTS

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Objectives: Arthritis affects more than 21 million Americans, including millions of veterans. Focal arthritic defects are the target of a number of new techniques aimed at repair or regeneration. Techniques under development involve the use of growth factors, tissue engineering (autologous cell impregnated scaffolds) and periosteal/perichondral explants. Several of these techniques provide a source of pluripotential cells within the defect capable of differentiating into bone, cartilage, or fibrocartilage. The differentiation process and the resulting tissue phenotype are regulated by biochemical factors as well as local mechanical cues. The objective of this study is to examine the role of mechanobiology in the physical rehabilitation of articular cartilage.

Methods: In this study we created finite element models of an idealized joint both with and without an osteochondral defect. The surface of the joint was exposed to a sweeping pressure load representing an articulating joint during flexion and extension motion. The stress and strain distributions within the defect were examined in the context of a tissue differentiation theory used previously to study fracture healing[1], distraction osteogenesis[2], and implant fixation[3].

Results: When the joint load passes over the defect region, the tissue throughout the defect experiences hydrostatic pressure that is similar in magnitude to that experienced by the adjacent undamaged cartilage. Although this stimulus is expected to be chondrogenic, the repair tissue may not have adequate initial strength to support the stresses associated with full weight bearing. In addition, due to the material property difference between regenerating tissue and the surrounding cartilage, high tensile (and distortional) strains are generated in the defect tissue that are not present in normal cartilage. According to our tissue differentiation theory these tensile strains are expected to promote fibrocartilage, rather than articular cartilage, development.

Conclusions: The predictions from this model are consistent with the results of numerous studies in animals and humans. Due to differences in tissue stiffness between the healthy cartilage and the regenerating tissue abnormal tensile and distortional strains are created at the interfaces of the two materials. This mechanical situation is problematic since not only will this encourage fibrous tissue formation in the defect, but elevated levels of octahedral shear stresses (and distortional strains) will be created in the adjacent cartilage. These octahedral shear stresses will tend to accelerate the degenerative process in the healthy adjacent cartilage. The study provides new insights into the role of mechanobiology in the repair of focal cartilage defects. These insights will influence the design of novel physical and biological techniques for the repair of articular cartilage defects leading to improved long-term clinical outcomes.

References: 1) Carter et al., J Orthop Res 6:736-748, 1988; 2) Carter et al., Clin Orthop & Rel Res 355S:S41-S55, 1998; Giori et al., J Arthro 10:514-522, 1995.

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A-4

COMPARISON OF OLDER ADULTS AND EXPERTS ON RANKING OF EXERCISE DETERMINANTS

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Objectives: Factors that influence exercise initiation and adherence have been described in terms of an elder's knowledge, attitudes and beliefs (KAB) about exercise. KAB determinants of behavior include: health benefits, exercise knowledge, perceived health, body image, perceived access to facilities, intent to be physically active, perceived exertion, perception of available time, and enjoyment. The purpose of the study was to establish the importance of exercise determinants in elders and to determine the congruence between exercise experts (E) and older adults (OA) on prioritization of determinants.

Methods: Experts were drawn from the fields of geriatrics, wellness, nursing, and rehabilitation medicine specialists. OA (n=62, age range 55-85) participating in a strength training program volunteered for this study. They used the same scale as the E and ranked the determinants for importance in influencing both initiation and maintenance of exercise behavior. A scale from 1 to 10 was used for the rankings, and descriptive statistics and Spearman rank correlation were used to analyze the data.

Results: No statistically significant correlation was found between the OA and E on total rankings of the determinants. For initiation of exercise behaviors, E and OA agreed on approximately 60% of the top three determinants with OA ranking health benefits and E ranking intent to be physically active as most important. For maintenance of exercise, 33% agreement was found in the three determinants ranked most important, with OA ranking health benefits and E ranking enjoyment as the most important.

Conclusions: These results suggest that OA are consistently concerned with health benefits of exercise and that OA and E may differ in perceived importance of KAB determinants of exercise. These data convey the importance of individually tailored approaches to foster exercise behavior in elders.

Clinical Relevance: The effort to understand how to promote more active lifestyles is of great importance to the health of this nation. Health care settings such as the VA hospitals offer a unique opportunity to counsel older adults about exercise as well as other healthful behaviors. When promoting exercise amongst elders, it is important to know what factors influence their decisions in starting and maintaining an exercise program so health providers can tailor the exercise plan around these needs. Funded by Rehabilitation Research & Development Service, Department of Veterans Affairs Project # E825-RA.

A-5

EFFECTS OF A 12-MONTH RESISTIVE TRAINING INTERVENTION ON STRENGTH IN OLDER MALES AND FEMALES

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This study was designed to evaluate the effects of a 12-month resistive training program on older males and females. Thirty older volunteers (mean age 71.6 years; 25 females and 5 males) served as exercise subjects (ES). The ES strength trained 3 times a week, an hour a day for the first 6 months and 2 days a week the last 6 months. The subjects trained at 50%, 60% and 70% of their one repetition maximum (1RM). The training sessions consisted of 50 minutes of resistive training and 10 minutes of cool-down and flexibility exercises. The subjects trained 5 upper extremity, 3 trunk and 3 lower extremity muscle groups on a multi-station Nautilus system. To begin, exercise subjects were evaluated every 4 weeks and again at 6-months for 1RM strength and resistance was adjusted to insure that the work was equal to the desired percent of maximal strength. The data were analyzed using descriptive statistics, percentiles and ANOVA. The results show that both male and female ES increased upper extremity, trunk, lower extremity and total body strength significantly during the first 6 months and maintained strength from 6 to 12 months. The largest increase for both genders was for lower extremity strength, with the females increasing 37% and the males 27%. Trunk increased the least (15%) for the females and upper extremity increased the least (18%) for the males. The rate of strength increases for the males were generally similar for upper extremity, trunk and total body as the increases were within 2% of each other. The rate of strength increases for the different body segments of the females was not similar as there was at least a 5% difference between the rates for all body segments. Although, the specific responses of the different segments of the body to resistive training are different based on gender, these data illustrate that older males and females receive significant strength benefits from a moderate intensity 12-month resistive training intervention. These data further suggest that three days a week provide strength gains and two days a week insure strength maintenance in both males and females.

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CHRONIC INACTIVITY AND BONE DENSITY IN ELDERLY VETERANS IN LONG-TERM INPATIENT REHABILITATION

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Objectives: Bone loss, characterized by a decrease in bone mineral content (BMC), appears to be part of the aging process in healthy as well as disabled persons. Chronic physical inactivity, bed rest or immobilization accompanies and even exacerbates this loss. BMC, an indicator of peak bone mass, is the absolute amount of mineral in bone or in bone and reflects bone density. A paucity of research exists to determine whether veterans with disabilities such as paralyses, amputation, or other chronic conditions that lead to extended periods of inactivity are at greater risk for loss for BMC or decreases in bone density, which in turn, lead to increased risk of localized osteoporotic fractures and other debilitating conditions.

Methods: Twenty elderly male veterans (age ± 75) admitted for long-term in-patient rehabilitation at the Houston VAMC were recruited as subjects. BMC was measured bilaterally using dual-energy X-ray absorptiometry (DEXA) on arms, legs, trunk sides and total body upon entrance into the study and three months later. Differences in BMC in affected vs. non-affected limbs as well as in total body over time were determined for each subject.

Results: Preliminary analyses show the average 3-month loss of BMC in the arms, legs, trunk, and total body to be 4%, 8%, 2.2% and 1% respectively. In stroke patients, a greater loss of BMC was found to exist in affected limbs compared to non-affected limbs (13.2% vs. 2.2% respectively). However, in all patients, loss of BMC occurred at a greater rate in upper extremities (6.7%) compared to trunk (3.3%) or leg (2.4%).

Conclusions: Loss of BMC was found to occur over time in elderly veterans in long-term in-patient rehabilitation, and this loss was greatest in limbs rendered inactive by clinical conditions. Patients in long-term in-patient rehabilitation should be considered at highest risk for osteoporotic fractures and falls. Further data are needed to confirm this observation. Nonetheless, interventions such as strength training programs and encouragement toward increased physical activity should be implemented as part of the rehabilitation process in all patients in our services.

Clinical Relevance: Immobility is a common problem for hospitalized older adults. Excessive bed rest results in multiple adverse physiologic consequences such as bone loss, which may contribute to functional decline, poor mobility, or increased risk for falls. It is commonly accepted that inactive lifestyles compound the effects of disability and make this a major public health issue. Long-term effects of inactivity among veterans with disabilities are a legitimate concern for the VA Medical System. Future research should include physical activity interventions to provide protection against these conditions by retarding further bone loss, increasing bone strength, and preventing other debilitating bone related conditions.

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A-7

ACCELEROMETRIC ANALYSIS OF WHEELCHAIR/CAR TRANSFER STRATEGIES FOR INDIVIDUALS WITH SPINAL CORD INJURIES

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Objectives: The objective of this pilot study was to investigate car-to-wheelchair transfer motion patterns as a risk factor for long bone fractures in the spinal cord injured (SCI) population. Fracture of the insensate osteopenic limb is a serious problem, with car-to-wheelchair transfers accounting for nearly 25% of lower limb fractures in this population.

Methods: Experimentation was performed in a motion analysis lab, using six healthy non-SCI individuals. Due to time and safety concerns, non-SCI subjects simulated transfers between a fixed car seat and a wheelchair for this study, emulating videotaped performance by three SCI subjects. Video images and 3-axis accelerometric data were recorded at four locations along the left side of the subject's body. The following comparisons were made between transfer strategies: feet-first vs. body-first, transfers involving multiple stages vs. one-movement transfers, and "safe" vs. "dangerous" transfers. The latter simulated inadvertant catching of the foot on the car door rim or wheelchair footrest. Comparisons were based on vector magnitude and body segment angle derived from accelerometric data. Tibial torsion load was estimated from the difference in axial rotation between proximal and distal tibial sensor sites.

Results: It was determined that transferring the body in multiple stages is safer than transferring in one movement, based on the criterion of minimum area under the peak acceleration magnitude curve (equivalent to velocity). Feet-first transfers have approximately the same peak accelerations and tibial torsion as body-first transfers, implying that feet-first transfers are as safe as body-first transfers. Catching or holding the foot during body transfer resulted in a torsional load on the tibia, which may put the transferee at increased risk for fracture. Differences in height between car seat and wheelchair of less than 4 inches had no effect on peak acceleration, but resulted in more small peaks due to additional shifting of weight prior to transfer and prolonged time to completion.

Conclusions: By gaining a greater appreciation for accelerations and torques that occur during car-to-wheelchair transfers, safety of various strategies may begin to be quantified. This preliminary study should be extended to include actual instead of simulated SCI subjects and vehicles.

Clinical Relevance: Accelerometric motion analysis may be a useful tool for reducing risk of lower limb fractures by optimizing safe transfer techniques, by providing feedback to transferees while learning transfer methods, and by identifying person- or vehicle-specific risk factors.

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A-8

EFFECT OF VENTILATION-FEEDBACK TRAINING ON EXERCISE PERFORMANCE IN COPD

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Objectives: The primary purpose of this pilot study was to begin evaluating the efficacy and feasibility of a unique program of ventilation-feedback training combined with leg-cycle, walking, and upper body strength exercise to improve exertional tolerance, perceived dyspnea and quality of life in persons with COPD.

Methodology: Four male subjects 66±8 yr of age completed the study. Average pulmonary function values were FEV_1 1.0±0.32 L, MVV 41.3±11 L/min, and FEV_1/FVC 35.2±3.6%. All participants completed symptom limited leg cycle and treadmill tests at baseline, six and 12 weeks post-training, respectively. After baseline testing each subject began a six-week interval-training program combined with ventilation-feedback on a leg-cycle ergometer followed by an additional six-weeks on a treadmill. Upper body strength training using elastic Therabands® and dumbbells was completed during the last 15 min of each session. Exercise intensity was ~85% of the individual's peak oxygen uptake. Ventilation-feedback was provided in the form of a computerized incentive system driven by inspiratory and expiratory flows. As subjects inspired and expired, they moved a horizontal bar across a computer screen hitting specified targets.

Results: Subjects' exercise duration improved by 88% and 163% on the CWR leg-cycle and treadmill tests, respectively. Similar improvements of 44% and 81% were realized with the incremental maximal cycle and treadmill tests. The Borg ratio scale was used to measure perceived dyspnea during e testing. Linear regression procedures were used to determine the slopes for the relationship between ratings of perceived dyspnea and exercise time during the CWR cycle tests for each participant. The mean dyspnea slope pre-training was 0.58 ± 0.44 and decreased to 0.23 ± 0.19 post-training ($P < 0.05$, Wilcoxon). Similarly, a 57% decrease in perceived dyspnea slope was found during CWR treadmill test (dyspnea slope pre-training 1.31 ± 1.18; and post-training 0.44 ± 0.22). Breathing frequency declined from 23.0±4.5 breaths/min at baseline to 13.8±4.4 after six-weeks of training (40% decline) and VT increased from 1.3±0.3 L to 1.9±0.6 L at six-weeks (42% increase) for the same absolute workload. The Dyspnea subscale of the CRQ showed moderate improvement (effect size = 0.78) in the three subjects (3.53±0.95 baseline; 4.27±1.17 six weeks after training).

Conclusion: In these subjects, ventilation-feedback combined with exercise training was a clinically effective method of pulmonary rehabilitation. Moreover, the improvements in exercise tolerance seen in these subjects were markedly greater than those previously reported in the literature. A randomized clinical trial is now necessary to verify the efficacy of this new innovative approach to pulmonary rehabilitation.

Clinical Relevance: Ventilation-feedback combined with exercise training may be a clinically effective method of pulmonary rehabilitation.

Funding: Rehabilitation Research & Development Career Development Award, #D1003CD

A-9

OPPORTUNITIES TO PROMOTE INDEPENDENCE AMONG DEMENTED NH RESIDENTS

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Objectives: In 1990, there were 400,000 cases of dementia among veterans with an addition of 50,000 new cases annually. In the face of a growing population of aging veterans, the prevalence and incidence estimates of dementia are also expected to increase. By 2000, there are expected to be 600,000 existing cases of veterans with dementia with the addition of 100,000 new cases annually. The purpose of this study was to lay the ground work for a randomized clinical trial to evaluate environmental interventions to promote independence and reduce behavior disturbance in demented NH residents with vision loss. Specific objectives were: (1) describe the independent and interactive effects of cognitive and vision impairment on functioning and behavior disturbance in demented NH residents; and (2) identify environmental interventions that are potentially effective in reducing excess disability in NH residents with both dementia and vision loss.

Methods: Data collection included clinical testing to characterize cognitive and vision status and nurse ratings of behavior and daily functioning. A cascade testing approach enabled us to assess acuity and contrast sensitivity with severely demented subjects. Quantitative analyses were used to describe the relationship of cognitive and vision status to disruptive behavior, mobility, and dependence in activities of daily living (ADL). Staff's observations about interventions that may reduce excess disability in patients with co-existing dementia and vision loss were identified using small group techniques. The study was conducted at 4 VA NHCUs and 1 non-VA SNF in North Carolina and Georgia. The final sample consisted of 146 subjects.

Results: The sample was severely demented (mean MMSE <13) and many were vision impaired (mean acuity worse than 20/100). Vision and cognitive status were independently related to ADL functioning, but cognitive status had a more profound effect on ADL dependence. Contrary to expectations, we found only limited relationships between vision and behavior disturbance. Overall, the relationships between cognition, vision, behavior, and function were not as strong as predicted, suggesting there are other important determinants affecting these relationships, such as the possible effects of environmental conditions and care approaches. Staff recommended environmental interventions that compensate for cognitive deficits (cue wayfinding and orientation) as well as vision deficits (better lighting, improved contrast, less glare).

Conclusions: Aggressive behavior and catastrophic reactions often occur in conjunction with daily care and may be associated with having to interpret helping behaviors of staff. Thus, ADL independence is seen as a set of abilities that, if preserved, could be used to reduce aversive stimuli from care-giving, in turn, reducing the likelihood of behavior disturbance. Environmental interventions are an appealing but untested strategy for promoting independence among demented NH residents. Such interventions need to be targeted to multiple deficits and coupled with staff training on care practices that promote independence among individuals with dementia.

Project #E2044-2R, Rehabilitation Research Service, Department of Veterans Affairs, Washington, DC.

A-10

READING BETWEEN THE LINES: A QUALITATIVE ANALYSIS OF QUANTITATIVE DATA FROM SHOULDER FUNCTION SCALES

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Objectives: The purposes of this study were to: (1) analyze respondents' unsolicited, written comments on four, closed-ended scales of shoulder function and (2) compare the qualitative findings with the results of a Rasch analysis of the quantitative data.

Methods: 190 patients completed the American Shoulder and Elbow Surgeons Patient Self-Evaluation Form (ASES-f), the disability subscale of the Shoulder Pain and Disability Index (SPADI-d) the Simple Shoulder Test (SST), and the function subscale of the University of Pennsylvania (UPenn-f) scale. Unsolicited written comments were analyzed using qualitative methods. Quantitative responses were calibrated using a Rasch model, an approach in which scores are obtained based on a probability function. Model fit statistics were calculated.

Results: Though none of the scales provided space for respondent comments, 41% wrote remarks or made special marks (e.g., question marks, circling words); 47% skipped items. Some comments were an apparent effort to provide context for item responses (e.g., "Now complaint is with RIGHT [shoulder]. Will answer quest[ions] based on right . . ."), but most comments referenced specific items. The item most referenced was the ASES-f item, "Reach behind back, fasten bra." Nine persons, all male, added comments or marks to this item including writing "N/A" by the item and circling "bra" and writing, "DO NOT USE." UPA-f items that provided a list of examples (e.g., "throw overhand, swim, or racquet sports") initiated participants circling or crossing out elements in the list to specify a single activity. This is consistent with previous research showing such lists threaten the validity of a measure since persons may experience difficulty with one, but not all activities. The scale that drew the most comments was the SST. The SST offers only two response options (yes/no). Respondents showed apparent discomfort with the dichotomous format by: (1) circling the space between "yes" and "no", (2) writing in a qualifying phrase (e.g. "with pain"), (3) omitting items, and (4) writing "?" by items. Generally, the qualitative findings were supported by the Rasch analysis. For example, the item, "Reach behind back, fasten bra" was identified in the Rasch analysis as a misfitting item. However, the Rasch analysis failed to flag some problem items.

Conclusions: Researchers analyze quantitative data after it is in a database, thus missing valuable information in respondents' unsolicited comments and markings. Participants express their discomfort with item content or format in a variety of ways, including: (1) adding clarifying remarks, (2) skipping items, and (3) creating an additional response category. Quantitative methods may not identify all problematic items. Construction of self-report measures should include interviews with participants ***pre-*** as well as ***post-***instrument development. Clinicians and researchers wanting to use such measures should evaluate whether the item content and format is appropriate for their clinical population. Such evaluation is particularly important in VA with its emphasis on patient-centered outcomes.

This study is part of a project funded by VA HSR&D [*Development of a Flexilevel Scale of Shoulder Functioning (IIR 98-077-1)*].

A-11

DEVELOPMENT OF MODELS OF STRESS URINARY INCONTINENCE

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Objectives. Stress Urinary Incontinence (SUI) is a common debilitating condition of the elderly, who constitute a high proportion of the Veteran population. Two possible causes of SUI are pudendal nerve injury and tissue damage secondary to vaginal distension in childbirth. Leak Point Pressure (LPP) measurement is the standard clinical method of diagnosing SUI. However, decreased LPP due to either vaginal distension or pudendal nerve injury has not been demonstrated directly. The objective of this study was to determine if either pudendal nerve injury or vaginal distension causes SUI in female rats.

Methods. The pudendal nerve was crushed bilaterally in 12 virgin female rats by closing a Castroviejo needle holder over the nerve twice for 30 seconds duration. In a second group of 18 virgin rats, the vagina was distended to 3 ml for 30 minutes with a 10Fr. Foley catheter with the tip cut off. Seventeen age-matched female rats were used as unoperated controls. Two or 14 days after the initial surgery, a catheter was implanted in the dome of the bladder. Two days later (4 or 16 days after initial surgery) the animals underwent LPP testing as follows. The animals were urethane-anesthetized and the bladder catheter was connected to both a syringe pump and a pressure transducer via a stopcock. The bladder was emptied, then filled via the catheter with room temperature saline at 5ml/hr. When the contained volume reached 0.5ml, the abdomen was slowly depressed while bladder pressure was measured through the catheter. As soon as urine leaked out the urethra, the pressure on the abdomen was removed. The peak pressure was used as LPP. Nerve, urethra, and vaginal tissues were dissected and prepared for light microscopic analysis.

Results. LPP was significantly increased four days after either pudendal nerve crush (29.3 ± 3.4 cmH_2O) or vaginal distension (31.0 ± 2.5 cmH_2O), when compared to control LPP (42.7 ± 3.1 cmH_2O). Sixteen days after vaginal distension, LPP (41.7 ± 5.2 cmH_2O) returned to control values and was no longer significantly different. Sixteen days after pudendal nerve crush, LPP (31.2 ± 7.5 cmH_2O) was lower than control values but not significantly different. Light microscopic examination revealed nerve injury and degeneration in the pudendal nerve crush group. Signs of nerve injury and trauma to the vagina and urethra were present in the vaginal distension group. No vaginal, urethral, or nerve injury was observed in the controls.

Conclusions. Pudendal nerve injury and vaginal distension cause decreased LPP and create SUI in female rats. Both models could be used to develop novel rehabilitation protocols and medical treatments for SUI. This will improve functional recovery of SUI and enhance the healthcare of elderly Veterans.

Funding. This project was funded by Veterans Administration, RR&D Service, Grant no. B2159PA and a VA Advanced Rehabilitation R&D Career Development Award to MSD.

A-12

ARE THE FUNCTIONAL INDEPENDENCE MEASURE MOTOR SCALE AND BARTHEL INDEX RESPONSIVE TO STROKE RECOVERY?

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Objective: Two disability outcome measures frequently used to assess the effects of interventions on recovery from stroke are the motor subscale of the Functional Independence Measure (FIM) and the Barthel Index (BI). The need to demonstrate the responsiveness of these measures to change is widely recognized, but no consensus has been reached on best measures of responsiveness. This study compared multiple measures of responsiveness of the FIM and BI to stroke recovery between 1 and 3 months after stroke.

Methods: Data on 1 to 3 month change in the FIM and BI were available for 401 of 459 participants in the Kansas City Stroke Study with 152 of these subjects showing improvement on the modified Rankin Scale (MRS) and 222 showing no change. Responsiveness to change was assessed with improvement on the MRS as a gold standard. Techniques included: Area under the ROC curve using change versus stability on the MRS to define groups, Guyatt's effect size (ES) based on the ratio of meaningful clinical difference to variability of change scores in stable subjects, paired t-statistics from change scores, F-statistics from Mixed model analyses, one ES ratio of change to baseline standard deviation and one ES ratio with change to standard deviation of change. For the last 4 techniques, separate analyses were run for all subjects and for subjects who exhibited change on the MRS.

Results: All techniques showed responsiveness to be similar for the FIM and BI with some favoring the FIM and others the BI. Although difference in responsiveness is minimal between the BI and the FIM, relative differences favor the FIM for subjects who change on the RMS compared to all subjects.

	ROC	Guyatt ES	Paired t		ES (change)		ES (baseline)		Mixed Model F	
			All	Chg	All	Chg	All	Chg	All	Chg
FIM	.675	1.90	11.9	11.6	.61	.94	.28	.46	9.0	11.0
BI	.650	2.04	12.0	10.6	.62	.86	.30	.48	9.5	10.3

Conclusions: The FIM and BI are comparable in responsiveness to recovery between 1 and 3 months after stroke. Results highlight the importance of selecting subject that exhibit change on the underlying characteristic of interest in assessing responsiveness to change on that characteristic.

Funding and support for this research has been provided through the Rehabilitation Research and Development, Office of Research and Development, Veterans Health Administration, Department of Veterans Affairs.

A-13

USABILITY OF THE COMPUTERIZED EXERCISE EXPERT SYSTEM BY OLDER ADULTS

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The computerized Exercise Expert System (EES), developed by Boyette, et al. (1998), proposes individualized exercise prescriptions for healthy, older individuals. Medical history, mood, functional and mental status, as well as personal preferences are taken into account by the software to maximize exercise adherence.

Objective: This study examined the usability of the EES interface by older adults and the level of acceptability of the system-generated exercise prescription.

Method: Thirty-three healthy community-dwelling adults, ranging in age from 60 to 87 (M=70.52, SD=6.96), volunteered to participate in this study. Participants were initially trained to use the mouse and to navigate the system with an illustrated manual (similar to that used by Echt, et al., 1998). The participants then completed the EES questionnaire items using the computer. Demographics, amount of time for task completion, difficulties encountered, experience with technology, acceptability of the exercise prescription and subjective ease of use ratings were measured.

Results: The average time needed to train the participants to use the computer was 3.76 minutes (SD=1.50). The average time required to complete the EES items was 32.58 minutes (SD=15.57). Requests for assistance were categorized as due to either mouse, presentation, or comprehension difficulties. The majority of difficulties were encountered in relation to item presentation and these were significantly correlated with levels of technology experience ($p<.001$). Those participants with higher levels of technology experience were found to take less time (M=26.58, SD=12.14) to complete the items than those participants with lower technology experience (M=40.71, SD=16.39; $p<.01$). Likewise, participants with higher technology experience had substantially fewer difficulties with presentation (M=.89, SD=1.33) than those with lower technology experience (M=2.36, SD=1.50; $p<.01$). Nevertheless, subjective acceptability ratings of the EES generated exercise prescription and usability ratings of the EES interface were high across technology experience levels. Acceptability ratings ranged from 17 to 26 (on a scale from 1-26; M=22.5, SD=2.32) and average ease of use ratings ranged from 3 to 5 (on a scale from 1-5; M=4.58, SD=.66).

Conclusions: The difficulties that were encountered by the participants, lend insight into the manner in which expert system interfaces may be improved for use by older adults. Self-reported levels of experience with technology and the manner in which computerized questions are presented are important considerations in the design of interactive technology systems for health promotion in older adults.

Clinical Relevance: Keeping older individuals active as long as possible with regular physical exercise can delay or prevent transition to frailty. Exercise promotion in older adults is one of the most important challenges of preventative medicine for the coming decades. The use of computer technology, that is elder-friendly and requires minimal time investment by the provider for the provision of individualized exercise prescriptions, represents an essential step toward meeting these challenges.

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A-14

EFFECTS OF AGING ON MOTOR UNIT CONTROL PROPERTIES IN THE VASTUS LATERALIS MUSCLE

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Objectives: This study is part of a larger project investigating the effects of exercise on elderly individuals. That project was motivated by reports in literature suggesting that neural factors play a more significant role than hypertrophy in the strength gains that the elderly derive from exercise. Previously, we observed significant differences in the neural control of muscles in young and elderly subjects. We hypothesize that these altered neural control patterns in the elderly may be moved closer to those in the young through exercise. An investigation of the effects of exercise on muscle control in the elderly will elucidate the mechanisms involved thus enabling more enlightened prescription of rehabilitation and training regimens. Furthermore such understanding will provide means of identifying the individuals who are more likely to benefit from exercise programs, so that those not likely to benefit from training may be saved the strenuous exercises of a strength-training program reducing the risk of injury. The present study was aimed at determining if the age-related differences observed in the control of motor units in the First Dorsal Interosseous (FDI) muscle of the hand also prevailed in the Vastus Lateralis (VL) muscle of the leg. We chose to investigate the VL muscle in the exercise study, since it has relevance rehabilitation point of view. This muscle is important in the performance of daily activities such as stair climbing or getting up from a chair. However, given the significant differences in the size and tasks of the VL and FDI muscles, it is possible that there are differences in the normal control of the two muscles (see abstract by Adam *et al.*) as well as the way aging affects them. Hence it needs to be verified that the previously observed age-related differences in the control of motor units are also manifest in the VL.

Methods: The control of motor units in the VL was studied in young and elderly subjects during a voluntary isometric knee extension task. Electromyographic (EMG) signals were detected using the fine wire technique. Surface EMG signals and the force generated by the muscle were also recorded. The Precision Decomposition Technique was used to identify firing times of motor units. The recruitment thresholds, mean firing rates, and the correlation among the firing rates of motor units were investigated in relation to the force output of the muscle.

Results: Preliminary results show that motor units in the VL muscle display age-related changes similar to those observed in the FDI muscle.

Conclusions: The age-related changes in the control of motor units in the VL may represent a disturbance to neural control. This disturbance may be eradicated by training, causing an enhanced benefit in addition to the improvement caused by exercise-induced muscle hypertrophy.

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A-15

SLEEP, ACTIVITY LEVEL, BEHAVIOR DISTURBANCE, AND DEPRESSIVE SYMPTOMS IN DEMENTED NH RESIDENTS

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Objectives: Providing outdoor spaces for use by NH residents with dementia is frequently advocated as a means to humanize long-term care settings and normalize the daily experiences of residents. However, outdoor spaces are often valued only as amenities. The health-related benefits of using these spaces and, thus, the clinical importance of providing them and supporting their use have not been systematically assessed. The objective of this preliminary developmental study was to describe the current status of a sample of demented NH residents in 4 domains potentially affected by going outdoors and engaging in outdoor activities (sleep, behavior disturbance, activity level, depression).

Methods: Sleep, light exposure, daytime activities, and activity levels were monitored for 5 days and nights. Behavior observations were completed at 20 minute intervals to describe subjects' daytime locations and activities. Sleep status was estimated with wrist actigraphy (Actillume™). The same instrumentation incorporates a photocell and was used to measure daytime light exposure. Activity level was assessed with activity monitors (Tritrac™). Subjects' behavior disturbance and depressive symptoms during the study period were assessed by nurse ratings using standardized instruments. The study was conducted in two facilities with outdoor space.

Results: The sample of 8 men and 9 women was severely demented (MMSE mean/SD = 13.06/9.42). Although the majority were fully independent in mobility, most had a sedentary lifestyle (average daytime hourly calorie expenditure = 63 $\pm$13). Subjects were most often observed in their rooms or in close proximity to it. When outside their rooms, they were often engaged in passive activities (e.g., people watching). Few went outdoors. One-minute daytime light exposure, averaged over all minutes monitored, ranged from 3.6 lux (nearly totally dark) to 249 lux (slightly dimmer than usual hallway lighting levels) with a mean of 71 lux for all subjects. Sleep was highly fragmented (sleep percent = 86%, average awakenings per hour ranged from .17 to 1.59). Behavior disturbance was present in the sample and half exhibited aggression, physical agitation and/or verbal agitation once a week or more often. Nearly half exhibited depressive symptoms.

Conclusions: Preliminary data indicate a need for interventions to improve demented NH residents' sleep, activity level, behavior disturbance, and depressive symptoms. Further research is needed to evaluate the efficacy of providing outdoor space and promoting participation in meaningful outdoor activities as a means to improve sleep, activity levels, behavior, and affect.

Project #C992, Atlanta VA Rehab R&D Center Developmental Projects Program.

A-16

EFFECTS OF FUNCTIONAL INCIDENTAL TRAINING ("FIT") AMONG FRAIL, GERIATRIC VA NHCU RESIDENTS: PRELIMINARY RESULTS

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Objectives: The prevalence of urinary and fecal incontinence is inordinately high in the nursing home population. Incontinence compromises skin integrity, increases the risk of pressure ulcers and is related to a higher incidence of sickness episodes and hospitalizations. Moreover, the literature consistently demonstrates an inverse relationship between incontinence and mobility and cognitive functioning. This study examines the effects of an exercise, strength training and prompted voiding intervention, Functional Incidental Training (FIT) in relation to mobility endurance, strength, transfer ability, physical activity and continence outcomes in frail, cognitively impaired residents of VA NHCU's.

Methods: After baseline assessments were conducted participants were randomly assigned to an intervention or control group. The FIT intervention involved the FIT rehabilitation aides and research supervisor making rounds every 2 hours between the hours of 8 am and 4 pm Monday through Friday to approximately 4-5 residents per aide to deliver the prompted voiding protocol and provide toileting assistance, endurance and strengthening exercises. Each of the residents on the 8-week intervention protocol had the opportunity for 4 bouts of FIT per day. After Post Intervention I assessments were conducted the control group received the 8 week intervention and the intervention group returned to routine care. All participants were then assessed a final time.

Results: Preliminary results are presented from Site 1 of this four year, five-site study. Residents in the intervention group showed improvements on measures of upper body extremity strength and endurance. In addition, the intervention group improved on measures of continence and appropriate toileting episodes relative to the control group. The pre to post intervention improvements on measures of functional performance and continence were similar for the two groups, but the magnitude of the differences between the groups was slightly less at the final assessment phase suggesting some maintenance of intervention effects after 8 weeks of return to routine care.

Conclusions: The FIT program has been shown to be beneficial to residents of community nursing homes, but has not been previously tested in VANHCU's. Taken at face value the preliminary results suggest that even very frail, de-conditioned, cognitively impaired, geriatric, VA nursing home residents can benefit from a low intensity strength and endurance program.

Project # E2152-2R, Rehabilitation Research Service Department of Veterans Affairs, Washington, D.C.

A-17

THE EFFECT OF HYDROSTATIC PRESSURE ON DISC CELL METABOLISM

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Objectives: It is commonly held that compressive forces applied to the intervertebral disc are one of the factors that probably affect disc degeneration. However, the nature of the association between force and disc degeneration remains obscure. When a compressive force is applied to the disc, it increases the hydrostatic pressure within the disc. The question arises: Is the functioning of the disc cells affected by increases (or decreases) in hydrostatic pressure? More specifically, do high hydrostatic pressures, as produced by heavy labor, result in altered functioning of the disc cells or, less obviously, do low hydrostatic pressures, as produced by low activity, result in abnormal functioning of the disc cells? In a previous experiment we compared the effect of 1 MPa hydrostatic pressure against atmospheric pressure on the synthesis of collagen and proteoglycan by the disc cells, whereas in this experiment we compared 0.35 MPa against atmospheric pressure. (1 MPa is the approximate hydrostatic pressure in the disc during light manual work, whereas 0.35 MPa approximates to erect relaxed standing). For this study, we employed a culture system that takes advantage of an alginate (a linear copolymer of D-mannuronic acid and L-guluronic acid).

Methods: As described before (Spine 24(15)1507-15, 1999) the lumbar spine was harvested from each of eight male dogs. The nuclei from the discs in any one dog were pooled, as were the anuli. The cells were exposed for 9 days to hydrostatic pressure inside two pressure vessels: One vessel at 0.35 MPa and the other at atmospheric pressure. We measured the synthesis of proteoglycans and collagen by [^{35}S]-sulfate and [^{3}H]-proline incorporation, respectively. mRNA was extracted and quantitative changes between aggrecan core protein, types I and II collagen mRNAs were compared using RT-PCR .

Results: Rather than dwell on the comparison between 0.35 MPa and atmospheric pressure, we decided to focus on a comparison between 0.35 MPa and 1MPa. For the anulus 1MPa (compared to 0.35 MPa) produced increases in collagen (7%) and proteoglycan (223%), whereas for the nucleus there was a decrease of 11% in collagen and an increase of 150% in proteoglycan.

Discussion: Our large differences are in the increase in proteoglycan production in the nucleus and anulus at 1MPa. This could suggest that, in life, the higher pressure (1MPa) which would tend to cause a fluid egress from the disc, stimulates an increase in production of proteoglycans, which carry hydrophilic side chains. In other words, disc cells respond to higher pressure by producing more proteoglycans, which have the capacity to resist fluid loss.

Clinical Relevance: The disc cells response to hydrostatic pressure is highly relevant to understanding the etiology of disc degeneration and disc disease.

Acknowledgement: This project was funded by a VAMC Merit Review Grant (A2270-RA).

A-18

ACCELEROMETRIC ANALYSIS OF SIT-TO-STAND AS AN EVALUATION TOOL FOR BALANCE IN PARKINSON'S PATIENTS

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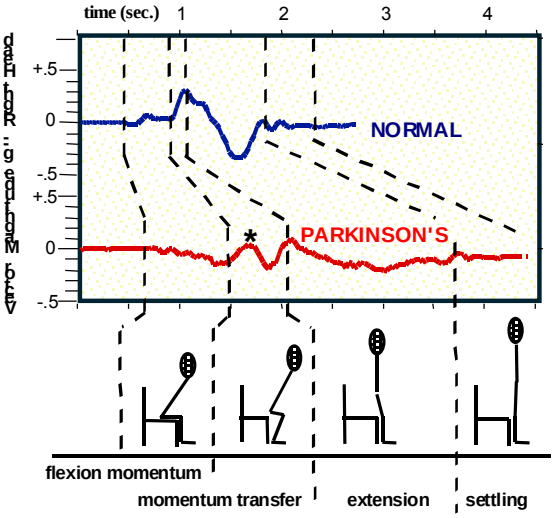
Objectives: Difficulty with sit-to-stand (STS) is a neuromuscular performance risk factor associated with falls. The ability to identify impaired motor patterns in complex activities of daily living is the first step in designing assistive devices to evaluate balance and decrease falling in balance-impaired populations. The objective of this study was to determine whether quantitative measures of STS can easily be identified and whether they correlate with increased fall risk in persons with Parkinson's Disease (PD).



Methods: Seventeen ambulatory PD subjects were asked to perform 14 static balance tasks varying in difficulty from sitting balance to one-legged stance. Tasks were scored on a Qualitative Balance Scale (QBS) by a clinician. Subjects also completed a self-report mobility history from which a fall injury index (FI) was derived. STS was performed at normal speed, arms crossed (unless unable), and recorded using a wearable accelerometric motion analysis system (WAMAS). Video of STS was synchronized to start and stop of data acquisition. The WAMAS unit consists of two 3-axis sensors on eyeglass frames to measure head motion, and two sensors above each hip on a belt at the waist, along with a self-contained data acquisition package . Time between maximum and minimum values (TMM) of averaged right and left waist vector magnitudes and values of maximum (t_{max}) and minimum (t_{min}) acceleration vector magnitudes were evaluated. Data were compared by Pearson's Product Moment Correlation.

Results: While subjects used a variety of methods (i.e.. using hands vs. not using hands) to perform STS, maximum and minimum vector magnitude peaks were consistant with specific kinematic events. The maximum peak (preceding the minimum) corresponds to end of momentum transfer and the minimum is the end of the accelerative phase of extension during STS. The time between the maximum and minimum corresponds to the period of greatest instability during the task. There was high correlation ($p<.005$) between QBS scores and FI and a low to moderate correlation ($p<.005$) between TMM and FI. No correlation existed between FI and t_{min} or t_{max}. Subjects who fell more than 6 times in the last year were more likely to have sit-back failures, increasing TMM substantially.

Conclusions: STS is a complex task to analyze. The ability to easily recognize key kinematic events and the moderate correlation to the FI shows the potential of using accelerometry in assessing complex motor tasks to be used in fall prevention.

Clinical Relevance: With the rapidly increasing population of fall-prone elderly veterans, methods for fall prevention are urgently needed. Our collaborators have hypothesized that some motor symptoms of Parkinsonism may be alleviated by visual, auditory and/or tactile feedback provided upon real-time recognition of impaired motor patterns (e.g.. initiation of gait after STS). A next-generation WAMAS is being designed with these capabilities in mind, for trial in a randomly selected Parkinson's population.

Acknowledgments: VA RR&D Merit Review projects E601-2RA, -3RA. We thank Dr. James Tetrud of the Parkinsons Institute for referral of subjects and his continued interest.

A-19

EVALUATION OF MAIL ADMINISTRATION OF THE STROKE IMPACT SCALE

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Objective: Collecting outcomes data via mail questionnaires could potentially improve efficiency of clinical trials and outcomes research. The purpose of this study was to assess mail survey response of stroke outcomes using a new measure, the Stroke Impact Scale (SIS).

Methods: One-hundred and forty-nine patients (mean age 67 ± 9.7, 96% male, 70% white) enrolled in a VA prospective cohort study of 6 month post-stroke rehabilitation outcomes were mailed the SIS after a telephone follow-up interview. Telephone assessments included the Functional Independence Measure, IADL measure, and the SF-36. SIS: Version 1.0 (100 items) was mailed within 2 weeks of the telephone interview and patients received one follow-up letter to remind them to return the SIS. If patients could not complete the mailed SIS, we accepted proxy responses. Chi-square, t-statistics and Pearson Correlation Coefficients were used to test statistical differences.

Results: Sixty-two percent of the SIS questionnaires were returned with a mean response time of 34 ± 16 days from 6 month telephone interview. Comparison of demographic and baseline stroke characteristics of responders and nonresponders showed no differences in age, race, education, income, cognitive status, stroke type, location, or severity. Among the responders, proxies (n=40) were more likely to complete the questionnaire if the patients were less educated, did not live alone, had a hemorrhagic stroke, and were more cognitively impaired. There were few missing responses (0 to 5%) to any of the SIS items. Correlation of SIS scores to telephone FIM, IADL, and SF-36 physical scores were very good (.60 to .70).

Conclusions: Mail administration of the SIS yielded good response rates, little missing data and good concordance with telephone assessments of outcomes. We are currently evaluating if response rates increase with a shorter version of the SIS.

Funding and support for this research has been provided through the Health Services Research and Development Service, Office of Research and Development, Veterans Health Administration, Department of Veterans Affairs.

A-20

DEPRESSION AND STROKE RECOVERY

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Objectives: The present study was to investigate prevalence of depression after stroke and examined its effect on independence of basic and instrumental ADLs.

Methods: The Kansas City Stroke Study enrolled 459 stroke patients and prospectively assessed their stroke impact and recovery at baseline, 1, 3, and 6 months after stroke. Baseline data were evaluated within 2 weeks of stroke onset. Stroke severity was assessed by the Orpington Prognostic Scale. Depression was defined as present (Geriatric Depression Score of 6 to 15) and absent (GDS 0 to 5). Outcomes are dependency of BADL (Barthel index < 60), independence of BADL (Barthel index > 90), complete independence in preparation of meals (MEAL), getting to places (PLACE), and taking medications (MED). Logistic regression was used to examine the relationship between depression and associated outcomes.

Results: The prevalence of depression was 33% at baseline, 35%, 33 %, and 30% at 1-, 3-, and 6-month after stroke, respectively. Depression was also associated with stroke severity ($P < 0.05$). Percentages of patients that were dependent in BADL, independent in BADL, independent in PLACE, MEAL, and MED were 18%, 49%, 27%, 51%, and 50%, respectively. Patients with depression were shown to be more likely to be dependent in BADL (OR = 2.6; $p < 0.01$) and less likely to be independent in BADL (OR = 0.2; $p < 0.001$) compared to patients without depression after controlling for stroke severity. Similarly, after controlling for stroke severity, odds ratios associated with depression for independence in PLACE, MEAL, and MED were 0.2 ($p < 0.001$), 0.4 ($p < 0.001$), and 0.6 ($p = 0.03$), respectively.

Conclusions: Depression was common among stroke survivors and its occurrence did not decrease at 3-or 6-month follow-up. Depression affected both ADL and IADL recovery.

Funding and support for this research has been provided through the Rehabilitation Research and Development, Office of Research and Development, Veterans Health Administration, Department of Veterans Affairs.

A-21

PHSICAL EXERCISE STRENGTH TRAINING IN RENAL DIALYSIS PATIENTS: AN INTERIM ANALYSIS

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Purpose: Although aerobic (A) based physical exercise training (PET) is recommended for renal dialysis (RD) patients, the potential benefits of strength (S) based PET are not widely reported among RD patients. This randomized study compares the effects of A-based and P-based PET programs on measurements of physical performance in RD patients.

Design: RD patients without contraindications to PET (i.e. cardiac and orthopedic limitations) are randomized to receive a program of eight week, thrice a week, sessions of either A-based or S-based PET sessions. Mean and standard deviations for both groups are provided for these measurements of physical work capacity (VO_{2peak} and maximal workload) measured by cardiopulmonary exercise stress testing (CPX) using a metabolic cart and lower extremity strength (knee and ankle torque) using a Kin Com apparatus at entry (pre) and following the eight week PET programs (post).

Results: Interim findings of 6 male RD patients (age = 54.6 +/- 11.6 years) who have completed this study reveal the following pre to post measurements of physical performance: 1.) A-based PET (n = 3): VO_{2peak} (22.43 to 21.63 ml O_2/Kg/min), maximal workload (105.3 to 104.3 watts), Kin Com testing [knee torque (right 97.1 to 113 Nm, and left 102.2 to 113.6 Nm), ankle torque (right 61.3 to 55.2 Nm, and left 61.7 to 96.2 Nm)], and 2.) R-based PET (n = 3): VO_{2peak} (19.87 to 16.4 ml/O_2/Kg/min) maximal workload (71.3 to 92 watts), Kin Com testing(knee torque[right 85.7 to 93 Nm, and left 77.4 to 106.3 Nm], and ankle torque[right 45 to 55.8 Nm, and left 50 to 87 Nm].

Conclusions: The interim findings, which have important implications for designing PET programs for RD patients, indicate that both A-based and S-based PET programs improve physical function among RD patients. The intent of this on-going study is to provide more conclusive findings by completing a larger sample size and to examine for potential differential effects of these two programs on the various measurements of physical performance.

A-22

EFFECTS OF LONG-TERM RESISTIVE TRAINING ON STRENGTH AND STAIR CLIMBING IN OLDER DIABETIC ADULTS

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Objective: In the older diabetic, functional skills are more affected by the aging process than in those without diabetes. Mobility and balance difficulties, which can occur during the aging process, lead to falls and lower extremity injuries, all of which can be exacerbated by diabetes. Devising methods that can slow down or reverse this decline of function is of great importance to our aging veteran population. Therefore, the purpose of this study was to evaluate the effect of an 18-month resistive training intervention on the functional task of stair climbing in older diabetic adults.

Methods: Fifty older diabetics (mean age = 66.1 years) volunteered to serve as subjects, with 28 serving as exercisers (ES) and 22 as comparisons (CS). Over 18 months, the ES resistive trained 3 times a week for the first 6 months and 2 days a week the last 12 months. Training intensities were prescribed at 50%, 60%, and 70% of one repetition maximum (1RM). ES trained plantar flexors, knee flexors, and knee extensors using a Nautilus multi-station system. CS were told to maintain their routine activities which did not include resistive training. All subjects were evaluated at baseline and every 6 months for strength by 1RM tests performed on the plantar flexors, knee flexors, and knee extensors. They were also evaluated on 2 stair climb tasks: 1) time required to walk up 10 steps, and 2) time to walk down 10 steps.

Results: The data were analyzed using descriptive, correlation, and repeated measures ANOVA statistics. In the ES, there was an increase ($p < 0.05$) in strength for all three muscle groups for each of the testing periods. Based on lower extremity strength (mean strength of plantar flexors, knee flexors, and knee extensors) the ES were 30.7% stronger after 18 months of training than at baseline with the largest strength gain occurring in the plantar flexors. The ES improved ($p< 0.05$) on both stair climb tasks during the 18-month intervention. Based on total stair climb time (time to go up the stairs plus the time to go down the stairs) the ES were 14.7% faster after 18-months of training. There was a significant negative relationship between strength and stair climb for the ES at baseline. While the ES improved both strength and stair climb, the rate of improvement was greater for strength. Although there was a trend toward improvement, no significant changes for strength or stair climb were observed for the CS.

Conclusion: These results indicate the important task of climbing stairs can be improved in older diabetic adults up to 18 months with moderate intensity strength interventions.

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A-23

EFFECT OF WRIST WORKLOAD ON MEDIAN NERVE FUNCTION

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Background: Although numerous studies have suggested that carpal tunnel syndrome is work-related, no clear "dose-response" relationship has yet been determined between the amount or severity of work and the incidence or severity of the syndrome. The potential direct relationship between repeated work tasks and the development of carpal tunnel syndrome has polarized many groups. Some experienced scientific investigators strongly oppose any causal relationship between repeated wrist activity in the workplace and median nerve pathology stating the absence of supporting scientific data. Patient advocates reference cohort and cross-sectional studies in an effort to explain the development of carpal tunnel syndrome on the basis of presented physical stressors. Whether or not carpal tunnel syndrome is caused by repetitive hand and wrist activity during work has serious implications to patients, physicians, employers, insurance carriers and state and federal governments.

Key Objectives: This study proposed to investigate the dose-response relationship between wrist workload and carpal tunnel syndrome symptoms, described in terms of median nerve response to stressor stimuli. Through the systematic evaluation of contributory occupational factors, safe and unsafe levels of wrist workload could be defined as a function of both physical stressor(s) and duration of exposure. This would facilitate the establishment of threshold limit values and time-weighted averages for "toxic mechanical agents" of the carpal tunnel.

Methodology: In a controlled laboratory environment, 27 asymptomatic female participants were required to perform repetitive motions of the hand/wrist in the flexion-extension plane (neutral forearm) for a period of two hours, during which an angle of 120 degrees was subtended about the neutral position. Four levels of wrist acceleration corresponding with $0^{o}s^{-2}$, $200^{o}s^{-2}$, $600^{o}s^{-2}$ and $1000^{o}s^{-2}$, defined as static posture, low, moderate and high-workload were prescribed, corresponding with 0 repetitions per minute, 22 RPM, 38 RPM and 49 RPM respectively. Task assignment was randomized. Wrist workload was recorded using a state-of-the-art 3D electromagnetic human motion tracking system (HumanTRAC), from which mathematical descriptors of angular wrist motion were calculated. Sensory median nerve response to imposed biomechanical stressors was monitored antidromically using a clinical electroneurometer every ten minutes throughout the work-session.

Results: A highly significant within-subject effect of duration of exposure (time) was detected for each condition, where a significant change in median sensory conduction velocity was first distinguishable from the initial measure for low, moderate and high workload conditions after 80, 60 and 90 minutes of exposure, respectively ($p < 0.05$). Using 40.2 meters per second as the empirical upper limit of normal conduction velocity, the duration of exposure needed to exceed normal values was 4.2 hrs (static), 1.9 hrs (low), 1.7 hrs (moderate) and 2.1 hrs (high-workload). Mean initial and mean induced (ending) waveforms illustrate the resultant waveform shift that occurred after two hours of uninterrupted exposure. Tukey's HSD (honestly significant difference) test was used to perform a same time analysis of between workload effects. Results indicate that the static condition differed significantly ($p=0.01$) from the low, moderate and high workload conditions after only 10 minutes.

Discussion: In this controlled study, normal wrists were repeatedly flexed and extended producing a measured threshold shift in the sensory median nerve conduction. Recorded sensory conduction velocities at the low and high workload conditions approached levels diagnostic of carpal tunnel syndrome before completing 120 minutes of repetitive wrist activity. Normal electrodiagnostic levels were exceeded for the moderate workload condition during the same period. The highest workload condition, ($1000^{o}s^{-2}$) in our study produced a smaller mean waveform shift than the moderate ($600^{o}s^{-2}$) condition. Actual wrist workloads at low and high workload conditions showed similar but lower mean peak amplitudes (94.72^{o} and 96.20^{o} respectively) of motion across subjects when compared to the moderate workload condition (99.81^{o}). Thus, angular amplitude subscribed during repetitive activity of the wrist may be an important workload factor when evaluating the effect on the nerve. It is also possible that the relationship between wrist acceleration and shift in median nerve sensory latency is non-linear, with a more complicated and interesting interaction. Repetitive flexion and extension of the wrists increases carpal tunnel pressures and sensory median nerve latencies. As sensory median nerve latency increases from normal to levels diagnostic of CTS, continued repetitive wrist activity is potentially harmful and its negative effect on the nerve most likely cumulative.

Conclusions: A direct dose-response relationship between work performed by and on the wrist and resulting detrimental effect on the function of the median nerve has been demonstrated.

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A-24

QUALITY OF LIFE OF PROSTATE CANCER PATIENTS: DEVELOPING REHABILITATION STRATEGIES

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Objectives: The primary objective of this study was to evaluate quality of life and its correlates over time of patients with prostate cancer treated with radiotherapy. A secondary objective was to develop rehabilitation strategies to improve quality of life in these patients.

Methods: Participants were asked to complete the following instruments: Functional Assessment of Cancer Therapy - Prostate (FACT-P), Beck Depression Inventory (BDI), Epworth Sleepiness Scale (ESS) and Piper Fatigue Scale (PFS). Patients were evaluated before radiation therapy (PRT), at middle of radiotherapy (MRT), at completion of radiotherapy (CRT), and at 4 weeks (FRT1) and one-year follow-up (FRT2). Forty-two of 53 patients completed all instruments across all study periods. Mean age of the patients was 67.3 years (range 55-79). Wilcoxon Sign Rank test was used for comparing changes over time periods. Bonferroni test was performed to adjust for multiple comparisons (adjusted p-values are being reported).

Results: Median scores on the FACT-P declined but not significantly at MRT, CRT, FRT1, and FRT2 as compared with PRT. However, there was a significant decline in Physical Well Being (PWB) sub-scale score of FACT-P at MRT ($p<0.001$), CRT ($p<0.003$) and FRT2 ($p<0.004$), but, not at FRT1. No significant decline was detected in Emotional Well Being (EWB); Functional Well Being (FWB) and Social Well Being (SWB) sub-scales of FACT-P. A significant decline was noted in Prostate Specific (PS) sub-scale of FACT-P at MRT ($p<0.02$), and CRT ($p<0.01$). At FRT2 the median score of Prostate Specific sub-scale was higher as compared to PRT values (35.5 vs 33.0). On PFS, the median scores increased significantly at MRT ($p<0.03$), CRT ($p<0.01$), and FRT2 ($p<0.0004$) as compared with PRT values, scores decreased at FRT1 but did not return to the baseline levels. A significant relationship was found between FACT-P, PFS, and BDI scores across study periods. There was a significant relationship between PFS scores, PWB and PS sub-scales scores of FACT-P across study periods. Patients scoring higher on the fatigue scale were more likely to report poor quality of life on these domains. 37% of the patients were sexually active before radiotherapy. At CRT, FRT1 and FRT2, 35%, 31%, and 40% were sexually active, respectively. Only nine patients (23%) reported normal erection at PRT evaluation. There was no change in the number of patients experiencing normal erection at CRT, and FRT1. At FRT2, 32% of patients were reported to have normal erection. No significant changes were noted in BDI and ESS scores during treatment and at 4 week and one year follow-up.

Conclusions: There was a trend towards decline in Quality of life over time. Depression and sexual problems were common even before initiation of treatment. Fatigue appeared to be more common at long-term follow-up as compared to completion of radiotherapy. Different etiologies may play a role to explain fatigue at different time periods. For example increased fatigue at completion of radiotherapy may be due to transient affects of radiotherapy at neuromuscular efficiency and a further increase in fatigue at long-term follow-up may be the result of inactivity. Rehabilitation strategies have to be developed to prevent these problems. One such strategy, the role of exercise in prevention of fatigue, and to improve physical and psychological function, is being investigated.

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A-25

BALANCE PERTURBATIONS DURING A LIFTING TASK THAT ARE LIKELY TO CAUSE A FALL INJURY EVENT

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Objectives: Injuries in the elderly due to slips and falls are a common source of morbidity, impairment and even death thus constituting a serious health problem in association with high costs. A slip increases the risk for a fall and ensuing acute injuries, especially if the person is lifting or carrying a load. In the current study, phases of a simple box-lifting task during which an individual would be most susceptible to a balance perturbation were investigated.

Methods: To date, eighteen healthy subjects have been tested while performing a repeated box lifting and lowering task. They stood either in parallel stance or in a in step stance with the right foot in front of the left one. A box (4.5 kg) was lifted five times between a work bench (height 0.7m) and a shelf (1.3m) placed within comfortable reach for the subject. A cycle lasted for 6 seconds and consisted of four equally paced phases; box-on-desk, transition-up, box-on-shelf, and transition-down. The Center of Pressure (COP) was measured by a force plate and sampled at 100 Hz together with kinematic data of trunk and limb segments (Motion Star, Ascension Tech). The different phases of the task where identified by signals from electrical contact switches located on the desk and shelf.

Results: During the box-on-desk and box-on-shelf phases of the task the COP was maintained in a stable location anterior to its initial position. In the two transition phases, the COP traveled in a posterior direction for about 0.4 s and then back both during the parallel and step stance conditions. The a/p COP travel distance for parallel stance was 4 cm and for the step stance 8 cm. During step stance, the COP also displayed a right-left displacement during the task (4 cm). Thus, during the step stance condition subjects tended to support their whole body weight on one leg in the initial part of both transition phases.

Conclusions: For the simulation of realistic slipping situations during box lifting tasks it is essential to consider the degree of stability of the subject during the task. When the box rests at desk or shelf, slipping is not likely to occur as COP is more stable and additional support is present at the upper extremities. Based on the trajectory of the COP during the lifting task, subjects are most susceptible to a slip in the transition phases between 0.2-0.6 s after lift off. At this point, the COP acceleration in the a/p reaches a peak. During step stance, subjects may be more sensitive to lateral balance perturbations due to an uneven weight distribution between the two feet. This information will be used when designing balance perturbation experiments during lifting.

Clinical Relevance: These results will provide a better understanding of fall related injury mechanisms as well as lead to advice regarding safe lifting and load handling techniques.

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A-26

MECHANOBIOLOGY OF DELAYED FRACTURE HEALING

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Objectives: Fracture risk in the elderly osteoporotic patient is a major clinical concern. Fractures experiencing delayed union may result in pseudarthroses (false joints) which are often associated with chronic pain and disability. Understanding the role of mechanical factors in the development of pseudarthroses will give further insight to clinicians treating these debilitating fractures. A tissue differentiation hypothesis developed in our laboratory proposes that: 1) hydrostatic pressure directs the pluripotential mesenchymal tissue of a fracture callus down a chondrogenic pathway; 2) significant shear or tensile strain leads to fibrogenesis; and 3) given adequate vascularity, minimal levels of hydrostatic stress and shear/tensile strain allow direct intramembranous bone formation.[1,3] The objective of the present study was to test this tissue differentiation hypothesis with a finite element (FE) model of an oblique fracture to determine if delayed union and pseudarthrosis formation could be predicted based on stress and strain distributions within the fracture callus.

Methods: *Model I:* An idealized 2-D FE model of an oblique fracture was created based upon the geometry of a typical oblique pseudarthrosis.[2] A compressive axial force was applied to the cortical bone ends and plane strain analysis was performed to determine patterns of hydrostatic stress and maximum tensile strain. *Model II*: A contact model was then developed incorporating sliding contact surfaces within the interfragmentary gap corresponding to locations of high tensile strain and regions of callus failure predicted in Model I.

Results: *Model I*: Stress distributions showed low levels of hydrostatic tension at two periosteal corners of the fracture ends, high levels of hydrostatic pressure at the opposing periosteal corners, and intermediate levels of hydrostatic pressure throughout the interfragmentary gap. Maximum tensile strains were highest within the interfragmentary gap and lowest within the external callus. *Model II*: Hydrostatic stress distributions in the contact model were similar to those of Model I. Maximum tensile strain distributions, however, were quite different. Tensile strains decreased within the interfragmentary gap and increased within the external callus. These results would predict fibrocartilage maintenance within the interfragmentary gap and bone formation at the two periosteal corners experiencing low hydrostatic tension and low tensile strain. These results are consistent with *in vivo* patterns of bone and fibrocartilage formation in oblique pseudarthroses.[3]

Conclusions: We have predicted interfragmentary tissue failure, fibrocartilage formation, and locations of bone formation and resorption[4] consistent with initial stages of pseudarthrosis development seen *in vivo*. These results provide us with a better understanding of how the stresses and strains at a fracture site may cause delayed union, nonunion, and pseudarthrosis formation. This information may lead to improved fixation techniques and clinical outcomes for osteoporotic patients undergoing fracture treatment.

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A-27

VARIATION IN STRUCTURE AND PROCESS OF STROKE CARE IN THE VHA

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Objectives: In the VHS, up to 13,000 veterans are hospitalized for stroke annually. Approximately 70% of all stroke survivors receive some type of rehabilitation care. In spite of this large volume of health care need and resource utilization, issues of access and clinical guideline effectiveness for stroke care are not receiving critical evaluation. Our study objectives are to: 1) evaluate access to rehabilitation services by assessing variation and ongoing changes in structure and process of stroke care; 2) evaluate the relationship between structures, processes, and costs of stroke care and risk-adjusted outcomes; and 3) monitor outcomes and provide feedback to facilities and VISN's about the structure, processes and outcomes of care.

Methods: This study is a two-year multi-site, prospective, observational design. Eleven VA facilities within 9 different VISN's have been recruited to enroll and prospectively evaluate stroke patients with data gathered at baseline and 6 months post-stroke. Subjects are followed through their first post-acute rehabilitation episode of care. Structure and process variables are collected from facilities and medical records. AHCPR guideline compliance was based on chart abstraction. Primary outcome variables include functional status, health related quality of life, survival time, community dwelling days, cost of care, and patient satisfaction with care.

Results: Approximately 300 stroke patients have been enrolled over a 15-month enrollment period. The patient cohort has the following demographics and clinical profile: mean age (sd) 67 years (10); male 97%; married 48%; white 66%; full social support 81%; living at home (prior) 98%; Barthel (prior) mean (sd) 94 (13); ischemic stroke 92%. At baseline (immediately post-stroke), the cohort had the following clinical profile: Barthel mean (sd) 53 (28); FIM motor mean (sd) 56 (21); FIM cognitive mean (sd) 29 (7); Orpington mean (sd) 3.4 (1); Folstein Minimental mean (sd) 25 (5); SF-36 Physical mean (sd) 63 (29). Ninety percent of the patient sample received their acute and post-acute care (if applicable) from the VHA. Post-acute services were delivered to the sample in the following proportions: none 30%; low level (subacute-nursing home-outpatient-home health) 36%; high level (acute rehabilitation) 34%. For patients receiving post-acute care, 68% received 1 episode of care (one setting) and 32% received two or more episodes of care (two or more different settings). Mean compliance with AHCPR clinical guidelines for acute care was 67% (14) with a range of 18%-92%. Mean AHCPR compliance for post-acute care was 68% (16) with a range of 26%-91%. Site means for acute AHCPR guideline compliance ranged from 61% to 74%. Site means for post-acute AHCPR guideline compliance ranged from 39% to 74%.

Conclusions: Significant variation exists in the structure/process of stroke care in the VHA.

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A-28

REDUCED USEFUL FIELD OF VIEW IN OLDER ADULTS IS EXPLAINED USING PHYSICAL PERFORMANCE MEASURES

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Purpose: The purpose of this project was to determine group differences in physical performance measures to describe the contribution of visual attention as measured by useful field of view (UFOV) to mobility in older adults.

Subjects: Seventy-seven community-dwelling elders aged 70 to 89 (76 +/- 4.8) participated in the study. Each subject had a history of falling in the previous year.

Methods: Two physical measures that have been related to dependence in mobility and increased fall risk were recorded. Timed Up and Go (TUG) is the time to stand from an armchair, walk 3 meters, return to the chair, and sit. Functional Reach (FR) is the distance one is able to reach forward while standing without taking a step. UFOV was measured using the UFOV attention analyzer to describe UFOV as a percent reduction.

Analyses: Independent t-tests were performed and a Bonferroni correction was applied. A significant p value with Bonferroni correction is 0.025.

Results: Forty subjects had UFOV scores greater than 50% (70.8 +/- 12.4) and 37 subjects scored less than a 50% reduction (38.7 +/- 7.6). The two groups differed on TUG (t=2.8, 75 df, p=.006) and FR (t=-4.23, 75 df, p=.0001).

Conclusion: UFOV is a measure of visual attention comprised of a composite score of perceptual speed, divided attention, and selective attention. Ball and colleagues report that greater than 50% UFOV reduction predicts car crashes in older individuals. However, the relationship between UFOV and mobility remains unclear. The results suggest that individuals with reduced UFOV scores have limitations in mobility as measured by TUG and FR, validating UFOV as related to physical mobility.

Revelance: The interaction between cognitive processes and physical performance is important to consider in the rehabilitation of older adults with mobility limitations. Future studies will investigate using UFOV to predict falls and immobility in older individuals and the effects of UFOV training on physical performance, mobility, and fall risk.

A-29

THE PAIN-DEPRESSION RELATIONSHIP: IS AGE A FACTOR?

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Approximately 50% of chronic pain patients display significant levels of depression (Romano & Turner, 1985); however, pain severity is not a strong predictor of depression among chronic pain patients. Turk et al. (1995) reported that, while this was true for their overall sample of pain patients, a strong relationship between pain severity and depression did emerge among their elderly pain patients. Given the small body of literature on chronic pain and the elderly and given the potentially important clinical implications of Turk et al.'s findings, their results need to be further tested.

Objectives: The aim of this study was to examine the effect of age on chronic pain patients' experience of pain, adjustment to pain, and beliefs regarding pain. An additional goal was to examine age differences in the cognitive-mediational model of pain and depression. This model proposes that pain alone is not a sufficient condition for the development of depression; rather, cognitive appraisal variables (e.g., control) mediate this relationship.

Methods: All patients referred to the Pain Management Program of the Houston VAMC over a three year period were asked to complete pain-related questionnaires as part of their initial assessment. Although information on referral source was not available for analysis, patients utilizing rehabilitation services were well represented in the sample. A total of 564 questionnaire packets were returned (44.6% response rate). Measures analyzed include: the Center for Epidemiological Studies – Depression Scale, the Multidimensional Pain Inventory, the Survey of Pain Attitudes, and the Sickness Impact Profile - Roland Scale.

Results: Using a significance level of $p < .004$ in order to adjust for the number of correlations calculated (12 correlations), age was not significantly correlated with any of the pain-related variables examined in this study. Using a less conservative standard of $p < .01$, age was significantly related to only two variables: belief in the effect of emotions on pain ($r = -.11$) and belief in the efficacy of pain medication ($r = .12$). In support of the cognitive-mediational model, we found pain intensity to be only moderately correlated with depression in the total sample ($r = .25$). Furthermore, we found no evidence that pain intensity was more strongly related to depression among older patients ($r = .20$ among those 70 and older).

Conclusions: These results suggest that older patients seeking assistance for chronic pain differ very little from their younger counterparts in pain reports, affective reactions to pain, and beliefs regarding pain. Our finding that pain is not more strongly related to depression among older patients has relevance to clinical practice. This suggests that health care providers should not limit their efforts to pharmacological or physiological interventions when working with older veterans. Gagliese and Melzack (1997) reported that many older adults do not receive adequate treatment for their pain in part because of misconceptions about the appropriateness of pain management techniques to the elderly and their willingness to participate in such treatments. Our results suggest that the full range of multidisciplinary treatments should be considered and offered regardless of patient age. Given the increasing age of those served by the VHA, these results clearly are relevant to the veteran population.

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ACCELEROMETRIC MOBILITY DIAGNOSIS AND THERAPY

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Objectives: The sense of balance declines with age, resulting in impaired mobility and increased risk of falls. We are developing an instrument that is clinically useful for quantifying hitherto qualitative measures of balance, for feedback during therapy and home care, and for preventing injurious falls – a balance orthosis for fall-prone elderly individuals.

Methods: We have designed and built several versions of a computerized wearable accelerometric motion analysis system ("WAMAS") consisting of two small 3-axis sensors attached to both corners of eyeglass frames to measure head motion, and two sensors above each hip on a belt at the waist, along with a self-contained data acquisition package. A remote control is used to command the wearable unit, so the wearer is unencumbered by cables.

Results/Conclusions: This paper presents brief summaries of four project components: 1. Reliability & Validity of Accelerometric Gait & Balance Diagnosis - We are establishing statistical reliability and validity by comparison of accelerometry with laboratory gait and balance measures (force platform, joint angle goniometry and video imaging) of elderly subjects having well-defined mobility status, using a test-retest protocol. A total of 84 subjects have been tested at least twice. 2. Analysis of Head & Waist Motion During Falls From a Tilting Platform - In preliminary studies to prevent fractures from falling onto the hip, we examined forward, backward and lateral falls by 12 young able-bodied subjects standing on a platform held level by an electromagnet until released at a random time. Falls in any direction were identifiable, and lateral falls could be distinguished from backward falls by greater horizontal acceleration at either left or right sensor site. 3. Pressure & Motion Feedback to Prevent Skin Breakdown in the Sensorimotor Impaired - We are testing the hypothesis that a wearable motion and pressure sensing system will help prevent skin breakdown. This system will wirelessly interact with skin interface pressure sensors, provide real-time visual, tactile and/or auditory feedback to the user, communicate patient status to a remote clinician, and recognize that it is unused or incorrectly used if a patient is not complying with a therapeutic pressure-relief regimen. 4. Multi-Link Human Body Motion Simulator - Since it is difficult for a human to exactly reproduce a motion trajectory, we plan to test accelerometers using a multi-link model having joints equipped with angle encoders and magnetic brakes; motive power is provided by a 6-axis robot arm. The model permits tests with sensors correctly oriented or misaligned, and with simulated soft tissue interposed between sensors and linkage.

Clinical Relevance: As veterans age, they become increasingly at risk for injurious falls; hence the need for a balance orthosis to help maintain independence. If therapist time with each patient is limited, the motion analysis system can act as a surrogate therapist, monitoring a patient's performance and compliance with a course of therapy. Local clinical collaborators have used the method for diagnosis of veterans with peripheral neuropathy, and non-local researchers have studied fatigue in walking by the elderly and standing balance in a variety of subjects, including children with cerebral palsy. A number of clinicians are interested in real-time analysis of Parkinson's disease patients' acceleration patterns so as to generate cues to promote successful activities of daily living. Other collaborators are measuring effects of yoga training on balance, and combined head- and eye-tracking for vestibular research.

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A-31

DESIGN OF A UNIVERSAL TOILET TRANSFER SEAT FOR ELDERLY AND DISABLED VETERANS

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The purpose of this project was to complete the development of a universal, floor-mounted transfer seat that is designed to replace a standard raised toilet for older people who need support while completing a standing transfer as well as nonambulatory individuals who use a sliding transfer. The final design is based on the results of prototype testing by the Principal Investigators in a prior Merit Review project. The new design, developed in collaboration with Maddak, Inc., a major manufacturer of aids for daily living, includes horizontal handholds on each side for a sliding transfer as well as slots on each side to accept vertical handles for a standing transfer. In addition, the fixture includes side cutouts for people who require bowel care and a footrest to assist in maintaining balance while seated on the toilet.

Following development and fabrication of a full-scale mockup, the fixture was evaluated to determine whether it responded to the performance goals established for the target populations and to obtain feedback from users about the effectiveness of the new design. Thirty subjects simulated getting on and off a toilet using the same testing protocol as the prior merit review project and previously reported. The ambulatory/semiambulatory group used the vertical handles, whereas the nonambulatory group used the horizontal handles. Results from a post-trial questionnaire developed for the prior project demonstrated that perceptions of difficulty were significantly lower and perceptions of safety were significantly higher than those reported previously for a typical raised toilet with grab bars.

A CRADA has been signed with Maddak, Inc. to fabricate the new transfer seat. The universal toilet transfer seat is highly relevant to VA as it directly addresses an important problem that can negatively impact independent functioning and quality of life for older adults and people with spinal cord involvement (SCI), two of VA's largest beneficiary populations. The vertical handles compensate for the types of mobility limitations that are characteristic of the majority of older veterans who are ambulatory or semiambulatory, whereas the provision of horizontal handles as well as side-cut outs for bowel care are intended for nonambulatory individuals and particularly those with SCI who have functional levels that will enable them to transfer to the new fixture.

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A-32

MECHANOBIOLOGY REGULATES CARTILAGE THICKNESS IN SESAMOIDS

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Objectives: Sesamoid bones, such as the patella, are found within tendons in regions that wrap around bony prominences and are often implicated in the pain and disability associated with osteoarthritis. To investigate the etiology and progression of osteoarthritis in sesamoids, we must understand the factors that regulate cartilage maintenance in sesamoids. In this study, we elucidate the role of mechanics on bone development and cartilage maintenance in sesamoids. Sesamoid bones form by the ossification of cartilages that develop in utero. Sesamoid cartilages are formed after tendon continuity is established. Prior to sesamoid cartilage formation, geometric conformity between the tendon and its articulating contact surface exists. However, nonconformity between sesamoid and articulating surface arises naturally during growth. As development progresses, the sesamoid cartilage begins ossification via one or more nuclei within its interior.[3] These nuclei rapidly coalesce and spread outward while preserving a layer of cartilage at the articular surface.[3]

Methods: We used 2-D finite element analysis to investigate the behavior of a simple sesamoid cartilage model. The geometry was based on a sesamoid cartilage embedded within a fibrous tendon[2] that wraps around a bony articulation, such as the distal femur. Patterns of cartilage ossification and maintenance were predicted using an ossification index that was previously used to predict epiphyseal ossification.[1,4] We investigated if loading history and joint nonconformity contribute to the formation of multiple ossification nuclei and to the preservation of a cartilage layer at the articular surface of sesamoids.

Results: For a fully conforming joint, the ossification index did not distinguish between regions of bone formation in the sesamoid substance and a layer of preserved cartilage at the articular surface. For a nonconforming joint, the ossification index predicted regions in the sesamoid substance where ossific nuclei normally appear and a region where cartilage is maintained at the articular surface.

Conclusions: We found that a simple mechanical loading history applied to a tendon containing an embedded sesamoid cartilage in a conforming joint does not predict regions of bone formation in the sesamoid substance and cartilage maintenance at the articular surface. In nonconforming joints, however, the loading history predicts patterns of cartilage ossification and maintenance that are observed in sesamoids in vivo. The ossification index predicts a diffuse ossification stimulus within the interior of the sesamoid cartilage. These findings suggest that the ossification stimulus is not localized and may be favored in multiple regions within the sesamoid, except near the articular surface where a cartilage layer is preserved. Furthermore, our results suggest that joint nonconformity leads to a thicker cartilage layer at the articular surface of the sesamoid at least early in development. Joint nonconformity or poor joint tracking, however, may lead to cartilage degeneration and osteoarthritis later in life. Our findings could improve techniques for the prevention or rehabilitation of cartilage damage in patients with osteoarthritic joints.

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A-33

OSTEOARTHRITIS AND BONE GROWTH ARE REGULATED BY IDENTICAL MECHANOBIOLOGICAL PROCESSES

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Objectives: Osteoarthritis (OA) is an age-related disease that results in chronic pain and disability for millions of Veterans. The pathogenesis and progression of OA has been shown to be regulated by mechanical loading of the joint.[1] In particular, we have proposed that the degeneration of articular cartilage in OA is promoted by cyclic octahedral shear stress and inhibited by cyclic hydrostatic compressive stress.[2] OA can be considered as the final stage of endochondral ossification of the skeleton, and therefore has many biological processes in common with those of bone growth and development. The objective of this study is to determine if our views on the mechanobiological regulation of osteoarthritis can be extended to describe and predict the response of growth plates (physes) to variations in joint loading.
Methods: A 2D, plane stress, finite element model of a generic long bone with a growth plate was generated. Four different joint compressive loading distributions were applied and, for each case, hydrostatic and octahedral stress were determined in the growth plate. The hypertrophic region (growing region) of the growth plate consisted of the three rows of cartilage elements directly above the interface with diaphyseal bone. The growth rate in this region was calculated using an assumed biological growth rate that was modulated by the mechanobiological growth contributions of hydrostatic compression and octahedral shear stress.

Results: With no loading the bone grew at a constant biological growth rate and the growth front progressed evenly across the physis. With a moderate compressive load across joint surface, growth was promoted and the growth front progressed further than without loading. Under a severe compressive load, however, growth was inhibited and the growth front progressed less than without loading. Under a linearly increasing moderate compressive load across the joint surface, growth was promoted the most where the load was the highest. This resulted in a growth differential across the physis. The hypertrophic zone grew more on one side than on the other, and the bone began to curve. With a linearly increasing severely compressive load, growth was inhibited the most where the load was the highest and the bone curved in the other direction. These results are consistent with clinical findings of the normal and abnormal growth of bones in children.[3,4]

Conclusion: We have found that the same mechanobiological principles that are associated with OA also govern the growth of the physis. These findings support the view that the endochondral ossification process, whether it is in growth and development or osteoarthritis, is promoted by octahedral shear stress and inhibited by hydrostatic compressive stress. These findings establish a mechanobiological framework for clinical treatment for the management of OA within the context of principles used for the treatment of other conditions of cartilage growth, development and degeneration.

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A-34

MEASUREMENT OF FAT FREE MASS WITH DUAL ENERGY X-RAY ABSORPTIOMETRY, BIOELECTRICAL IMPEDANCE, AND ANTHROPOMETRICS IN ELDERLY INPATIENT REHABILITATION PATIENTS

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Advancing age is often associated with changes in body composition such as the profound undesirable loss of muscle mass. This reduction in muscle mass is associated with reduced strength and functional capacity or even death in frail elderly (Evans & Campbell 1993; Frontera et al. 1991). As the role of fat free mass (FFM) in rehabilitation outcome gains recognition, accurate and practical methods to measure body composition in the specific population being treated are required. A common reference method in body composition measurement is dual-energy x-ray absorptiometry (DEXA), however, it is expensive and oftentimes impractical. Bioelectrical impedance analysis (BIA) and anthropometric methods to measure body composition are less expensive and can be performed at the bedside, but have not been validated in elderly inpatient rehabilitation patients. The accuracy of BIA depends heavily on the population and the validation method (Roubenoff, 1997).

Objectives: Seeking to validate methods to measure FFM in our elderly inpatient rehabilitation patients, we examined the accuracy of BIA and anthropometric equations in measuring DEXA-derived FFM in a group of elderly male patients in a VA inpatient rehabilitation unit and a group of elderly female nursing home patients.

Methods: 39 cases, 13 females and 27 males, aged >65 years, were examined in the study. DEXA, BIA, and anthropometrics measures were performed on each patient within a week of each other. DEXA was used as a reference technique, and was compared with two different BIA equations and two anthropometric equations. One BIA equation was provided from the manufacturer (RJL) and the other was developed for the elderly using data from 455 participants in the Framingham Heart Study (Roubenoff, 1997). One anthropometric equation was developed using an elderly population (Chapman et al. 1998) and the second was an unpublished equation developed on 400 males aged 25-65 (Jackson & Pollock, 1978).

Results: The correlation between RJL-derived FFM_{BIA-1}, and FFM_{DXA} was 0.926 (R^2 = 0.857; SEE= 2.34 Kg) in females and 0.938 (R^2 = 0.879; SEE= 3.48 Kg) in males with a significant mean difference between the two for both females and males (3.81 ±2.23 Kg; $p<0.001$ and 5.24 ±3.52 Kg; $p<0.001$ respectively). This reveals a systematic error in FFM_{BIA-1}, and an overestimation of FFM_{DXA} in our sample. However, using Roubenoff's equation, no systematic error was revealed for either gender, and the correlation between FFM_{DXA} and FFM_{BIA-2} was 0.881 (R^2= .776; SEE= 2.87) for females and 0.937 (R^2= .879; SEE= 3.55) for males. The correlation between FFM_{DXA} and $FFM_{ANTHR-1}$ was 0.819 (R^2= .640; SEE =4.41 Kg) for females and 0.893 (R^2= .798; SEE= 4.59) for males, with a significant mean difference (12.79 ±3.57 Kg; $p<0.0001$ and 11.65 ±4.55 Kg; $p<0.0001$ respectively). The second equation showed a correlation between FFM_{DXA} and $FFM_{ANTHR-2}$ of .880 in males (R^2= .776: SEE= 4.99), but still overestimated FFM, albeit with a lower systematic error (mean difference = 5.92 ±5.36 Kg; $p<.001$).

Conclusions: BIA is a practical way to assess FFM and body composition in elderly patients, however, equations that are validated on populations with similar characteristics must be used. More studies are needed to develop an accurate anthropometric equation and to uniformly validate the procedure in the elderly veteran patient population in order to have a precise measure of FFM and body composition in this specific patient population.

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A-35

CARTILAGE REPAIR AND REGENERATION: EFFECTS OF MECHANICAL LOADING ON OSTEOARTHRITIC CARTILAGE CELL METABOLISM

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Objectives: This study addressed the hypothesis that specific mechanical loading regimens will function as a stimulus for the restoration of normal phenotypic expression of injured articular cartilage cells. The experimental aims examined the effects of intermittent hydrostatic pressure on the expression of three major categories of articular cartilage cell products, extracellular matrix proteins, proinflammatory mediators and cartilage degrading enzymes.

Methods: Articular chondrocytes were isolated from human osteoarthritic joint cartilage using collagenase treatment. The isolated cells were allowed to attach in DMEM/F12 medium containing 10% FBS for five days. For loading, the culture plates were immersed in 45 ml of serum-free medium in sterile, heat-sealed plastic bags. Control cultures were maintained under identical conditions. Hydrostatic pressure was applied intermittently at 1 Hz at a level of 10 MPa for periods of (A) 2, 4, 8 12, and 24 hours or (B) 4 hours per day for 4 days. Each experimental time point was tested using triplicate and the experiment loading protocol was carried out in five trials. Total nucleic acid was extracted by the phenol/chloroform method and converted to cDNA using reverse transcription. PCR was carried out within a single reaction using beta-actin as control. The amplified products were fractionated on agarose gels and ^{32}P-signal levels were determined. Release of matrix proteins into the culture medium was determined by concentration of all samples using membrane concentrators with MW cutoff of 10 kD and subsequent SDS-PAGE in 10% acrylamide gels with protein visualization following silver staining. IL-6 and MCP-1 protein levels were measured by ELISA.

Results: Applying intermittent hydrostatic pressure using an interval loading pattern that included a 4 hr period of stimulation followed by a 20 hr period of inactivity increased the levels of type II collagen and aggrecan mRNA signal levels, relative to unloaded control cells. Continuous application of intermittent hydrostatic pressure inhibited human osteoarthritic chondrocyte release of MMP-2 at 6, 12 and 24 hr, relative to unloaded control cultures. Zymographic analysis did not demonstrate an effect of intermittent hydrostatic pressure on chondrocyte release of MMP-9 at any time period tested. APMA activation also revealed inhibition of both active forms of MMP-2 (62 and 68 kD). Intermittent hydrostatic pressure inhibited human osteoarthritic chondrocyte release of IL-6 by 41, 43, and 20% at 6, 12 and 24 hr, respectively, relative to unloaded control cultures. Intermittent hydrostatic pressure inhibited human osteoarthritic chondrocyte release of MCP-1 by 12, 31, and 49% at 6, 12 and 24 hr, respectively, relative to unloaded control cultures.

Conclusions: Application of intermittent hydrostatic pressure effectively modulated the metabolic products of isolated osteoarthritic articular chondrocytes in a manner that would be conducive to induction of extracellular matrix repair and regeneration. The levels of proinflammatory cytokines and the matrix degrading enzymes were suppressed by the loading whereas mRNA signal levels for the major matrix molecules, aggrecan and type II collagen, were increased.

Clinical Relevance: The results presented in this study confirm that alteration of mechanical loading within rehabilitation medicine protocols will contribute to the success in treatment and alleviation of early manifestations of osteoarthritis in the aging veteran population.

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A-36

TEAM CHARACTERISTICS AND PATIENT OUTCOMES ON VA REHABILITATION SERVICES

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Objectives: The primary objective of this three year multi-site study is to investigate the relationship of team characteristics to patient outcomes on VA inpatient Physical Medicine and Rehabilitation Services (PM&RS). Comprehensive measures of team, hospital, and patient characteristics are being studied in relationship to patient functioning measured by the Functional Independence Measure (FIM) and other outcome measures such as a composite "good", "sent home", and LOS.

Methodology: Fifty VA inpatient rehabilitation teams that subscribe to the FIM participated in the study. These hospitals represent practically all (>95%) VA hospitals with inpatient rehabilitation services. Project staff conducted a one-day site visit at each hospital to administer questionnaires and interviews concerning team functioning and organizational culture. The patient outcome measure (FIM) data were obtained from archival files at PM&RS Headquarters. Team questionnaire data was analyzed using principal factor rotation, and merged with patient data and subjected to regression analyses.

Results: Statistical analyses are ongoing. To date, factor analyses include confirmation of organizational and leadership factors and two factors related to interprofessional relations (IR). Organizational factors were positively and significantly associated with "Good", "Sent Home" and LOS outcomes. The two interprofessional relations factors were significantly associated with "Good", "Sent Home", and LOS outcomes as well. Patient age, marital status = married, and FRG category were, also, found to be significant.

Conclusions: Results suggest that team and organization characteristics are associated with good patient outcomes and that these associations can be measured through appropriate survey instruments.

Funding Acknowledgements: This study was funded by the VA Rehabilitation Research and Development Services (Merit Review #E853-R).

Clinical Relevance: Rehabilitation teams are cost and labor intensive. Therefore, the results of this study may prove crucial to the provision of cost-effective rehabilitation services by identifying those aspects of team functioning and organizational characteristics that are associated with good patient outcomes. Future research possibilities include training to better enhance the teams' unique contributions to patient recovery and aid in the development of integrated systems of care, a more rigorous hypothesis testing of Strasser's Model of Team Effectiveness, and the extension of results to other settings that utilize the team approach.

A-37

THE STROKE IMPACT SCALE: A SENSITIVE AND CONSISTENT MEASURE OF STROKE RECOVERY

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Objective: Researchers often use categorical outcomes of health status to assess intervention effectiveness in clinical trials. This study examined the potential value of the Stroke Impact Scale (SIS) as a more sensitive measure for interventions designed to enhance stroke recovery.

Methods: The SIS was administered to 105 of 459 participants in the Kansas City Stroke Study with complete data obtained for 91 subjects at month 1, 79 at month 3 and 70 at month 6. We compared distributions of two SIS subscales (physical and social participation) between and within subpopulations defined by binary outcomes for three accepted measures of stroke recovery, the Modified Rankin Scale (MRS≤2), the Barthel Index (BI>90) and the NIH Stroke Scale (NIHSS≤5) using descriptive statistics and ANOVA.

Results: Both subscales showed expected differences at all times between groups defined by the cut point for each measure, as within-group effects. For example, 3-month mean physical scores were 86, 71, 52, and 28 with mean social participation scores of 88, 63, 49, and 25 for MRS levels 1,2 and 3,4 respectively, with strong evidence of differences between means for all levels ($p<.01$, adjusted using Tukey HSD) except Levels 2 and 3 for social participation ($p=.13$). The differences between MRS levels were large compared to differences within levels across time, which were generally in the range of 2 to 7 compared to standard deviations of 13 to 20 within time and level. Similar results were found for groups defined by the Barthel and NIH.

Conclusions: The SIS physical and social participation subscales provide outcomes that are consistent with accepted categorical outcomes across time. However, large differences in SIS subscale scores between participants within subpopulations defined by single cut points suggest that the continuous SIS outcomes will be more sensitive to effects of interventions than the binary outcomes.

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ENHANCING QUALITY OF LIFE THROUGH OCCUPATIONAL WELLNESS

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Introduction: The promotion of health and wellness has been a national effort since the surgeon general first introduced the idea in *Healthy People 1979*. Specific populations such as certain low income ethnic groups, persons with disabilities and the elderly were said to be at risk for diminishing health if they didn't change their lifestyles. The Center of Excellence on Healthy Aging with Disabilities at the Veterans Affairs Medical Center (VAMC) recognized the need to provide interventions for older veterans so they can lead healthier lifestyles and maintain an optimal quality of life. This research project whose goal is to enhance the wellness of older veterans who have had strokes was funded to develop an occupational wellness assessment which will be used by occupational therapists in rehabilitation at the VAMC to promote a holistic perspective in their treatment planning and implementation. Occupational wellness refers to daily patterns of meaningful, purposeful and satisfying occupations of individuals that contribute to maintaining health and wellness (Reed, 1998).

Objectives: 1. To develop an occupational wellness profile of older veterans who have had strokes. 2. To design an occupational wellness assessment (OWA) that reflects the uniqueness of the veterans in the study. 3. To pilot the OWA with a small number of veterans in rehabilitation at the VAMC in order to determine its clinical usability.

Methods: 1. Nine veterans over 50 years of age who had had a recent stroke were interviewed using a guided interview schedule, along with a family member, making a total of 17 persons. They were all given a Quality of Life Profile for Seniors to provide an additional data source. 2. The qualitative interviews were transcribed, and coded for wellness descriptors. Themes were identified from the descriptors and wellness stories in the literature which were then reviewed by a panel of experts prior to starting the development of the OWA. The occupational wellness model (Reed, 1997) was also a source of wellness descriptors. 3. The OWA was created from the analysis of the data and piloted for usability. At that time occupational therapists who treated the veterans were interviewed before a final revision of the OWA is completed.

Results: A summary of the preliminary results from the study will be presented along with discussion of plans for a future longitudinal study of veterans with disabilities at the VAMC, using the OWA during rehabilitation. Follow-up study of these veterans will provide incite into the ability of the veteran to maintain changes in their lifestyle over time and sustain their occupational wellness.

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DOCUMENTING FALLS AMONG OLDER ADULTS TRANSITIONING TOWARD FRAILTY WHILE RECEIVING A TAI CHI OR WELLNESS INTERVENTION: PRELIMINARY FINDINGS

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Objectives: To determine if an intense intervention of Tai Chi Chuan or a Wellness Education Program can delay the onset of falls among older adults transitioning toward frailty (Speechly & Tinetti, 1991).

Methods: As part of a randomized, blinded clinical trial, data on prospective fall events have been gathered from 143/300 adults (age > 70 years). Interventions are randomized by paired independent living facilities into a Tai Chi program (60-90 minutes, twice weekly) or a Wellness Education program (60 minutes, once weekly) for 48 weeks. Sites are stratified by socioeconomic status. Data have been accumulated thus far are from 10/20 sites. Falls' adjudication is performed weekly and falls are classified as: grabbing or leaning onto an object; falling back into a chair when attempting to arise; accidentally landing on a person or object; and falling to the ground or floor.

Results: Among the first 6 facilities recruited, there was a significant difference between the number of persons in each group having at least 1 fall during the first 7 months of the intervention ($p = .01$). Comparing groups, the age adjusted relative risk of falling onto an object or to the ground was 1.56 ($p = .02$) for the first 8 facilities (N=114) during the firs 5 months of intervention. A similar finding was seen over the first 9 months in 4 facilities (RR=2.08, $p = .04$). The rate of falls to the floor or ground per month by group across all facilities over the first 12 months was significantly different (RR=1.51, $p = .043$). All these findings pertain to the same group.

Conclusions: These data suggest that one intervention may be reducing the number and rate of fall events in transitional elderly.

Clinical Relevance: If fall reductions are occurring in the Tai Chi group and if these findings are also applicable to injurious falls, then Tai Chi may become a worthwhile intervention to delay fall onset among older adults transitioning toward frailty. The relationship of fall events with behavioral, functional, physiological, and biomechanical data must still be undertaken and must demonstrate meaningful correlations if the intervention is ultimately to have merit.

A-40

IMPROVING THE ASSESSMENT OF OSTEOPOROSIS AND FRACTURE RISK USING DXA OF THE CALCANEUS

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Objectives: Ten million Americans have osteoporosis, and 1.5 million osteoporotic fractures occur each year in the United States. These fractures are associated with significant morbidity and mortality, especially in elderly patients. To prevent osteoporotic fractures, clinicians must be able to identify individuals with low bone density who are at risk for osteoporotic fracture. Dual-energy X-ray absorptiometry (DXA) of the calcaneus is one of the best procedures available for assessing bone density and fracture risk at many commonly fractured sites including the hip and spine. However, DXA normally gives an areal bone mineral density (BMD) that depends on both volumetric bone density and bone size. We propose that the assessment of osteoporosis and fracture risk can be improved if volumetric densities are used to remove the confounding effects of bone size. The purpose of this study was to develop a simple method for determining such volumetric densities of the calcaneus.

Methods: We measured the volume (V_{disp}) and average medial-lateral thickness (t_{calip}) of 23 excised human calcanei. We then performed DXA scans with the specimens immersed in 15 cm of water and the X-ray beam oriented in the medial-lateral direction. Bone mineral content (BMC), projected area (A_{DXA}), and areal bone mineral density (BMD = BMC / A_{DXA}) were recorded. The volumetric bone apparent density was calculated as þ = BMC / V_{disp}. Because direct measurements of calcaneus thickness are not available for in vivo studies, an alternative method for computing the calcaneus thickness is needed. Assuming geometric similarity, the calcaneus thickness should be proportional to (subject weight)$^{1/3}$, (subject height)^{1}, and (calcaneus area)$^{1/2}$. Linear regressions of t_{calip} versus these variables were performed to identify the best estimator of the average calcaneus thickness (t*). Bone mineral apparent density was calculated as BMAD = BMC / (A_{DXA} t*). Regressions of BMD and BMAD versus V_{disp} were performed to investigate the dependence of BMD and BMAD on calcaneus size. Linear regression was also used to evaluate the relationship þ = k BMAD and to determine the value of the proportionality constant k.

Results: The variable (calcaneus area)$^{1/2}$ was the best predictor of calcaneus thickness, followed by (subject height)^{1}. Assuming that t* = $A_{DXA}^{1/2}$, BMAD = BMC / $A_{DXA}^{3/2}$. Linear regressions of BMD and BMAD versus V_{disp} showed that BMAD is independent of bone volume (slope = 0.000; $p = .786$) while BMD increases with increasing bone volume (slope = 0.003; $p < .05$). Linear regression of þ versus BMAD indicated a significant linear relationship ($p < .0001$) with the constant of proportionality k = 1.822 ± .026 SE.

Conclusions: We have developed a simple method for determining volumetric densities of the calcaneus from standard DXA measurements. By using BMAD and þ, we can improve the utility of DXA measurements in clinical applications. Osteoporosis, for example, can be better diagnosed using volumetric densities that do not depend on bone size. Fracture risk can also be better assessed using volumetric densities since low BMD reflects increased fracture risk when it is due to low volumetric bone density but not when it is due to small bone size. Thus, more useful clinical information can be extracted from DXA exams by calculating volumetric densities as described in this study.

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CALORIE, PROTEIN, AND MICRONUTRIENT INTAKE IN LONGTERM HOSPITALIZED REHABILITATION PATIENTS

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In recent years physical medicine and rehabilitation clinicians are now realizing that treating clinical manifestations of disabilities that patients present with is not enough. Mindfulness should be given to conditions that hold great potential for significantly jeopardizing the success of interventions instituted in the care of the disabled. Malnutrition is reported to prevail in 30 - 85% of the nation's 1.5 million elderly currently residing in extended inpatient facilities. Detrimental effects of malnutrition such as debilitating and painful pressure ulcers, infections, and severely compromised functional status can, in turn, impact on rehabilitation services rendered in the VAMC. Malnutrition is serious and can quickly become a precursor to greater disability if left unchecked. It is widespread and extremely difficult and expensive to treat once progressed, but it is also preventable and modifiable.

Objectives: To characterize the prevalence and progression of nutritional deficiencies manifested in elderly disabled patients admitted for extended inpatient rehabilitation.

Methods: In a longitudinal cohort study, macro and micronutrient consumption of elderly rehabilitation patients newly admitted to extended inpatient services and receiving standard care is being measured at 1, 6, & 12 months. Consumption is assessed using Nutritionist V analyses of foods weighed (to .1gm) before and after eating.

Results: Preliminary data from 38 of 100 patients followed are reported. Patient means and range values for intakes of calories, protein, and four micronutrients important to maintaining weight, immune function, wound healing, and pressure ulcer status are depicted:

	1 month	6 month	1 year
Calories (% depleted at < 2000kcal)	435 - 2606 (78%)	501 - 2270 (78%)	438 - 2097 (95%)
Protein (% depleted at < 60 g)	16 - 117 (53%)	26 - 125 (53%)	14 - 92 (77%)
Vitamin A (% depleted at < 1000mcg)	183 - 2005 (53%)	398 - 2574 (59%)	244 - 1890 (68%)
Vitamin C (% depleted at < 60mg)	**20 - 445 (34%)**	**26 - 363 (29%)**	**31 - 297 (68%)**
Vitamin E (% depleted at < 10mg)	1.2 - 59 (63%)	1.3 - 55 (56%)	1.4 - 45 (73%)
Zinc (% depleted at < 15mg)	4.1 - 33 (82%)	3.1 - 27 (84%)	2.1 - 22.1 (86%)

Data showed that: 1) compromised macro and micronutrient intake was frequently present at 1 month and continued over time in elderly patients receiving standard care in extended inpatient rehabilitation; 2) those considered adequately nourished at admission dramatically decreased intake over time; and 3) patients on oral supplementation consumed a daily average of 32.5 Cal/Kg in contrast to 22.9 Cal/Kg by those not supplemented.

Conclusions: Close attention should be paid to nutrition throughout the entire hospitalization of all elderly rehabilitation patients admitted for extended lengths of stay because: 1) the prevalence of macro and micronutrient deficiencies remains high in these patients over time; and 2) while patients identified as "at high nutritional risk" upon admission appear to be given adequate nutrition support when receiving standard care, patients initially assessed as "good eaters" and not identified as "at high risk" quickly become at risk over time. We are now studying how macro and micronutrient deficits relate to nutritional biomarkers, body composition, and relevant immunologic, integumentary, and functional indices. We also seek to identify which commonly recognized markers of malnutrition serve as predictors of poor clinical outcome despite rehabilitation interventions instituted. Last, we will develop and test nutritional, clinical, and pharmaceutical prescriptions to prevent and reverse detrimental clinical correlates of macro and micronutrient compromises in elderly rehabilitation patients.

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ACCELEROMETRIC ANALYSIS DETECTS FUNCTIONAL UPWARD REACH MOTION PATTERNS FOR ASSESSMENT OF BALANCE

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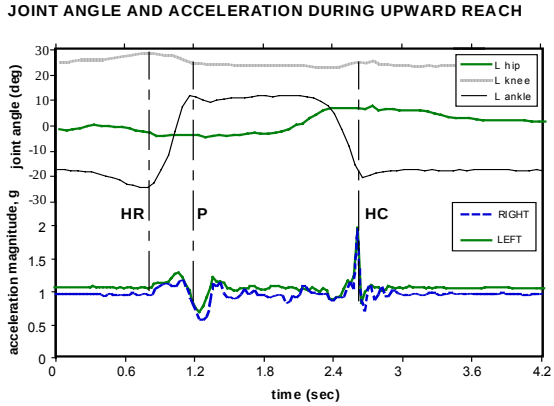
Objectives: Diagnosis of balance disorders can be done by evaluation of an individual's performance in a task intended to stress the postural control system. One common diagnostic task involves reaching toward a target, which requires adjustment of posture prior to and during movement of the arm [Bouisset & Zattara, *J Biomechanics,* **20:** 735-742, 1987]. An example is the Functional Reach test, which is reported to be reliable and valid in predicting falls in an elderly veteran population [Duncan, *et al, J Gerontol Med Sci*, 47:M93-98, 1992]. In this study, accelerations and joint angles during reaching toward an overhead target were analyzed to identify components of the task most amenable to use as diagnostic measures.

Methods: Six healthy elders (2 males, 4 females) were asked to reach upwards, rising up on toes, to touchan overhead target placed 3 in. directly above their fingertips when arms were extended upwards using normal stance. Head and trunk motions were recorded using a wearable accelerometric motion analysis system (WAMAS), consisting of two 3-axis sensors on eyeglass frames to measure head motion, and two sensors above each hip on a belt at the waist, along with a self-contained data acquisition package . Joint angles were digitally recorded from electrogoniometers (Biometrix "Penney & Giles") on the left ankle, knee, and hip. Subjects also wore reflective markers for quantitative video analysis.

Comparisons of upward reach motion patterns were made between accelerometric vector magnitudes ("VEC") and electrogoniometric ankle excursions. Three events of upward reach were identified: initial heel raise (**HR** in figure), peak (**P**) heel raise, and heel contact (**HC**). Times between these 3 events were calculated, and plotted motion patterns from VEC and ankle angle data were evaluated.



Results: 3 events (**HR, P, HC**) could be clearly detected from the VEC vs. time curve, and found to consistently coincide with those displayed by the curve of the ankle angle. Initial **HR** was identified as the first major upward deflection from baseline, signifying a positive acceleration as the body is pushed upwards when the heels are raised.
The VEC curve then reverses and approaches its first major minimum at **P**, when deceleration occurs as the heels are raised to their highest end of the ankle excursion. **HC** is distinguished as a marked upward deflection, a positive acceleration most clearly seen as a sharp spike when the subject lands hard on the heels, or more subtly when the subject lands softly with more graded control. Repeatable patterns were found between different upward reach trials from the same subject. Timing between the phases of **HR, P**, and **HC** were also similar in repeated trials.

Conclusions: Changes in acceleration magnitude patterns correlate with changes in ankle angle, and clearly correspond to detectable events during upward reach. It is possible to identify different strategies that may allude to issues of motor control and balance when performing the fairly destabilizing activity of upward reach. Although upward reaching strategies varied, accelerometric motion patterns were still similar across subjects and events were repeatably identified in the same manner.

Clinical Relevance: An easy-to-use method of quantifying balance-related upper body motion would enable clinicians to diagnose more subtle disorders of postural neurocontrol and more precise gradations of improvement or worsening of a patient's condition. Wearable self-contained motion sensing apparatus should reduce errors of qualitative judgement during clinical balance assessment, and permit quantitative balance testing in a natural setting.

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COMMUNICATION, SENSORY AND COGNITIVE AIDS

Abstract #
C43 - C74

C-43

E ASSESSMENTS FOR VISION REHABILITATION

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Objective: The purpose of this study was to develop and validate discipline-specific training outcome assessments (performance measures) that are used to determine the efficacy of the VA's vision rehabilitation programs. Efficacy measures provide an estimate of the training effect acquired in the controlled, treatment setting. This presentation will focus on the pre- and post- assessments developed for Computer Access Training Skills (CATS), Living Skills (LS), Orientation and Mobility (O&M), and Visual Skills (VS).

Method: Phase I consisted of: 1) establishing clinical work groups comprised of representatives from the training disciplines at each of the nine Blind Rehabilitation Centers (BRCs); 2) identifying training outcomes for each discipline using a modified *Delphi* technique; 3) developing appropriate scaling; 4) pilot testing preliminary versions; and 5) conducting psychometric analyses and revising instrumentation as necessary. Initial analyses addressed content and construct validity as well as the reliability of the instrumentation. In Phase II, the revised instrumentation was field tested at two BRCs on over 300 veterans. Data analyses for this phase included examination of the role of item response theory (IRT), which is important in establishing scalability. The inter-rater reliability of clinicians' scores was estimated within and between centers. Change scores, effect sizes, and a reliability index were computed for each disciplinary assessment. Mean paired t-tests were used to determine if significant changes in skill levels had occurred. Veterans also rated their perceived ability to independently perform the identified outcomes at admission and discharge and the self-ratings were compared to the objective ratings provided by trained instructors.

Results: The scales developed for LS and O&M assessments contain a 10-point ordinal scale. Both CATS and VS have a scoring criteria that assigns points based upon abilities to complete sub-components of the training outcome with a maximum total score of 100 points. Content and construct validity were confirmed in Phase I. Although results from the Phase II analyses are too numerous to list in this abstract, results reported in the presentation will focus on the reliability of the measures, a reliability index of the change scores, and the associated effect sizes for each discipline. Significant training and clinical effects were found across the four disciplines. A wide range of correlation was found between veterans' and instructors' ratings across disciplines and the domains within disciplines. This finding supports other published studies that indicate a lack of congruence between self-report ratings and measured ability.

Conclusions/Clinical Relevance: The training outcome assessments provide clinicians with a reliable method for assessing visual needs, developing treatment plans, and determining the duration of treatment. Patient profiles will be created from the training outcome data, which will eventually be used by clinicians to more precisely tailor training to meet the individual needs of veterans. In addition, once efficacy is established for a program, the theoretical link between changes in a veteran's level of performance and the impact this has on long-term outcomes (i.e. measures of effectiveness) can be determined.

C-44

RELIABILITY OF THE VETERAN AFFAIRS SENTENCE TEST (VAST)

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Objectives: (1) To select an appropriate presentation level (dB HL) on which to begin threshold testing using the VAST, and to evaluate the efficiency of the VAST, that is, the minimum number of trials or sentences required to maintain accuracy and reliability. (2) To assess the test-retest reliability and to determine the homogeneity of the various versions and sub-lists of the VAST protocol in terms of the obtained SRT scores. (3) To examine the effects of lexical variables, word expectancy and confusibility, on observed intelligibility. (4) To assess the influence of audiometric characteristics of the listener and linguistic background.

Methods: All sublists of the VAST were compared in a test-retest format with a one-week delay. Testing was performed in a quiet environment. Subjects ranged in age from 22 to 65 years, were native speakers of English, and all had normal hearing as defined by ≤0 dB HL from 250-4000 Hz, normal immittance measures, reflex thresholds <95 dB HL. An adaptive procedure was employed to track VAST thresholds for thirty-six subjects.

Results: Reliable speech reception thresholds can be obtained with the VAST protocol within 10 to 12 sentence presentations, with a test-retest difference of less than 3 dB-HL. Further, no significant difference across sublists of the VAST were found when lexical characteristics were controlled. Previous studies, demonstrating significant ($p < .001$) differences attributable to word usage frequency and word confusibility were replicated. High-usage words were more intelligible than low-usage words, and words in sparse neighborhoods were more intelligible than words in dense neighborhoods when overall RMS levels were equated. Additional data are currently being collected to assess the reliability of the VAST for non-native speakers of English.

Conclusion: These sentences will form the basis for a new speech recognition test that isolates significant non-acoustic sources of variation using sentence materials. The protocol will greatly improve the evaluation of speech communication in any environment, through a more efficient, reliable, and valid method.

Funding Acknowledgement: This project is supported by a Merit Review from Rehabilitation, Research and Development Service, Department of Veteran Affairs.

Clinical Relevance: These test materials are easily adaptable to an audiology environment in which precise measures of speech intelligibility are required for both aided and unaided measures of speech recognition.

C-45

EFFECTIVENESS OF ACCESSIBLE PEDESTRIAN SIGNALS

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Objective: The purpose of this developmental project is to evaluate commercially available Accessible Pedestrian Signals (APS) and select two for future research based on an eight item protocol. A second purpose of the project is to reduce the number of measures in the eight item protocol if there is a strong correlation between the measures.

Methods: Eight of the ten different APS from the three different category types were selected. These devices were installed in four different intersections along the same street in Decatur, Georgia. The intersections were selected to be comparable in number of traffic lanes and traffic density. As part of a meeting of the Southeast Orientation and Mobility Association (SOMA) data was obtained on 178 participants. There were three major reasons for using these orientation and mobility specialists as subjects. First, they have all been trained in the use of orientation and mobility techniques as part of their professional training. Second, they provide a large subject pool in a short period of time in a geographical area with limited subjects. Third, this professional group has extensive experience with training individuals with a visual impairment to use pedestrian signals and to cross streets. The O&M specialists were divided into groups of 3s: one person was under blindfold using the APS to cross the street, one served as the spotter and one collected the data. The order of APS trials was randomly assigned to each group. The data was collected using the following protocol based on the work of Crandall, Bentzen and Myers (1998). The following measures will be obtained from each group for each APS.

Safety

1) The time from the activation of the walk signal until the subject starts crossing measured at the point the foot touches the street.
2) The number of walk cycles before subject crosses after subject is at the curb.

Alignment/Precision

3) Distance from the center of the of the crosswalk of the beginning corner.
4) Distance from the center of the of the crosswalk of the destination corner measured at the curb.
5) The difference between 3&4 above (the amount of veer).
6) The speed of the crossing.

Security

7) On a scale of 1-10, the level of confidence the subject had in the street crossing.
8) On a scale of 1-10, the level of comfort/ease the subject experience in the street crossing.

Results: The data (including performance times and errors, self report Likert scales indicating subject preferences, and open ended questions for subject comments and suggestions)is being analyzed in the following manner: a 2-way repeated measures ANOVA (APS and Measure). Descriptive statistics to assess overall function with the APS systems is also being included. Correlations between functional measures are being generated to assist the investigators in reducing the number of measures.

Conclusions: The data analysis is not far enough along and therefore any conclusions would be premature.

Funding Acknowledgment: This project was supported by the Atlanta VA Rehab R&D Center Core funds as a developmental project.

Clinical Relevance: This proposed research is essential for further research in an effort to develop a comprehensive wayfinding/orientation system for visually impaired individuals. This proposed work will complement the research (Global Positioning System, “dead reckoning,” and cybercrumbs) underway by Ross and Blasch to develop a comprehensive wayfinding/orientation system.

C-46

LEXICAL EFFECTS ON DICHOTIC WORD RECOGNITION IN YOUNG AND ELDERLY LISTENERS

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Objectives: The Neighborhood Activation Model (NAM) of spoken word recognition assumes that words are recognized in the context of other similar sounding patterns in memory. Investigators have demonstrated that both the speed and accuracy of processing spoken words differ as a function of the lexical properties of the words. Moreover, the lexical properties have differential effects on word recognition performance in older and younger adults, suggesting that age-related changes in cognitive capacities might reduce the efficiency of accessing words in memory and thus contribute to the poorer word recognition ability characteristic of older listeners. This study was designed to examine the effects of age and hearing loss on dichotic word recognition within the framework of the NAM.

Method: Monosyllabic word pairs differing in the lexical properties of *neighborhood frequency* and *neighborhood density* formed the following dichotic pairings: (1) an EASY word with a HARD word, (2) a HARD word with an EASY word, (3) an EASY word with EASY word, and (4) a HARD word with HARD word. The words were presented at 70-dB HL to 24 young adults with normal hearing, 24 elderly adults with normal hearing, and 24 elderly adults with mild-to-moderate sensorineural hearing loss.

Results/Conclusions: The data for young adult listeners indicate that EASY words are recognized correctly more often than HARD words in all listening conditions. More importantly, the lexical characteristics of words have an effect on the way words are recognized dichotically. With HARD words to the left ear, and EASY words to the right ear, there is a significant right-ear advantage. With EASY words to the left ear and HARD words to the right ear, the right-ear advantage is minimal (non-significant). It is hypothesized that the differences in ear advantage may be a result of the processing of stimuli from the left ear. Data on half of the elderly subjects have been collected and indicate a similar ear pattern as well as reduced word recognition ability as compared to the young adult group and poorer word recognition for elderly listeners with mild-to-moderate SNHL as compared to those with normal hearing. Data collection and statistical analysis will be completed by December 1999.

Funding Acknowledgement: The first author is on a Career Development Award sponsored by the Rehabilitation, Research and Development Service.

Clinical Relevance: Explanations for age-related deficits in word recognition that are based on cognitive factors (i.e. the NAM), rather than the more traditional sensory factors, have important consequences when choosing rehabilitation strategies. The use of hearing aids has been the primary intervention for improving speech perception. Although this approach is successful in many cases, research focusing on more cognitive-based explanations for difficulties with word recognition suggests that a focus on sensory factors alone may have only limited clinical utility. An integrated approach incorporating both cognitive and sensory factors is likely to be of greatest benefit in designing strategies for improving speech perception in older adults.

C-47

OUTCOMES ASSESSMENT OF THE REHABILITATION OF VISUALLY IMPAIRED

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Objectives: The purposes of this project are to establish the psychometric properties of instruments used to gather data relevant to blind rehabilitation outcomes, to refine the scaling and scoring protocols for the instruments, and to revise and refine the instruments.

Methods: This ongoing three year project is gathering outcome and demographic data from an estimated 1,500 visually impaired persons per year using the following core measures: Blind Rehabilitation Service Follow-up Outcome Survey (BRSFOutSur) measuring functional performance, Blind Rehabilitation Service Data Base (BRSDBase) recording subject characteristics, Blind Rehabilitation Service Satisfaction Survey (BRSSatSur) measuring satisfaction with rehabilitation. The demographic database consists of the extensive information about the blinded veteran demographic, rehabilitation, and medical history. The satisfaction survey consists of eighteen items pertaining to programmatic issues in residential blind rehabilitation. The analyses of this rich pool of data will be used to validate and test the reliability of the instruments and to begin to propose benchmarks for blind rehabilitation services. All demographic data are sent to the Atlanta VA Rehabilitation R&D Center at the time of the subject's discharge. A research associate from the Rehabilitation R&D Center telephones the subject within a month of completion of Blind Rehabilitation and administers the Blind Rehabilitation Service Follow-up Outcome Survey and the Blind Rehabilitation Service Satisfaction Survey. The data gathered will be assessed on an annual basis for reliability through test-retest (5% of subjects called again within one week of the post-rehab administration), inter and intra observer (5%), and internal consistency (coefficient alpha) methods. Assessment of criterion validity will be based both on agreement between BRSFOutSur data and expert ratings of functional performance derived from videotapes of 5% of the subjects demonstrating task performance in or around their homes. Subject characteristics contained in the BRSDBase will be evaluated for association with rehabilitation outcomes and risk adjustment models and casemix measures will be developed.

Results: As of June 25, 1999, data from 2,932 subjects have been collected for the demographic instrument, 1,745 subjects for the functional outcomes instrument, and from 2,125 subjects for the satisfaction instrument. Findings to be presented at IMC X will be based on a significantly larger number of subjects.

Clinical Relevance: It is anticipated that these findings and the further development of outcome instruments in this area will contribute to greater efficiency and effectiveness of the delivery of VA blind rehabilitation services.

This project is funded by the Department of Veterans Affairs Rehabilitation Research and Development Merit Review Grant # C-2179-R & C-2241-R.

C-48

EFFECTS OF LEXICAL DISCRIMINATION ON WORD RECOGNITION

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Objectives: The experiments were designed to examine the effectiveness of the Neighborhood Activation Model (NAM, Luce and Pisoni, 1998) to account for the effects of higher level lexical information on spoken word recognition in normal and hearing-impaired listeners. NAM suggests that words are recognized relationally in the context of other phonetically similar words (similarity neighborhood). Characteristics of the neighborhood structure are "neighborhood density" (number of words similar to target word) and "mean neighborhood frequency" (average frequency of occurrence of words in the neighborhood) while a third factor, "word frequency" (frequency of occurrence of target word in the language), biases the system toward optimal word recognition processing.

Methods: During a developmental phase, 1020 familiar CVC (consonant-vowel-consonant) words were identified and partitioned into eight lexical groups by performing median splits on the value of each of the three lexical characteristics. Combining the three lexical variables and two levels (high, H or low, L) resulted in eight experimental conditions, HHH, HHL, HLH, HLL, LHH, LHL, LLH, and LLL (designated by high (H) or low (L) word frequency, neighborhood density and mean neighborhood frequency, respectively). From the available words, 400 test words were chosen, 50 words in each lexical condition. Each group of 50 words contained equivalent numbers of phoneme types. A male and female recorded the words which were then digitized as a sampling rate of 24 kHz. Three experiments were conducted: 1) 20 young normal hearers listened to the words in speech-shaped noise; 2) 34 young normal hearers listened to the words in quiet; 3) 20 elderly persons with moderate sensorineural hearing loss listened the words in speech-shaped noise.

Results: The rank order of the eight lexical conditions, from highest to lowest in intelligibility, was similar for both normal and elderly hearing-impaired listeners. As predicted by NAM, the highest scores were obtained for the condition incorporating high word frequency, low neighborhood density and low mean neighborhood frequency, and the lowest scores were found for the condition with low word frequency, high neighborhood density and high neighborhood frequency. Analysis of variance (ANOVA) identified significant main effects for each of the three lexical factors.

Conclusion: The results verified the predictors of the NAM model and extended results to listening condition in noise and in quiet and to elderly persons with sensorineural hearing loss. Future development of speech recognition tests should allow for the effects of higher level cognitive (lexical) factors on level phonetic processing when evaluating veteran as well as non-veteran populations with hearing loss.

Acknowledgments: This research as supported by VA RR&D grant C2225R and National Center Grant, RCTR-S97-0160.

From: VA Greater Los Angeles Healthcare System; National Center for Rehabilitative Auditory Research and UCLA School of Medicine.

C-49

EARLY DETECTION OF OTOTOXICITY USING A RAPID PROCEDURE WITH HIGH SENSITIVITY

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Objectives: The aim of this study was to identify auditory frequencies at which serial threshold testing would provide the greatest sensitivity for early detection of ototoxicity. The overall objective is to develop a more time-efficient ototoxicity monitoring protocol.

Methods: Threshold data were analyzed from 370 hospitalized patients treated with aminoglycoside antibiotics (AMGs) or cisplatin (CDDP) who received serial auditory monitoring before, during and after treatment at conventional (0.25–8 kHz) and high (9–20 kHz) frequencies.

Results: For patients showing hearing changes due to ototoxicity, a frequency range was identified for its apparent high sensitivity to initial ototoxicity. This sensitive range is identified according to an individual's hearing threshold configuration, and is, therefore, unique for each patient. The range consists of five frequencies, generally separated by 1/6 octave, e.g., 8, 9, 10, 11.2 and 12.5 kHz. To determine frequencies and combinations of frequencies that were most often involved in ototoxicity detection, threshold data in the sensitive range were analyzed in detail. This analysis suggests that patients receiving treatment with AMG or CDDP can be monitored for hearing thresholds at only five frequencies, resulting in an 84% detection rate for AMG and 94% for CDDP compared to monitoring at all conventional and high frequencies.

Conclusions: This comprehensive analysis supports earlier observations that a sensitive, limited frequency range exists where serial threshold monitoring will provide early warning of ototoxicity prior to effects in the speech frequency range. This finding is now being evaluated in a prospective investigation.

Funding Acknowledgement: VA RR&D Service (RCTR 597-0160; C227-3RA)

C-50

DEVELOPMENT OF A COMPUTERIZED SYSTEM FOR CONDUCTING AUDIOMETRIC RESEARCH

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Objectives: For the conduct of auditory research, there is the continuing need for specialized instrumentation to execute the experimental testing protocols. Commercial instrumentation used for conventional clinical testing is not modifiable for specialized research purposes. We have also found that research instrumentation is not adequate. Custom hardware and software have therefore been developed in this laboratory to enable flexibility in carrying out the unique testing protocols. The objective of this presentation is to describe the system and its variety of functions for research utilization. Two custom testing systems will be demonstrated at the meeting as part of this presentation.

Methods: The first requirement was to design and build hardware that could be controlled by a computer and facilitate all of the functions needed for audiometric research. The PAL3000 (Programmable Auditory Laboratory–3000) is the instrument that was developed for this purpose. The PAL3000's embedded microprocessor works in conjunction with sophisticated analog circuits providing both pure-tone and noise signal generation, audio signal conditioning, switching, mixing, attenuation, and power buffering. The instrument is controlled through the use of simple ASCII commands transmitted over an RS-232 computer serial port. The commands can be entered interactively by an operator at a terminal, or they can be transmitted by a software program running on a personal computer (providing a custom programmable interface for specific laboratory experiments).

Result: Two complete testing systems have thus far been developed using the PAL3000. The first is a specialized audiometer for monitoring auditory thresholds of patients receiving treatment with potentially ototoxic medications. This audiometer enables testing at 1/6-octave frequencies throughout the audible frequency range. This technique is being evaluated in a current study for early detection of ototoxicity. The audiometer automatically identifies the “sensitive range for ototoxicity,” and displays special windows for testing in this range. Changes in auditory threshold indicating ototoxicity are flagged automatically. A second system has been developed for conducting computer-automated evaluation of tinnitus loudness and pitch matches. This system utilizes the PAL3000, and a second, linked, computer which drives a second video screen for the patient. The patient sits facing the video monitor which displays testing instructions. The patient responds to all aspects of testing by finger-touching the screen. Multiple studies have been completed using this system, and data show good test-retest reliability of hearing thresholds, loudness matches and pitch matches.

Conclusions: The RR&D Center for Rehabilitative Auditory Research has fully developed core hardware and software for conducting various types of psychoacoustical research. Two current projects demonstrate the considerable flexibility of this system to be adapted to different auditory research needs. The system has future applications for all projects to be conducted under the auspices of this RR&D Center and are under continual development.

Funding Acknowledgement: VA RR&D Service (RCTR 597-0160; C891-RA; C227-3RA)

C-51

LOW VISION DEVICES MOST PRESCRIBED BY VA PRACTITIONERS

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Objective: staff of the department of veterans affairs blind rehabilitation centers (brc's) and visual impairment centers to optimize remaining sight (victors) are leaders in the field of low vision rehabilitation in terms of practice , education, and research. Device prescription reflects one element of practice patterns. There are multitudes of low vision devices available, and practitioners learn by trial and error which devices work best for most patients, are of high quality, durable, and economical. The purpose of this study is to determine the low vision devices (lvd's) most commonly prescribed to visually impaired veterans participating in programs of the department of veteran's affairs brc's and victors programs.

Methods: survey of device issuance by the department of veteran's affairs blind rehabilitation centers and victors. Surveys were sent to 9 brc's and 3 victors programs. All of the brc's and two of the victors programs responded.

Results: 44 specific devices were estimated to have been issued over 100 times each in fy 1997. Devices included 13 types of sunwear, 4 types of hand-held magnifiers, 2 types of reading stands, 3 types headband magnifying devices, 5 types of telescopic monoculars, 3 types of illuminated pocket magnifiers, 3 types of accessories, 2 types of spectacle mounted devices, 2 types of microscopic spectacles, 1 type of headbourne device, 2 types of cctvs, 2 types of lamps, and two types of handles for stand magnifiers. Devices will be listed by manufacturer and product number.

Conclusions: as the veteran population ages the department of veterans affairs will be presented with a ever burgeoning number of visually impaired veterans. The va must be ready to serve those veterans in an effective and cost efficient manner. Low vision rehabilitation requires specialized magnification devices and training in how to properly use each device. Some of this device prescription and training may be done in a primary eyecare setting. Study of the low vision devices most prescribed by specialized practitioners in the blind rehabilitation centers and victors programs may help form a core set of prosthetic devices to be used in primary eyecare clinics of optometry and ophthalmology throughout the department of veterans affairs healthcare system in order to provide timely low vision services to a larger number of visually impaired veterans.

C-52

RELIABILITY OF TINNITUS LOUDNESS MATCHES

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Objectives: Tinnitus, especially that associated with noise-induced hearing loss, is a major problem for veterans. However no standard protocol exists to manage, quantify, or document the existence of tinnitus in veterans. The objective of this study is to develop a clinically useful tool to quantify loudness-one acoustical parameter of tinnitus. Using a custom-built, fully automated system, two different test methods were employed in order to determine how best to obtain reliable, repeatable hearing thresholds and tinnitus loudness matches at a series of audiometric frequencies.

Methods: Twenty subjects with self-reported stable, tonal tinnitus were asked to make judgments regarding their tinnitus loudness in comparison to a matching tone presented contralateral to the ear with the most severe tinnitus. Instrumentation consisted of a desktop PC on the tester's side of the soundbooth, a custom-built signal generator designed at the Oregon Hearing Research Center, and a laptop PC located inside the booth for recording subject responses. Subjects read written instructions from the computer screen and indicated response choices by touching response "buttons" on the screen. Procedures were repeated twice over the course of two sessions, which were separated in time by a maximum of two weeks. Two different methods were used in each session. The "Fixed" method employed matching tones presented at fixed sensation levels relative to threshold. Using the "Random" method the matching tones were presented at randomized sensation levels.

Results: Data were analyzed to evaluate differences in repeated subject responses. Both threshold and loudness match results were found to be reliable and repeatable within and between sessions, regardless of which method (Fixed or Random) had been employed. Pearson r's were calculated for all combinations of within-session and between-session reliability of loudness matches. For comparison, Pearson r's were also calculated for hearing thresholds obtained in each condition. Pearson r's at all test frequencies for thresholds and loudness matches recorded in dB SPL were significant at $p < .001$.

Discussion: Continued research in the area of automated testing is expected to contribute to the on-going effort to quantify the acoustic parameters of tinnitus. Reliable clinical tools such as the automated system are essential to the process of developing a standardized approach to measuring and eventually managing clinically significant tinnitus in veterans.

Support for this project was provided by grants 0891 and RCTR 597-0160 (Portland RR&D Center) from the U.S. Department of Veterans Affairs, Rehabilitation Research and Development Service.

C-53

READING WITH A CENTRAL SCOTOMA: TRAINING AND DEVICE AFFECTS ON THE REHABILITATION OUTCOME

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Objective: This study assessed the amount of training needed and the relative effectiveness of different low vision reading aids. Central visual field loss (CVF), typically age-related maculopathy, accounts for most admissions to VA Blind Rehabilitation Centers. Service guidelines for reading rehabilitation with low vision veterans currently specify ten training sessions with an optical aid (OA) and 15 sessions with a closed circuit television (CCTV), and state that to prescribe a CCTV the patient should demonstrate 50% greater productivity with the CCTV. The first objective (Phase 1) of this study assessed the impact of varying amounts of training on reading performance. The second objective (Phase 2) compared the reading performance of central field loss patients using a CCTV and prescribed OA. A third objective (Phase 3) compared the Phase1 training model with that typical of non-VA low vision clinics (Brief Training; i.e., one training session with OAs and two sessions with CCTV).

Method: Ninety subjects (Ss) participated in the first phase of this project which compared reading performance (speed, duration, and comprehension) for Ss receiving either five (partial-training) or ten (full-training) 40-minute sessions of training with their prescribed OA, and either seven (partial-training) or 15 (full-training) 40-minute sessions with a CCTV. The order of presentation (OA or CCTV) was counterbalanced to eliminate order effects. Subjects were randomly assigned to groups and were volunteers in accordance with an approved protocol. In the second phase, which compared the effectiveness of OAs and CCTVs, the data from the 90 Ss in the first phase was collapsed and compared using t-tests on the subject means. The third phase methodology provided one session of OA training to each subject (N = 14), then four sessions of independent practice, followed by five sessions of training. Similarly, a CCTV group (N = 27) received two sessions of training, then five sessions of practice, followed by eight sessions of training. Thus, the two subject groups received the same amount of training and practice as did Ss in Phase 1's partial training. The performance curves of these Ss were compared to those in Phase 1, and t-tests were computed to determine if performance differences resulted from the different training protocols.

Results: Partial-training sessions with OAs and CCTVs were found to be as effective as full-training sessions in improving reading performance. CCTVs were found to provide significant benefits for patients with CVF losses. Brief-training sessions with OAs were not effective in improving reading performance with OAs. Since the delayed training of this condition was found not to be as effective as initial training this phase was terminated early because it was detrimental to Ss. Brief training with CCTVs was effective for some, but not all Ss. Correlations between reading speed and clinical measures were modest (i.e., $r=-0.26$, $p<0.014$). Initial and final reading speeds were strongly correlated (i.e., $r=0.76$, $p<0.000$), but initial and final durations were only modestly correlated (i.e., $r=0.44$, $p<0.000$).

Conclusions: The data suggest that VA reading training protocols can be reduced in length by 50% without decreasing the quality of patient outcomes. This would result in substantial cost savings over current guidelines, and provide improved methods to assess training outcomes. CCTVs offered substantial benefit, compared to OAs, for patients with CVF loss. The data suggest the VA should not adopt private sector models of reading rehabilitation as this would reduce quality of care. Future low vision reading studies can be improved by accounting for training/practice effects.

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C-54

THE FUNCTIONAL ASSESSMENT OF SELF-RELIANCE ON TASKS (FAST): A MEASURE OF VISION REHABILITATION TRAINING EFFICACY

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Objectives: The objective of this study was to assess the reliability and validity of the Functional Assessment of Self-reliance on Tasks (FAST) in measuring functional change in a clinical setting, and to explore its psychometric properties. In this context the term *functional change* is defined as an aggregate measure of a veteran's functional improvement (or decline) over a specific period of time (e.g., pre- and post- treatment).

Methods: During the pilot phase of this project, an iterative, staff-driven process was used to develop the FAST. Through this process 19 items were pilot tested and examined for validity (i.e., acceptance by the treatment team), and statistical significance. Items not meeting these criteria were culled. Treatment teams consisting of the patient's instructors from the four disciplines with Nursing's involvement scored items on a 10-point scale by arriving at consensus for each item. Each veteran was rated twice, once after an initial assessment and once just prior to discharge. A convenience sample of 230 visually impaired veterans enrolled at the SouthWestern Bind Rehabilitation Center, a residential, hospital-based program constituted the sample for the current study.

Results: Factor analysis revealed three subscales (Instrumental Activities of Daily Living, Orientation and Mobility, and Health Maintenance) accounting for 76% of the factor structure measured. The reliability of the subscales was determined using Chronbach's alpha with coefficients between .90 to .95. Multitrait scaling, adapted from an approach to multitrait analysis (Hays & Hayashi, 1990), was conducted to ascertain item-scaling correlations, or convergent and discriminant validity. Change scores indicated a significant training effect across the three subscales.

Conclusions: The FAST is a reliable and valid outcomes measure with the capability of benefiting clinicians, patients, and administrators. Clinicians are able to meet patient needs by identifying training effects, thus, achieving training objectives. Patients receive the requisite training thus achieving a higher level of functional status. Finally, administrators who use the FAST results are able to accurately describe the efficacy of the training program, thereby providing an efficient feedback loop for patients and clinicians. Above all, the FAST provides an added measure of program efficacy that has been lacking in vision rehabilitation.

Clinical Relevance: The FAST is a parsimonious measure of program efficacy that may be used by clinicians to facilitate the implementation of treatment programs (e.g., identify services needed, facilitate client placement, and establish duration of treatments), improve clinical communications, maximize resource utilization and demonstrate changes in status and function.

C-55

DEVELOPMENT OF AUTOIMMUNE SENSORINEURAL HEARING LOSS IN NORMAL MICE BY INOCULATION WITH THE DNA BINDING PROTEIN

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Objectives: The mechanisms by which autoimmune disease affects the inner ear is currently unknown. MRL/lpr autoimmune mice with spontaneous hearing loss have been shown to have abnormal binding of DNA in the ear, suggesting autoantibodies to this cell surface receptor may be responsible for the cochlear dysfunction. To test this hypothesis, normal mice were inoculated with the DNA receptor protein to determine if they develop autoantibodies and the pattern of serum and cochlear abnormalities seen in this clinical disorder.

Methods: Baseline auditory brainstem response thresholds were obtained to tone-burst stimuli at 4, 8, 16, and 32 kHz for each mouse in the study. Baseline measures of serum immune complexes and antinuclear antibodies also were established. Ten CBA/J mice and 7 C3H/HeSnJ mice were inoculated i.p. with the partially purified DNA receptor protein (10 g/200l PBS) every ten days for eight months. Control CBA/J mice received an equal volume of PBS i.p. on the same dates. ABR and serum collection were conducted every 6 weeks postimmunization to assess changes in auditory thresholds, as well as serum levels of immune complexes and antinuclear antibodies.

Results: Within 2 months of the first inoculations, both CBA/J and C3H/HeSnJ mice showed significantly elevated serum immune complexes and antinuclear antibodies, which continued throughout the inoculation period. ELISA analyses showed elevated antibodies specific to the DNA receptor protein. After 8 months of inoculation, a number of C3H/HeSnJ mice showed elevated ABR thresholds, amounting to as much as 30-40 dB compared to controls and baseline.

Conclusions: The inoculation of normal mice with the DNA receptor protein established the symptoms of autoimmune sensorineural hearing loss. This included elevated hearing thresholds, serum immune complexes, and antinuclear antibodies. These autoimmune symptoms were similar to what we have observed previously in C3H/lpr and MRL/lpr autoimmune mice. Furthermore, these changes match what is reported for patients with autoimmune sensorineural hearing loss. The identification of this possible autoimmune hearing loss mechanism will now permit us to evaluate patient sera for similar changes and establish interventional therapy protocols.

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C-56

TINNITUS PITCH MATCHING USING COMPUTER AUTOMATION

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Objectives: Tinnitus is the perception of auditory sensations (e.g., ringing or buzzing) in the absence of external sound stimulation. Although tinnitus is particularly problematic for veterans, the VA medical center system has no established protocol for tinnitus management. There are also numerous tinnitus claims submitted by veterans for compensation benefits, which are generally uncontested because no procedures exist to assess their validity. In 1998, over 115,000 veterans received tinnitus disability compensation amounting to over $110,000,000. The objective of this study is to determine a reliable clinical method for quantifying the pitch perception of tinnitus.

Methods: A psychoacoustical testing system was designed, assembled and programmed to perform automated tinnitus evaluation without operator intervention (except to answer questions). The testing hardware consists of a main computer and peripheral components, located in the testing room, and a portable "touch-sensitive" computer monitor located in the sound booth. The patient receives instructions via text displayed on the touch screen, and then touches the screen by fingertip to make response choices. Two experiments were conducted to determine the most reliable method for tinnitus pitch matching. All procedures were repeated over two testing sessions. Study 1 evaluated the "Octave" and "Binary" automated pitch matching techniques. These techniques were similar except that the Octave technique started testing at 1000 Hz while the Binary method started at 4000 Hz. Each techniques used a rendition of the two-alternative forced choice (2AFC) procedure in which two tones were presented to the subject, who selected the one closest in pitch to the tinnitus. Each response guided the computer to the next test frequency. For Study 2, the Binary protocol from Study 1 was compared to the "Subject-Guided" protocol, and to the "Manual" protocol (pitch matching controlled by an examiner). The Subject-Guided protocol allowed the subject greater control over the test stimulus by enabling the subject to guide the presentation of tones up or down in frequency to approach the pitch match.

Results: Twenty subjects completed Study 1, and 42 subjects completed Study 2. For Study 1 the Binary procedure resulted in better pitch match reliability than the Octave procedure, as verified by paired *t*-tests, correlation coefficients, and difference scores. The Binary procedure was therefore used in Study 2 to compare its results with other methods for pitch matching. Results of Study 2 indicated that all three methods provided good test-retest reliability as indicated by the Pearson *r*'s that ranged from .612 to .754 ($p < .0001$ for all). Overall, the Binary method provided the greatest overall pitch match reliability.

Conclusions: These data are from an ongoing series of studies that are designed to develop an automated matching method for the clinical assessment of tinnitus. With continued funding, the projects will result in a system that is capable of providing a battery of tinnitus tests for comprehensive tinnitus quantification.

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C-57

VISUAL CORRELATES OF MOBILITY IN PERSONS WITH AGE-RELATED MACULAR DEGENERATION

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Objectives: To determine the effects of reducing light level on mobility performance in persons with age-related macular degeneration (ARMD) and how performance relates to measures of visual sensory and perceptual function. ARMD results in the loss of central, high acuity vision and is the leading cause of vision loss in veterans participating in the blind rehabilitation programs of the Department of Veterans Affairs.

Methods: In 41 subjects with ARMD (mead age = 72.5 years), acuity, log contrast sensitivity, visual field extent, glare disability, color confusion, spatio-temporal contrast sensitivity, motion sensitivity, scanning ability and figure-ground discrimination were measured to determine their ability to predict mobility performance. Mobility performance was assessed under photopic (high illumination) and mesopic (low illumination) lighting conditions on a laboratory obstacle course and on two real world courses, and indoor hallway and an outdoor residential route.

Results: Reducing illumination resulted in significant increases in the time to complete each course and the number of mobility incidents (errors) that occurred. Two measures of overall performance, total time and total mobility incidents were calculated for each course by summing time and incidents over the two illumination levels. Combinations of vision variables were able to account for 30 to 60% of the variance in the measures of overall performance. Log contrast sensitivity measured with the Pelli-Robson chart test was the most important predictor of performance followed by visual field extent, scanning ability, peak contrast sensitivity for moving gratings, glare sensitivity, and color confusion. Except for log contrast sensitivity, the appearance and ordering of vision variables in predictive models of performance depended strongly on the performance measures and on the mobility task (course).

Conclusions: In contrast to previous reports, we found that reducing illumination from photopic to mesopic levels had an adverse effect on mobility in persons with ARMD. Furthermore, we found that measures of mobility and visual function were significantly correlated in both illumination conditions. The best overall predictor of performance in the laboratory and real world settings was log contrast sensitivity. However, scanning ability was nearly as important when the primary task was detecting and avoiding obstacles. Since scanning ability is a visual cognitive task, the possibility exists whtat cognitive training might improve performance.

Sponsorship: Department of Veterans Affairs Rehabilitation Research and Development Service, Washington, DC (project #C775-RA).

C-58

ACTIVE HEARING PROTECTION: AN INEXPENSIVE IN-THE-EAR APPROACH

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Objectives: The veteran who wears ear plugs or earmuffs religiously on the shooting range often will wear no hearing protection while hunting or in other situations that involve random impact noise. The wearable hearing protectors described in this report were designed: 1) to offer little or no sound attenuation in a quiet environment; 2) to "shut down" in the presence of any sound over 85 dB sound-pressure level (SPL); and 3) to be custom-molded in soft polymer ear plugs that fit comfortably in the ear canals of the wearer.

Methods: "Off-the shelf" hearing aid-amplifiers and transducers were configured to produce a maximum (saturation) sound-pressure level (SPL) of 88 dB in a standard 2-cm^2 acoustic coupler. These units then were incorporated into custom hearing protectors for both ears of 10 listeners with normal hearing. The subjects all were hunters or shooters. The "real-ear" attenuation provided by these hearing protectors was evaluated with standard (ANSI) 1/3-octave bands of noise presented from a loudspeaker in a sound-insulated chamber. First, auditory thresholds were measured for each subject with both ear canals open. Next, the hearing protectors were inserted and auditory thresholds were determined again for each subject with the hearing protectors set to "full-on" gain. Finally, auditory thresholds were obtained for each subject with the hearing protectors turned off. For one test subject, a miniature microphone was imbedded in the canal portion of her right hearing protector and spectral analyses of sounds in her ear canal were accomplished while her ear was one meter from the report of a hunting rifle.

Results: When the active hearing protectors were turned off, the mean hearing protection was similar to that provided by the best passive earplugs. When set to "full-on" gain they provided less than 10 dB of sound attenuation at the low frequencies and less than 10 dB of amplification at the higher test frequencies. For the subject who wore active protection in the presence of rifle fire, the SPL in her ear canal was no greater with the hearing protector set to "full-on" gain than it was with the device turned off. Subjectively, the experimental subjects reported: 1) that rifle and shotgun reports sounded like "misfires;" 2) that the hearing protectors were comfortable to wear; and 3) that they experienced no tinnitus aurium after using them for hunting or for trap shooting.

Clinical Relevance: Veterans, as a group, have more noise-induced hearing loss than the general population. Continued exposure to high-level acoustic signals typically adds to the total disability associated with speech intelligibility in a background of noise and with tinnitus. The hearing protectors described in this report provide a solution for the veteran who elects not to wear hearing protection while hunting or in other situations that involve random impact noise. The cost of parts for these active hearing protectors currently is less than $40.00 per ear.

Acknowledgement: This research was supported by the VA National Center for Rehabilitative Auditory Research, VAMC, Portland, Oregon.

C-59

FACTORS LEADING TO DISUSE OF LOW VISION DEVICES BY VISUALLY IMPAIRED ELDERLY

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Objective: Identify long-term use patterns of low vision devices prescribed for older adults, factors associated with disuse of a device, and appropriate modifications of devices and/or strategies indicated to facilitate more successful clinical outcomes.

Methodology: One hundred forty-two subjects who met inclusion criteria were enrolled (N=626 device-user pairs). Pre/post-test data was collected along visual psychophysical, ocular health, psychosocial, and physical health domains. Standardized research protocols were used for evaluation, training (a *criterion referenced* training protocol) and prescribing low vision devices. A monitoring system was used to track use and initiate a post-test phase. Separate sub-studies verified the accuracy of the monitoring system. Preliminary data was presented to a panel of experts representing consumers, experts in the field, and industry in order to better interpret and apply results to clinical practice and device development. Final data analysis, through Chi square, a Pearson correlation matrix, and basic t-tests, showed trends associated with device use.

Results: Unexpectedly, more than 93% of the devices remained in use, a lower than predicted level of disuse/dissatisfaction. Although this disputed much of the literature and limited the ability for pre-post-test comparisons, interesting findings emerged. Success was not associated with type of device, goal, sex, ethnicity, educational level, or diagnosis. No strong associations were seen among the various visual measures and the psycho-social/demographic measures (at the r=0.70 level or greater). Pre- and post-visual measures decreased in both successful and unsuccessful device/user pairs. Successful device-user pairs showed improvement on the Adaptation to Vision Loss scale, the Orientation/Memory/Concentration test, and the Social rating for the FAI.

Conclusions: Subject success limited post-test data available for comparison. Descriptive data emerged from this project, and interesting associations among these measures suggest important areas for further study. The interdisciplinary care strategy and the use of a new *criterion referenced* training protocol appears to have played an important role in the impressive clinical outcomes. These research methods have direct clinical application to programs designed to rehabilitate vision loss among veterans.

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C-60

REDESIGN & EVALUATION OF A DEVICE FOR REHABILITATION OF PEOPLE WITH VISUAL FIELD LOSS

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Objective: The objective of this project was to construct an improved Peripheral Vision Expansion System (PVES) prototype which would address design deficiencies identified in a previous VA Merit Review funded project and more accurately reflect the inventor's (Grech) original optical design. The device's intended use is by veterans with Retinitis Pigmentosa (RP) to increase their independence in mobility. Specifically, the research plan for this pilot project was to: 1) develop an optically improved prototype of the PVES ; and 2) provide quantitative and qualitative data concerning the effects of the PVES on orientation and mobility.

Methodology: Participants having RP (N=10) were recruited for this project. Criteria included a visual field diameter of between 5 and 20 degrees and best corrected visual acuity of 20/70 or better. Multiple clinical and extensive visual field tests were conducted with and without the prototype. Each also completed Smith's Mobility Survey for Persons with Low Vision as a pre-test evaluation of travel abilities and confidence in a variety of situations. A custom-made prototype was fitted and subjects were provided low vision mobility training in both indoor and outdoor environments with the PVES. After training was completed, participants completed a functional mobility evaluation pretest whereby the Percent of Preferred Walking Speed (PPWS) was collected in a small business setting and a shopping mall [Haymes S, Guest D, Heyes A, Johnston A. 1996. Mobility of People with Retinitis Pigmentosa as a Function of Vision and Psychological Variables. *Optometry and Vision Science, (73)*10:621-637]. During the next two weeks, participants were asked to complete daily homework assignments. They were contacted by phone several times per week to insure compliance, answer questions and provide support. Participants then completed a functional mobility evaluation post-test (collection of PPWS measures), and post-test data was collected on Smith's Mobility Survey for Persons with Low Vision and other qualitative measures.

Results: Preliminary findings suggest that the improved design largely corrected the limitations inherent in the original Grech prototype. Subjects were better able to determine depth, location and speed of travel of oncoming objects. The optics described in Grech's original prototype and analyzed by optical engineers in the previous VA-funded project appear to offer certain advantages in use (e.g., provided an easier visual transition between central and peripheral zones of the optical device).

Conclusions: The current prototype provided areas of improvement over the Gech device previously tested. In particular, the 1:1 central visual field combined with the minified "donut" peripheral field, when appropriately engineered according to the tenets of appropriate optical engineering, should provide a viable rehabilitation device for veterans with severe loss of peripheral vision, as seen in RP.

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C-61

PORTABLE SYSTEM FOR BEDSIDE OTOTOXICITY MONITORING

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Objectives: Hearing loss is a common side effect for many patients receiving treatment with potentially ototoxic drugs. Such drugs include the cancer chemotherapeutic agents cisplatin and carboplatin, as well as some aminoglycoside antibiotics. The hearing loss is often permanent and sufficiently severe to impact quality-of-life significantly. The objective of this study was to develop methodology and portable instrumentation for bedside testing. The fact that this type of testing is both quick and doesn't require the patient to leave his/her hospital room makes it feasible for use with patients who otherwise might not have been tested due to time or health constraints.

Methods: Instrumentation that was adapted for portable bedside testing included a Virtual 320 audiometer connected to a Macintosh Powerbook 180 lap-top style computer. The software that controls the audiometer was modified to identify the patient's "sensitive range for ototoxicity," track thresholds within this range relative to baseline, and flag shifts in hearing which might be due to ototoxicity. The testing system was contained in a portable case that opens at bedside for rapid setup and testing. The entire system was on a special cart which facilitated ease of transportation.

Results: The system was found to be efficient and convenient for portability and application at bedside. Ototoxicity monitoring in the laboratory has shown that testing in the "sensitive frequency range" was capable of a 90% early detection rate relative to using all frequencies (0.25 - 20 kHz). Data obtained at bedside were comparable to laboratory results. Reliability of hearing obtained at bedside was also a concern to due ambient noise in hospital wards. Threshold reliability was evaluated by comparing thresholds obtained during the patient's baseline test to those obtained 24 hours later. In most cases retest thresholds were within 5 dB of baseline, and across-ear mean differences between the sessions varied between 1.94 and 3.28 dB.

Conclusions: These data suggest that reliable hearing thresholds can be measured at bedside for patients receiving potentially ototoxic treatments. Testing the sensitive frequency range has been demonstrated to be a powerful early indicator of such hearing change. A testing protocol that is both quick and portable has the potential of benefiting population who previously could not be tested due to health related issues. Early identification of ototoxic hearing change allows for a prompt plan for its management.

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C-62

NORMAL LISTENERS' SEVERITY JUDGMENTS AND COMPREHENSION OF APHASIC DISCOURSE: VALIDATING A DUAL-TASK INSTRUMENT FOR THE ASSESSMENT OF SPOKEN LANGUAGE HANDICAP

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This investigation reports the results of two experiments conducted as part of the development of a dual-task instrument used for the evaluation of processing resource consumed by normal communicative partner while comprehending the impaired spoken language of persons with aphasia. As part of the criteria for estimating the relative degree of processing resource consumption, a reciprocal trading relationship between two simultaneously performed tasks must be demonstrated with the selective manipulation of each task's "difficulty" One procedure for this demonstration is to systematically present several difficulty levels of two tasks whose difficulty levels have been previously validated. The two experiments reported represent two preliminary studies that establish a set of dual tasks for the quantification of the trading of processing resources. In this case, the task involved the demonstration of four different levels of story retelling impairment that form one of the two tasks used in the dual-task paradigm.

One normal and 3 aphasic subjects were selected as representing four levels of spoken language competence (normal, mild, moderate, and severe) based upon their performance on standardized tests and linguistic analyses of their discourse. Twelve short story retellings from each subject served as the independent measure for both studies. In the first study, direct magnitude estimates (DME) served as the dependent measure of severity. In the second study the percentage of correctly answered multiple choice questions served as the dependent measure. The first study involved a within-subjects experimental design. Fourteen female and 6 male normal listeners (Age: M=63, range 31-78 years) made DME judgments of the severity of each of the 12 spoken samples from each of the 4 subject's. Mean differences (normal = 100; mild = 69; moderate = 22; severe = 10) were large and significant with a Friedman Repeated Measure ANOVA (X^2 = 231, 3 df, p>.000). The second study involved a between-subjects design. Fifteen (different) normal subjects answered multiple choice questions for each of the twelve stories, from <u>one</u> of the four story severities (60 total subjects: Age: M=23, range = 17-36) in order to assess the percentage of correctly answered multiple choice questions about the story's content. Results of a two-way (story severity X story form) ANOVA revealed a significant difference in the comprehension across the four levels of severity, with no significant difference across story form and no significant interaction.

The equivalence of the four story forms was also assessed from the DME and the multiple choice question data. Mean differences among DME judgments (Form A = 49; B= 50; C= 51; D = 52) and comprehension questions (obtained from the parallel story forms) were small and nonsignificant. No difference was found across forms for severity. Correlations coefficients among the four test forms were significant and high (Form A to B = .97; A to C = .98; A to D = .96; B to C = .98; B to D = .96; C to D = .98).

Results are interpreted as confirmation that the four severity level samples selected as stimuli for the development of the dual-task paradigm are reliably judged to be different and result in reliably different levels of comprehension. In addition, the data are interpreted as evidence that the previously developed four story forms are equivalent as measured by psychophysical judgment and objective level of comprehension. These results will be discussed relative to their importance in the development of a test for the clinical measurement of spoken language handicap.

C-63

IMPROVED STIMULI FOR ABR MONITORING OF OTOTOXICITY: CONVENTIONAL CLICKS COMPARED WITH HIGH FREQUENCY CLICKS AND SINGLE FREQUENCY TONEBURSTS

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Objectives: The primary purpose of this investigation was to compare auditory brainstem responses (ABRs) elicited by single frequency tonebursts, two different high frequency clicks (HFCs) and a conventional click. This comparison could be the basis for choosing stimuli most suitable for the ABR monitoring of ototoxicity.

Methods: Twenty subjects were tested in two different sessions. Duplicate ABRs were obtained in each session using four single frequency tonebursts, two HFCs and a conventional click. All stimuli were presented at 50 dB SL. The center frequency of the tonebursts were 8k, 10k, 12k and 14 kHz. One HFC had a flat acoustic output across the frequency range 8-14 kHz and the other HFC had a sloped output to more closely approximate the audiometric threshold configuration of most subjects. (The sloped HFC produced a spectral output of + 3 dB/kHz across the bandwidth 8-14 kHz). The conventional click had a frequency range of 1k-10 kHz.

Results: Effective objective testing methodology is needed for early detection of ototoxicity. The requirements for such a test include: 1. Responses that are reliable, 2. Sensitivity to ototoxic change, and 3. Time-efficiency. Although high frequency toneburst stimuli (8, 10, 12 & 14 kHz) have been shown to detect auditory changes in patients receiving aminoglycoside antibiotics and cisplantin, auditory brainstem responses to these stimuli lack the robustness of conventional click stimuli and are time inefficient to obtain. It was hypothesized that delivery of a wide-band of high frequencies, a high frequency click, would stimulate more nerve fibers than a single high frequency toneburst stimulus, and yield a more robust and easily identifiable waveform. This approach would also be more time-efficient. A previously reported stimulus, termed a high frequency click (HFC) was designed to elicit a robust response within the frequency region most likely to detect early ototoxicity (Fausti et al., ARO Abstracts, 1997). Comparisons were made of test-retest reliability, robustness and scorability of responses elicited by tonebursts and clicks. There was no difference in the reliability of responses to toneburst and the three clicks tested. The HFCs and conventional clicks produced more robust and scorable responses than the tonebursts. The responses to clicks had larger amplitudes and more identifiable waveforms than those from tonebursts. (While conventional clicks produce robust responses, they do not have the required sensitivity for testing ototoxicity.) There were more missing or unscorable responses from tonebursts than from the clicks. Finally, the calculated Testing Efficiency (in terms of detecting change) of both HFCs were as good or better than the tonebursts.

Conclusions: Both flat and sloped HFCs yielded more scorable and robust responses than the tonebursts. The HFCs did not compromise the test-retest response reliability as compared to single frequency tonebursts. The overall Testing Efficiency of the HFCs were equal to or better than the tonebursts. Given the testing protocol used in this study, the HFCs are preferred over single frequency tonebursts for the ABR monitoring of ototoxicity.

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INTRACOCHLEAR SOURCES OF ELECTRICALLY EVOKED OTOACOUSTIC EMISSIONS

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Objectives: The magnitude and frequency bandwidth of the electrically evoked otoacoustic emissions (EEOAE) depends on the spread of the stimulus current within the cochlea, which probably determines the generation sites of the EEOAE. The location and configuration of stimulating electrodes can affect the distance and shape of current spread. In this experiment we studied the origin of the EEOAE by systematically observing the relationship between the EEOAE transfer functions (i.e. ear canal sound level for constant current stimulation) and the locations and configurations of the electrodes.

Methods: Guinea pigs cochlea were exposed through a ventral surgical approach and the electrode was put on the round window (RW) at different positions: central, anterior, posterior, dorsal and ventral, and into scala vestibuli across turns with both monopolar and bipolar electrode configurations.

Results: The results showed that: (1) The cochlea has a wide frequency response to electric stimulation by a round window electrode, which would range from about 60 Hz to about 50-60 kHz. In the frequency range from 400Hz to 40kHz the EEOAE response is relatively strong. (2) For round window stimulation the EEOAE transfer function changed in both amplitude and frequency range with the different RW electrode locations. (3) When the electrodes were moved from the base to the apex of the cochlea, the main energy of the EEOAE shifted to low frequency ranges, and the amplitude of EEOAE tended to be lower when the electrode was moved to apex. This was more obvious for bipolar electrode stimulation. (4) The EEOAE response variability among animals for the amplitude of the transfer function was about 10 dB for a given level of current stimulus. For the same animal and same stimulation location, the EEOAE showed excellent repeatability.

Conclusions: It is concluded that the EEOAE is a stable and repeatable signal that originates mainly at the location near the stimulating electrode. Current spread within the cochlea can stimulate outer hair cells at remote locations, and thus the EEOAE can have multiple primary sources along the basilar membrane in the cochlea.

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C-65

A BIOMECHANICAL EVALUATION OF VISUALLY IMPAIRED PERSONS' GAIT

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Objectives: The purpose of this study was to compare gait and long cane mechanics between groups of visually impaired mobility trained subjects during normal and multi-tasked walking.

Method: Twenty subjects mean age 50.32 ± 18.36 years participated in this study. Ten reflective markers were placed on each subject and tracked through a calibrated space using a three-camera Motion Analysis Corporation videography system. Twelve dependent variables of gait and long cane mechanics were measured and analyzed. Subjects were grouped into Good or Bad categories based on their long cane techniques. Grouping designations were determined by a three person panel of orientation and mobility experts. Subjects were required to perform seven walking trials consisting of normal walking, walking while reacting to a simulated drop-off, walking while responding to an audible secondary task, and walking while reacting to a simulated drop-off while responding to an audible secondary task.

Results: No significant differences were found between the groups of Good and Bad travelers for the dependent variables examined. However, significant differences were found within groups by trial for components of hip flexion velocity, gait velocity, and stride length. These data indicate a significant alteration in the normal walking pattern of visually impaired persons when faced with multi-tasking situations. A decrease in both gait velocity and stride length were noted during trials requiring subjects to respond to an audible tone. Hip flexion velocity proved to be the most varied component with significant differences being found between all trial combinations.

Conclusions: These values indicate a wide range of responses from the subjects when faced with multi-tasked environments. Subjects were seen to "high step" or "shuffle step" during the tasked trials, which caused the hip flexion velocity values to be greatly varied. Results from this study indicate a potentially dangerous modification in the gait cycle of visually impaired travelers when faced with multiple somato-sensory inputs. These kinetic alterations could adversely affect the balance of this population during daily travel. Attention demanding tasks placed on visually impaired travelers during normal walking could decrease their ability to maintain spatial awareness and detect path obstacles thereby increasing the risk potential for falls and injury.

Funding Acknowledgement: This study was funded by the Rehabilitation Research & Development Center, VAMC Atlanta and completed as part of the Master's degree requirement of Georgia State University, Department of Kinesiology and Health

Clinical Relevance: Attention demanding tasks placed on visually impaired travelers during normal walking could decrease their ability to detect path obstacles thereby increasing the risk potential for falls and injury. Orientation and mobility training should include additional multi-tasking environments to improve veteran's spatial awareness and walking patterns.

C-66

QUANTIFIED STIMULUS FREQUENCY OTOACOUSTIC EMISSION: EVIDENCE FOR COCHLEAR AMPLIFIER AND MULTIPLE COMPONENTS

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Objectives: Although stimulus frequency otoacoustic emissions (SFOAEs) have been used as one of several non-invasive measures of cochlear mechanics, application of the SFOAEs has been limited by difficulties in accurately deriving quantitative information from the ear canal sound pressure. The aim of this study is to develop a method for quantitative measure of SFOAE amplitude and delay.

Methods: Sinusoidal acoustical stimuli were presented in the closed human external ear canal at an average sound pressure of 10 to 60 dB SPL in 10 dB steps and with frequencies from 200 to 2,000 Hz in 10 Hz intervals. Sound pressure amplitude and phase across frequencies were measured with an Etymotic microphone (10 B+). Using a newly developed signal processing method for multiple component analysis, the real spectrum was computed from the amplitude and phase spectra of the sound pressure in the ear canal. The delay-frequency distribution of the acoustical power in the ear canal was revealed by spectrogram of the real spectrum. The SFOAE and the acoustical stimulus tone were measured by the long delay component (LDC) and the short delay component (SDC). The amplitude of the SFOAE was presented as a percentage of the stimulus level.

Results: Preliminary data show that the ear canal measured- sound consists mainly of two components: a short delay component (SDC) and a long delay component (LDC). Time delay analysis indicates the SDC is incident sound directly from the speaker and the LDC is reflected sound from the ear. The normalized power distribution amplitude of the LDC has a negative relationship to the sound pressure level of the stimulus presented in the ear canal. At 10 dB SPL sound pressure level, the LDC amplitude is more than 60% of the SDC amplitude. The LDC could be completely suppressed by simultaneously presented acoustical tones near the probe tone frequencies.

Conclusions: 1) the newly developed signal processing method is able to quantified the SFOAE, which can be a useful tool for diagnosis of the auditory disorders for the veteran population. 2) Considering the power loss of the round trip of the LDC, the current results indicate the existence of the cochlear amplifier.

Funding Acknowledgement: Supported by VA RCTR-597-0160 grant from Department of Veterans Affairs-Rehabilitation Research and Development Service and grants R01-DC000105, P01-DC00078, and R03 DC033642 from NIH-NIDCD and grants and funds from Am. Otol. Society, and MRF of Oregon.

C-67

PRESENTATION OF ORIENTATION INFORMATION NEEDED BY VETERANS WITH VISUAL DISABILITIES

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Objective: The objective of this work was to determine the best means of presenting orientation information to a person with a visual disability who is traveling in both outdoor and indoor environments. The goal was to devise an aid capable of unobtrusively providing orientation cues to the user when needed to help them remain on a proper path to their intended destination. Three projects have been completed in which a variety of prototypes designed for this purpose were evaluated. A system for providing orientation information in structured indoor environments was evaluated in "Cyber Crumbs: Testing an Orientation Aid for Veterans with a Visual Disability." A system for providing orientation information for street crossings was evaluated in "Employment of Infra-Red Beacons as Guides for People with a Visual Disability." And finally, a system for providing orientation information in open (unstructured) indoor and outdoor environments was evaluated in "Evaluating 'Dead Reckoning' as a Navigation System for Veterans with a Visual Disability."

Methods: A variety of recently developed and innovative interface designs were constructed by the investigators and tested by subjects. These interface designs included both audio and tactile presentations. Special "earphones" were designed for audio presentations which did not cover the ears of the user. A special tactile interface developed by students at the MIT Media Laboratory was constructed to communicate intuitive tactile cues to the user. Audio cues tested included speech output, and mono and stereo-positioned tone outputs. Tactile cues were presented to the back of the subject in the form of a sensed movement indicating a direction in which to move or turn. Equivalent indoor and outdoor testing routes were established including both structured and unstructured (open) indoor and outdoor environments. Twenty subjects tested each of the interface designs in random order on randomly selected routes. Baseline measures of performance using no device were done both before and after testing the interfaces. Subjects were characterized by degree of light perception (if any), age, gender, and age of onset if not congenital. Performance measures included time to complete a route, orientation errors (e.g., moving off prescribed path, hesitating, etc.), and user confidence in using each device. User criticisms and suggestions for improvements were also recorded.

Results: To date, results indicate a preference for a stereo-positioned "beacon" tone indicating a desired direction toward which to move. However, subjects also complained that depending on other sounds in the environment (especially when walking next to a street with heavy traffic), they could not always hear it. There was also a difference between the congenitally blind and those with recent onset of blindness in terms of referencing the location of a "beacon" relative to body position versus head position. The former preferred references to their body position while the latter preferred sounds referenced to their head position. Many subjects liked the feel and non-intrusiveness of the cues provided by the tactile interface, but they didn't like having to wear it because of its size and weight and difficulty in putting it on and taking it off. Speech output was not preferred because it "talked too much" and was annoying.

Conclusions: The results to date indicate that out of the interfaces tested, stereo-positioned sound was the most preferred. However, the cues delivered by the tactile interface were found to be quite intuitive under all circumstances, and more useful in a noisy environment. Thus, a tactile interface might become the more desirable one if its physical obtrusiveness can be sufficiently reduced.

Funding Acknowledgment: These projects were supported by Atlanta VA Rehab R&D Core funds and VA Merit Review Pilot funding.

Clinical Relevance: Problems with maintaining spatial orientation and wayfinding are some of the most significant faced by visually impaired veterans who wish to travel independently in unfamiliar as well as familiar environments. Enhancing the ability of these aging veterans to orient to and navigate through their environment increases their functional independence and quality of life.

C-68

RETINAL CORRESPONDENCE AND BINOCULAR PERCEPTION CHARACTERISTICS IN PEOPLE WITH BIOCULAR CENTRAL SCOTOMAS

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Objectives: Previous studies of biocular PRLs (preferred retinal loci) have shown that about 1 out of 2 people with dense macular scotomas have eccentric PRLs with anomalous retinal correspondence (ARC) and that about 2 out of 3 of these people see biocular targets with one eye in a binocular viewing task. This study investigates the relationship between binocular perception of biocular targets and the retinal correspondence characteristics of PRLs in people with bilateral central scotomas.

Methods: The scanning laser ophthalmoscope (SLO) with graphics capabilities was used for macular perimetry and PRL assessment to determine the retinal location of visual stimuli directly on the retinal image in real time. The SLO with graphics capabilities obtains retinal images continuously with a nearly invisible infrared laser (780 nm) and scans graphics on the retina with a modulated visible red-light laser (632 nm). A SGI Crimson Elan graphics computer system was used for binocular PRL testing by displaying stereo pairs sequentially on a monitor at 120 Hz. The electronic eyewear, a liquid crystal viewing device synchronized with the monitor, channels the appropriate image to the appropriate eye. This stereo viewing system provides the ability of binocular vision testing in a comfortable yet effective free viewing format. Fifty-eight low vision patients were evaluated with the following tests: Snellen visual acuity (ETDRS); contrast sensitivity (Pelli-Robson); macular perimetry (SLO) for dense scotomas; PRL abilities and characteristics (SLO); and binocular perception for foveal/PRL and central visual field with biocular symbols of 2 degrees and central visual field with biocular words and patterns.

Results: 78% of the subjects demonstrated ARC in their biocular PRLs. 47.4% of the subjects with binocular perception had both PRLs displaced temporally from the fovea. However, most of the ARC was due to the PRLs being located in different directions from the fovea between each eye while the system appears to strive to maintain a similar distance from the fovea in each eye. Of the 38% of the subjects who did not have a similar distance from the fovea, 73% had their dominant PRL in the eye with the shortest distance. No relationship of retinal correspondence (normal or anomalous) or biocular acuity, contrast sensitivity, and PRL ability to binocular perception (fixation or macular) was found. 18% of the subjects had monocular perception with normal retinal correspondence and 26% of the subjects had binocular perception with ARC.

Conclusions: About 69% of low vision patients with biocular central scotomas have monocular perception when viewing targets in the PRL. The majority of this monocular perception may be due to suppression of the visual information from one eye (at least for briefly viewed targets). Prescription of monocular devices and training in vision rehabilitation services should identify the dominant eye and not force patients to use the eye where visual information is suppressed. Further research of cognitive processes (e.g., fMRI) is needed to investigate the neural plasticity mechanisms involved in this adaptation of the visual system to central scotomas.

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C-69

RETINOTOPIC DISTRIBUTION OF THE SPATIAL AND TEMPORAL ASPECTS OF LETTER IDENTIFICATION

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Objective: Many veterans with central vision loss regain some visual autonomy by participating in rehabilitation programs training them to use alternative eccentric fixation loci. We are creating maps of perifoveal visual function in order to select the optimum loci for eccentric viewing training. While there is much work describing the decrease in temporal and spatial resolution with increasing retinal eccentricity, there is relatively little work that has examined these eccentricity effects at more than one meridian. Data from all meridians is necessary in order to select the optimum preferred retinal loci for training. We have previously shown that the slope of the temporal threshold versus eccentricity function depends both upon the nature of the physical stimulus and the nature of the psychophysical task (Seiple *et al*., 1998). However, our previous studies were conducted at only one meridian. In the present study we examined whether letter identification temporal thresholds, grating acuity and grating contrast sensitivity exhibited similar patterns of retinotopic variation as a function of retinal eccentricity and meridian. Methods. All subjects were refracted to $\geq$20/20 best central acuity at each viewing distance used. Targets were presented on an Apple 12'' monochrome monitor (67 Hz frame rate). Mean background luminance was 46 cd/m^2 and target luminance was 73 cd/m^2. Peripheral testing is a difficult task since subjects tend to saccade toward briefly presented peripheral targets. To reduce large eye movements during target presentation the subject was instructed to fixate centrally on an illuminated LED. On each trial, the LED was either flickered or not, simultaneously with the presentation of a peripheral target. The subject was required to respond whether the LED flickered and to identify the peripheral target. Trials with incorrect fixation responses were discarded in order to insure that the targets always fell at the intended eccentricity. The target presentation was followed by a 'white' noise screen that physically controlled the temporal duration of the stimulus (i.e., it controlled for phosphor decay). In these experiments the dependent variable was target duration. Duration was controlled using a "3 down - 1 up" staircase procedure. The trial continued until 8 staircase reversals were obtained. Thresholds of the final four staircase reversals were averaged to determine the temporal threshold. Results. Grating Contrast: The slopes of the functions describing threshold duration and eccentricity are shallower for the horizontal meridian than for the vertical or oblique meridian. For any meridian, doubling the grating contrast increased detectability by approximately 2° in eccentricity. Acuity: The slopes of the functions describing threshold duration and eccentricity are also shallower for the horizontal meridian than for the vertical or oblique meridian. For any meridian, doubling the grating size increased detectability by approximately 7.5° in eccentricity. Letter Identification: The slopes of the functions describing threshold duration and eccentricity are shallower for the horizontal meridian than for the vertical or oblique meridian. For any letter size and for any meridian, doubling the presentation duration increased detectability by approximately 2° in eccentricity. Conclusion. Visual function is best in the horizontal meridian as a function of eccentricity and worst in the vertical meridian. Future research will investigate the usefulness of retinal visual function maps in selecting eccentric viewing sites. Funding for this project was provided by the Department of Veterans Affairs, Veterans Health Administration, Rehabilitation Research and Development Service.

C-70

A COMPARISON OF OPTICAL ENHANCEMENT DEVICES FOR PATIENTS WITH VARYING TYPES OF VISUAL FIELD LOSS

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Objective: Independent mobility and driving are important lifestyle issues to veterans with visual impairment. Our main goal in this study was to test the effectiveness for rehabilitation of three different types of vision enhancement lenses for three profiles of visual field loss.

Methods: Fifteen patients with peripheral vision loss due to retinitis pigmentosa, choroideremia, or Usher's syndrome Type II (Mean age, 45.2 years) were prescribed bioptic amorphic lenses. Twenty-five patients with central vision loss due to macular degeneration (age-related and juvenile-onset) (Mean age, 46.6 years) were prescribed expanded field bioptic telescopes. Ten patients with hemianopsia due to cerebral vascular accidents (Mean age, 45.5 years) were prescribed Fresnel Prisms and Gottlieb Visual Field Awareness Systems, both prism-based systems. All patients were given five weeks of visual skill rehabilitation training and eight weeks of driving training on a road course using curriculums designed in our laboratory. Data were collected on clinical visual functions (including Goldmann visual fields, Lighthouse visual acuity, and Pelli-Robson letter contrast sensitivity), psychophysical central and peripheral acuity, search and identification of peripherally presented letter optotypes, mobility, visual memory, scanning, and tracking on three test days (baseline, 3 and 6 months). All tests were coded for improvement relative to a test-retest criterion set by a control group of patients given neither training nor lenses.

Results: Patients with peripheral visual field loss who were given amorphic lenses and training showed increased visual functioning skills in the areas of recognition, mobility, peripheral detection, scanning, tracking, and visual memory. The percentage of tasks showing improvement ranged from 46% of the mobility items to 27% scanning of the scanning items. Patients with central vision loss who were given bioptic telescopes and training also showed improvement in all of the visual skills categories. These improvements ranged from 73% of the scanning items to 38% of the peripheral detection items. In this phase of the study, we separated the effects of lenses alone from the effects of the lenses plus training. We found that training in the use of the lenses resulted in greater improvement in all of the visual skill areas except tracking, when compared to the performance of patients given lenses without training. Patients with hemifield loss showed small improvements in all of the visual skills categories, ranging from 38% of the mobility items to 13% of the recognition items. There were no statistically significant differences between the two types of prism systems.

Conclusions: The greatest improvements in visual skill functioning were seen with the central vision loss group, followed by the peripheral vision loss group, and the smallest improvements were seen in the hemianopic group. Objective measures of improvement were consistent with the patients' self-reports about the enhancement systems. These data quantify the areas of trainable improvement with optical enhancement devices, and allow for a comparison of improvement across patients with varying profiles of visual field loss. Future research will be focused on identifying possible obstacles to improvement in some visual skills categories with certain groups of patients.

Funding for this project was provided by the Department of Veterans Affairs, Veterans Health Administration, Rehabilitation Research and Development Service.

C-71

VISUO-MOTOR CONTROL DEFICITS RELATED TO MACULAR SCOTOMAS

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Objectives: Visuo-motor control deficits could result from central visual loss because perception of an object's location in space relative to the body relies on the interaction in the brain of foveally-centered retinotopic maps and neural representations of the position of the eye in the head. Retinotopic maps and/or the eye-in-head signal may be in error in individuals with central visual loss because they use an eccentric retinal area (the "Preferred Retinal Locus" or "PRL") rather than the fovea to fixate objects of interest. Thus, perception of an object's location in space may be non-veridical and limb movements relative to the object may be inaccurate. Our objective was to test this hypothesis by measuring manual pointing accuracy of patients with central visual loss and well-defined PRL's.

Methods: Patients with dense central scotomas (N=12) and age-matched ocularly normal individuals (N=12) served as subjects. Retinal eccentricity of PRL's relative to the fovea were measured using a scanning laser ophthalmoscope. Manual pointing accuracy was measured as follows. While monocularly fixating a red LED at 0° (i.e., straight ahead) in an otherwise dark room, subjects were asked to point as accurately as possible at individually illuminated target LED's 10°, 20°, 30°, and 40° to the right of fixation. Infrared LED's attached to the subject's index finger allowed recording of finger position using an infrared-sensitive video camera. Videotaped images of target and finger position were measured to calculate the angular error between the finger and target.

Results: Normal subjects tended to "undershoot" when pointing (i.e., the finger did not move as far as the target) as previously reported. This pointing error increased linearly with target eccentricity, reaching approximately 5° undershoot for the 40° target. Pointing error depended on *horizontal* PRL eccentricity for patients. When the PRL was ~1.5° or less horizontally eccentric to the fovea (N=6) , pointing errors were identical to those of normal subjects even though *vertical* PRL eccentricity was as large as ~12°. When PRL horizontal eccentricity was greater than ~1.5° (N=6), pointing errors increased markedly with both undershooting (e.g., 15° for the 40° target) and overshooting (e.g., 5° for the 40° target).

Conclusions: These results suggest that the ability to manually localize objects in space relative to the body is compromised when the PRL is not horizontally aligned with the (non-functional) fovea (i.e., the PRL is highly eccentric horizontally). This deficit is not due to loss of visual acuity because patients with poor acuity (20/200 – 20/400) but with PRL horizontal eccentricities of less than ~1.5° pointed as well as ocularly normal subjects. Our results also suggest a lack of neural plasticity or "remapping" retinotopic maps and the eye-in-head neural signal relative to the PRL. Deficits in motor control associated with central visual loss could decrease quality of life (e.g., knocking over the coffee cup), and increase the risk of injury (e.g., touching the stove burner or tripping on a curb). Further information about such motor control deficits is needed for timely, effective rehabilitation of an increasing number of veterans suffering central visual loss. Supported in part by VA RR&D grant C838-2R.

C-72

THE RELATIONSHIP OF READING ABILITY TO SCOTOMA AND PREFERRED RETINAL LOCUS CHARACTERISTICS

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VA Rehabilitation Research and Development Grant #C849R

Objective We studied the relationship between functional measures of reading and characteristics of the scotoma and preferred retinal locus (PRL) for readers with macular degeneration.

Methods: Sixty subjects with macular loss were evaluated for acuity, contrast sensitivity, reading ability, macular perimetry (scanning laser ophthalmoscope {SLO}), PRL location and ability (SLO), and binocular correspondence. Print reading performance was also measured with standardized evaluation of critical print size, rate and comprehension.

Results: Scotomas to the right of the PRL were related to print reading errors on the right, slower rate and less accuracy. Placement of a scotoma below the PRL was strongly related to errors of skipping or rereading a line of print, slower rate and less accuracy in reading. Scotoma placement above or to the left of the PRL was not associated with committing a specific type of error and did not degrade rate or accuracy. Fixation score was positively associated with accuracy, fixation degrees was negatively associated with accuracy. A higher fixation score with a smaller area of fixation (smaller PRL) were related to highest reading accuracy. Critical print size and reading acuity were negatively related to change in fixation ability, critical print size was positively related to changes in pursuit ability. There was no significant effect of PRL dominance on reading performance either by grouping as monocular/binocular or as right/left/both eye(s). Reading comprehension scores were unrelated to any other reading, visual function, scotoma or PRL ability.

Conclusions: PRLs to the right or below the scotoma were most adaptive for reading ability for these subjects. They may re-learn to read with eye movements that differ from those of normally sighted readers. Binocular readers with ARMD appear to have no advantage over monocular readers. PRL ability and scotoma placement are strongly related to accuracy and rate, but are unrelated to comprehension.

Implications: Our research contradicts standard clinical heuristics that PRL placement to the left or right of a scotoma is less adaptive for reading than PRL placement above or below the scotoma. Our results show that PRLs that are below or to the right of the scotoma may be more adaptive. Veterans with visual impairments who receive optical or electronic devices for reading may be assisted by therapeutic intervention to re-train PRLs.

C-73

NEEDS ASSESSMENT OF VISUALLY IMPAIRED VETERANS

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Objectives: This six-month project gathered needs data from an estimated 3,500 visually impaired veterans using a short, large print, mailed questionnaire. The purposes of this descriptive, exploratory project were to establish general demographic characteristics and gain an understanding of the perceived needs of that population. While considerable data are available on veterans attending VA blind rehabilitation programs, little is known about visually impaired veterans who do not enter these programs. This information is crucial in the design and/or optimization of the delivery of clinical services and assistive technology to this veteran population.

Methods: The population surveyed was represented by a list of approximately 14,000 veterans currently on the compensation and pension roles of the Department of Veterans Affairs for blindness. A modified research design based on The Dillman (1978) Total Design Method (TDM) for mail surveys was employed to administer the survey instrument. The survey obtained basic demographic information such as age, date of last rehabilitation service, receipt of prosthetic devices from the VA, and living status. It also obtained information about specific rehabilitation needs in checklist form. The survey examined the current level of utilization of computer technology by the respondents, as well as the level of interest in learning to use computer technology.

Results: The quantitative and categorical elements of the responses were analyzed using pertinent descriptive statistics. Where appropriate, multivariate and non-parametric analytical techniques (cross tabulation, phi coefficient, odds ratio) were employed to ascertain relationships between demographic and need variables. Results indicate that 85% of respondents were 61 years of age or older, 4.3% are currently employed for pay, 2.7% are currently attending school or training, 12.4% volunteer, with 33.8% considering themselves recreationally active. Findings also show that 43.2% of respondents have never received VA sponsored blind rehabilitation training. Furthermore, these data indicate that of this population, 13.9% are currently using computers, while 25.8% express an interest in learning computers.

Conclusions: Due to the limitations of the survey instrument these data are somewhat general and broad. This was unavoidable due to the expressed desire and intentions of the project funding agency, Blinded American Veterans Foundation (BAVF), which felt that a brief, one-page, large print survey was the format investigators should follow when designing the survey instrument. What has been determined from these findings, however, is that significant variations and variability appear along and throughout the entire sample of visually impaired veterans examined. It is therefore crucial that further, more in-depth research looking at salient issues impacting this population, such as differences in receipt of services, as well as other programmatic, diagnostic and psychometric areas be pursued in the near future.

This project, AREF #001 Williams, was funded by the Blinded American Veterans Foundation.

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PREVALENCE AND CHARACTERISTICS OF CHARLES BONNET SYNDROME IN A VETERAN POPULATION

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Objectives: Determine the prevalence of Charles Bonnet Syndrome and photopsias in severely visually impaired veterans.

Research Plan: This study determines the prevalence of Charles Bonnet Syndrome (formed visual hallucinations after adventitious vision loss without evidence of psychological or psychiatric problems) and photopsias (subjective perception of flashes, sparks or flickering light) by interviewing veterans participating in the VICTORS Regional Low Vision Rehabilitation program.

Methods: Subjects were asked in a friendly, open-ended, non-judgmental manner if they had ever "seen something that they knew wasn't really there." Information gathered included age, eye diagnosis, visual acuity, date of onset and description of the visual phenomena, reaction to visual phenomena and if the subject had told anyone about these visual phenomena.

Results: One hundred and ten subjects participated in this study. The median age of the subjects was 75 with a range from 26 to 89. Eye diagnoses included age-related macular degeneration (66%), diabetic retinopathy (13%), optic nerve atrophy (4%), glaucoma (3%) and other (14%). Best corrected visual acuity ranged from 20/20 (subject with hemianopsia) to finger counting. Thirty-six percent (40/110) of these subjects were legally blind (20/200 or worse). Sixty-six per cent (73/110) saw formed images and/or experience photopsia. Of those who experience photopsia and/or formed images, 15% (11/73) saw formed images without photopsia, 67% (49/73) only had photopsia and 18% (13/73) experienced both photopsia and formed images. Almost 50% (35/73) of subjects experience photopsia and/or formed images daily The visualization of formed images and/or photopsia ocurred under dim illumination conditions in 49% (35/72) of the subjects, while 38% (27/72) saw the images or photopsias at anytime of day. It's interesting to note that 1 subject only saw images when driving, 4 saw images when watching TV and one saw images or photopsias when reading. Although 25% (18/73) of subjects admitted to being disturbed or frightened by the images, only 8 of these veterans spoke to a friend, spouse or doctor about it. Of the 73 subjects who saw images and/or photopsia, 49 (67%) did not talk to anyone about them.

Clinical Relevance: A high percentage of veterans with chronic severe visual impairment experience formed visual hallucinations and/or photopsias in the absence of psychological or psychiatric problems. Because vision loss is associated with age, many veterans with visual impairment who experience photopsias or formed images may be concerned about the possibility of dementia or Alzheimer's disease. Unfortunately, the majority of these patients do not talk about their formed images or photopsias. Geriatricians, optometrists and ophthalmologists should question their patients regarding these phenomena and provide reassurance counseling. Further research is needed to determine the etiology of Charles-Bonnet Syndrome and possible treatment options.

PROSTHETICS, AMPUTATION AND ORTHOTICS

Abstract #
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P-75

LOWER LIMB PRSOTHETIC FLEXIBILITY: A BIOMECHANICAL STUDY OF PREFERENCE AND PARAMETERS

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Objectives: In the past decade, clinicians, prosthetists and designers have recognized that flexibility (compliance) is a key component in the design of a comfortable, functional lower limb prosthesis. There is now a wide range of flexible components available and prescription thereof has become common. Although there is strong clinical evidence and stated subjective preference for flexible limbs, there seems to be no data available relating quantities such as amputee mass, limb length with preferred compliance or with measures of force, moment or displacement. Such information would prove valuable to the designer as well as the clinician, and would ultimately improve the care of amputees.

Methods: The study involved twenty subjects of similar walking ability (community ambulators) evaluating the compliance of an custom built adjustable pylon/ankle. The ankle allowed independent adjustment of the rotational spring rates in the anterior, posterior, medial and lateral directions. In addition an Otto Bock rotator was inserted to allow axial rotation. To facilitate their evaluation, subjects traversed a standardized course representing "normal" gait activities: level walking, ascent and descent of stairs, ascent and descent of an incline and a stretch of uneven surface. Starting with arbitrary spring constants the subject traversed the course and chose to make the limb stiffer or less stiff in a given direction. This is repeated until the subject is satisfied with the response. To help understand the interaction of the three rotations, they are evaluated one at a time and then in combinations of two and finally all three. There were three data collection sessions per subject spaced at two week intervals to evaluate subject's consistency in preference. During each trial data on axial force, anterior/posterior moment, medial/lateral moment and angular deflection around each axis were collected using a telemetric system.

Results: Data collection concluded in July of 1999. Data from approximately 25 miles of amputee gait are currently being analyzed.

Conclusions: Preliminary indications are that amputees have definite preferences for flexibility in each direction, especially with respect to anterior stiffness and rotation. Statistically analyzed results of preference and correlations with quantities such as angular displacement, limb length and mass will be reported. Conclusions will be discussed upon presentation.

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A PRECLINICAL MODEL FOR INVESTIGATION OF REHABILITATION ISSUES IN BONE HEALING

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Objective: To develop a preclinical model to investigate how substance abuse (alcoholism, smoking or drug abuse) during rehabilitation following fracture treatment delays or prevents bone healing.

Methods: Fracture healing in rat long bones occurs quickly within 4 to 5 weeks. The bone repair process in rodent species appear to short-cut the sequential stages of healing of injured bone observed in humans. We used a tissue-engineering approach to alter the bone repair process in the rat in an attempt to obtain a model that would resemble human bone healing and be sensitive for evaluating the effects of various factors that can compromise bone healing. A 4 mm-long segmental defect was created in rat fibula by osteotomy and repaired immediately with an 8 mm-long tubular specimen of demineralized bone matrix (DBM) by fitting it over the cut ends of the fibula. The experiments in this study involved various modifications of the DBM scaffold designed to reduce its osteoinductive activity: ethylene oxide sterilization (eoDBM), steam sterilization (sDBM), trypsin digestion (tDBM) and guanidine hydrochloride extraction (gDBM). Bone healing was evaluated by bending rigidity of the fibula, mineral content and histology of the repair site at 7 weeks post-surgery.

Results: The sDBM scaffolds resorbed completely by 7 weeks. Rigidities in the unmodified DBM and tDBM groups were comparable, whereas in the gDBM and eoDBM groups it was significantly reduced. Histologically, in the 4 mm defects repaired with unmodified DBM, direct and endochondral bone formation in the scaffold and the defect resulted in a neocortex consisting of woven and lamellar bone by 7 weeks post-surgery.

Conclusions: The tissue-engineered bone repair model in the rat recapitulates the normal human **bone repair sequence** up to the point of initial bony consolidation when an unmodified DBM specimen was used as the tissue scaffold. Reduction of osteoinductive activity of the scaffold resulted in a deficient outcome of bone repair suggesting that this model may be sensitive enough to demonstrate the metabolic effects of substance abuse on the ongoing repair process during bone healing.

Clinical Relevance: Patients with a history of substance abuse experience complications in bone healing following treatment using standard protocols. The model presented in this study may be used to investigate how bone healing is compromised and to develop new protocols to overcome the adverse effects by intervention during the treatment or rehabilitation phase of bone healing. Preliminary studies using this model suggest that continued ethanol consumption (and associated reduced food intake) during rehabilitation following the treatment of bone injury causes a fifty percent deficiency in the bone healing outcome.

(Research supported by VA Rehabilitation R&D Service and Creighton University Health Future Foundation)

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QUANTIFICATION OF PROSTHETIC TREATMENT OUTCOMES - ELASTOMERIC LINER & LOCKING PIN SUSPENSION VS. PELITE LINER & NEOPRENE SLEEVE SUSPENSION

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Objectives: This study compared two systems for the interface and suspension of trans-tibial prostheses. The Alpha Liner is an expensive, relatively new elastomeric gel liner worn on the residual limb and secured to the prosthesis with a distal locking pin. The PeLite liner is an inexpensive, traditional polyethylene foam molded to fit between the hard socket and the residual limb. The prosthesis is commonly secured to the body by a neoprene sleeve fitted over the socket and extending to the mid-thigh. This study compared patient satisfaction, pain, daily ambulatory function, and physical changes associated with use of both systems.

Methods: Fourteen subjects with trans-tibial amputation were studied. Each subject wore one system for 3 months, then switch to the other for 3 months. The order was randomized. At the end of each condition, the following measures were collected. Ambulatory activity was recorded as steps per minute for 2 continuous weeks using the Step Activity Monitor (SAM). Subjects completed the Prosthesis Evaluation Questionnaire (PEQ), an excerpt of the Brief Pain Inventory (BPI), and the Socket Comfort Score (SCS). A variety of anthropometric measures were collected including residual limb volume. Upon completion of the second condition, subjects selected their favorite system for continued use.

Results: Data collection will be completed in December 1999. At the time of submission, 5 subjects have completed the protocol. Excluding cost as a consideration, 3 subjects preferred the PeLite liner and 2 the Alpha Liner when asked which they would choose if a leg was to be their only prosthesis. Including cost (assuming burden on the subject), 4 preferred the PeLite and 1 the Alpha. However, 3 subjects opted to keep the Alpha system and 2 the PeLite at the end of the study. Extensive clinical feedback has been collected and indicates that for most subjects, each system has distinct advantages and disadvantages. Prosthesis suspension appears to be improved by the Alpha system, but the maintenance requirements and time and effort of donning and doffing are greatly increased.

Conclusions: Preliminary results indicate that neither system is clearly preferable for all subjects. This study will provide clinically needed information regarding subject response to the liner conditions and specific reasons for like/dislike and acceptance/rejection of these common socket systems. Future research will be directed to areas specifically identified through this study as having the greatest impact on comfort and function.

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THE RELATIONSHIP BETWEEN ISOLATED GASTROCNEMIUS TIGHTNESS AND FOREFOOT OR MIDFOOT PATHOLOGY IN PATIENTS WITHOUT NEUROLOGICAL IMPAIRMENT

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Purpose: Contracture of the gastrocnemius-soleus complex has well documented deleterious effects on lower limb function in spastic or neurologically impaired individuals. There is scarce literature, however, on the existence of isolated gastrocnemius contracture or its impact in otherwise normal patients. We hypothesized that 1) the inability to dorsiflex the ankle due to equinus contracture leads to increased pain in the fore/midfoot, and theerefore a population with fore/midfoot pain will have less maximum ankle dorsiflexion than controls and 2) the difference in maximym dorsiflexion will be present whether the knee is extended or flexed.

Methods: This investigation prospectively evaluated the gastrocnemius tension of two healthy age, weight, and sex-matched population groups over a four month period. The study group was comprised of 34 consecutive patients presenting to our University foot and ankle clinics with a diagnosis of metatarsalgia or related mid/forefoot complaints. The control group consisted of 34 randomly identified hospital personnel or patient spouses devoid of foot or ankle complaints. Exclusion criteria were defined as the presence of neurological disease, systemic disease potentially affecting the foot or ankle, confounding pre-existent foot or ankle surgery or trauma, or any bony block to ankle extension. Participants underwent a history and physical including clinical assessment of gastrocnemius contracture and were subsequently examined for gastrocnemius and soleus tightness using a previously validated ëequinometerí which measures maximal ankle dorsiflexion after applying an upward directed torque of 10 N-m to the aligned foot. Data was collected with the knee in full extension and 90 degrees of flexion.

Results: With the knee fully extended, average maximal ankle dorsiflexion was 4.5 (4.5 degrees, range -1.1 to 14.3 degrees) in the study and 13.1 (8.2 degrees, range 1.1 to 30.7 degrees) in the control groups ($p < 0.001$, power = 0.99). With knee flexion of 90 degrees, the results were 17.9 (9.0 degrees, range 6.1 to 37.0 degrees) for the study and 22.3 (10.9 degrees, range 7.6 to 51.1 degrees) for the control populations ($p = 0.09$, power 0.40). Gastrocnemius contracture (dorsiflexion, 5 degrees during knee extension) was identified in 65% of the study and 24% of the control populations. We made the correct clinical diagnosis in 76% (PPV 95%, NPV 42%) of the study and 94% (PPV 88%, NPV 96%) of the control groups.

Conclusions: Patients with metatarsalgia or related fore/midfoot complaints have less average maximum ankle dorsiflexion with the knee extended versus a control population without foot or ankle complaints. When the knee is flexed 90o to relax the gastrocnemius, this difference is no longer present.

Clinical Relevance: Findings should heighten awareness of the existence of isolated gastrocnemius contracture in patients devoid of neurological impairment, and suggest a relationship between it and the development of fore/midfoot pathology in otherwise healthy people. Data may have implications for preventative care of the chronic foot and ankle patient.

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THE VA CHICAGO MOTION ANALYSIS RESEARCH LABORATORY: A TOOL FOR STUDYING HUMAN MOVEMENT AND EVALUATING PROSTHETIC AND ORTHOTIC PERFORMANCE

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Objectives: We are developing a VA research laboratory—the VA Chicago Motion Analysis Research Laboratory (VACMARL)—for studying human movement mechanics and for evaluating the use and effectiveness of prosthetic and orthotic devices. We are particularly interested in human ambulation and aided-ambulation. VACMARL will be used to increase understanding of normal gait, and to compare and evaluate the gaits of persons who walk with prostheses and orthoses, which we hope will lead to improved design of these devices.

Methods: VACMARL is equipped with a 6-camera Motion Analysis Corp. kinematic measurement system for measuring the positions of markers placed on anatomical landmarks of the body. From marker positions, we can calculate the positions of joint centers of rotation and the joint rotation angles. There are six AMTI force platforms embedded in the walkway for measuring the forces exerted between the foot and the floor during gait. VACMARL also has a Noraxon 8-channel telemetered EMG system for recording muscle activation patterns with skin-surface electrodes. The kinematic, kinetic, and EMG data acquired from persons who use prosthetic and orthotic devices can be compared with data obtained from able-bodied persons to better understand how the prostheses and orthoses are being used, to identify compensatory patterns the user is adopting, and to determine limitations in current prosthetic and orthotic technology.

Clinical Relevance: VACMARL is similar to the motion analysis laboratories that have been established at the Seattle VAMC and the Longbeach VAMC. Motion analysis laboratories of this type are routinely used in civilian hospitals to evaluate the gaits of children with cerebral palsy and myelomeningocele in order to better understand and characterize the extent of disabling condition, and to assist with decisions regarding treatment options. We will use VACMARL in a similar capacity; we will conduct motion analysis studies of veterans using prosthetic and orthotic devices to evaluate the patterns of movement and to assist with the design of improved prosthetic and orthotic components.

Future: VACMARL is currently being used to study the effect of vertical shock pylons—a prosthetic component that provides shock absorption—on the gaits of veteran transtibial amputees. We will also use VACMARL to study stance-phase knee flexion units, which provide shock absorption in transfemoral prostheses. Other projects that will be initiated in the near future include a study of cadence-step length relationships in normal walking, a study of crutch ambulation mechanics, investigation of normal ambulators walking with knee and ankle casts, and an evaluation of prostheses use by upper-extremity amputees.

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P-80

RECIPROCAL CONTROL OF ELBOW EXTENSION USING BICEPS EMG

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Restoring control of the paralyzed upper extremity will improve the quality of life for veterans with high level spinal cord injuries. Individuals with C5/C6 spinal cord injury retain no voluntary elbow extension yet can possess some degree of elbow flexion. Elbow extension is crucial in performing activities of daily living. A successful method of restoring elbow extension is through switch controlled functional electrical stimulation (FES) to the triceps. The level of stimulation is set to a constant level when the switch is turned on, and individuals control elbow movement by flexing against the stimulated extension. However, constant triceps stimulation subtracts from the strength of voluntary flexion, and increases both biceps and triceps fatigue.

Another way to control the triceps stimulation would be to reciprocally link flexion and stimulated extension, in other words decrease triceps stimulation when the person flexes their elbow. This is being achieved by recording the biceps electromyogram (EMG) during triceps stimulation and decreasing triceps stimulation in proportion to the amplitude of the biceps EMG. Reciprocal control provides a natural method of grading extension without requiring extensive training, and EMG is a naturally occurring control signal that can be detected with an implanted system.

A PC based lab test system was designed to record biceps surface EMG and reciprocally control triceps stimulation. Blanking amplifiers eliminated the stimulus artifact by blanking. The RMS value of the remaining EMG was calculated as the control signal. A maximum and minimum value of the control signal were found by having a subject maximally flex and then completely relax their biceps. The control signal was then normalized to these values. When the control signal was at its minimum value the triceps stimulation was maximum. For control signals between 20% and 60% the stimulus strength decreased linearly to zero. Thus, for control signals above 60%, the triceps was not stimulated at all.

The system was tested in individuals with C5/C6 spinal cord injury who had implanted triceps electrodes along with a hand grasp neuroprosthesis. All testing trials were completed using no triceps stimulation, constant stimulation, and reciprocal control to compare across methods. Reciprocal control of triceps stimulation using biceps EMG significantly increased the range of elbow moments over constant and no stimulation, and significantly decreased the total amount of stimulation over constant stimulation. The ability of the subject to perform activities of daily living was the same as with constant stimulation and better than with no stimulation.

In summary, we have demonstrated a new method of restoring coordinated limb control. Further progress in this area will allow the spinal cord injured veteran cosmetically acceptable solutions to increasing function and fine control of the upper extremities.

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A RELIABLE AND ACCURATE METHOD OF MEASURING ORTHOSIS-WEARING TIME

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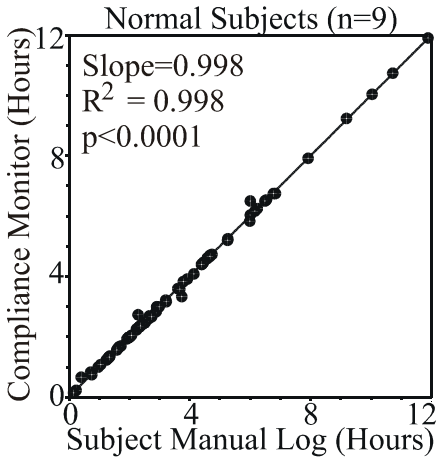
Objectives: Orthosis-wearing compliance is considered to be an important factor in the outcome of orthotic treatment for idiopathic scoliosis. Current estimates are based on self-reported compliance and estimated wear and tear of the orthosis itself. Availability of an accurate and reliable technique to measure how long a patient wears a prescribed spinal orthosis will allow clinicians to objectively study the relationship between patient compliance and outcome of orthotic treatment, and arrive at rational guidelines for prescribing orthosis wearing hours. The purpose of this study was to test the accuracy and reliability of a new method to objectively measure spinal orthosis-wearing time.

Methods: Nine custom-molded, bi-valved TLSO's were fabricated for this study. Four pressure switches were concealed in each orthosis in areas of high contact pressure to determine the wearing-status of the orthosis. The orthosis was assumed worn when at least two switches were "on." A solid state recording device concealed within each orthosis recorded the on/off status of the switches at preset sample intervals (30 seconds to five minutes).

Volunteer subjects were recruited to wear their TLSO's for up to 40 hours and keep a daily manual log of orthosis-wearing time. The subjects wore their orthoses for an average of 7 days (range: 4-14 days) with an average daily wear time of 4.2 hours (range 1.3-8.5 hours), yielding an average total wearing time of 29.6 hours (range: 6.6-45.6 hours). A total of 72 orthosis-wearing intervals (time period between orthosis donning and removal) were recorded from nine subjects over the duration of this study. The average orthosis-wearing interval was 2.5 hours (range: 0.15-11.9 hours). The sensor status data was downloaded at the end of the study and analyzed to determine the following measures of orthosis-wearing time: the accumulated times the orthosis was worn and not worn, and the actual times (within one clock sample interval) that the orthosis was donned and removed on any given day.



Results: A linear regression was performed on all orthosis-wearing intervals as recorded by the compliance monitor and by subject diaries to determine the ability of the compliance monitor to predict orthosis wearing time. This analysis yielded an adjusted R^2 value of 0.998 with a slope of 0.998 and a p value <0.0001. The regression analysis indicates excellent reliability and accuracy of the compliance monitor in measuring the actual orthosis-wearing time.

Conclusions: Previous attempts at measuring orthosis-wearing compliance using an E-cell and temperature probe reported poor correlation between the measured and reported wearing times, and thus have proven to be unreliable. The present study is the first report of a compliance monitor that yields accurate and reliable measurement of orthosis-wearing time. This compliance monitor will allow clinicians to objectively investigate the effect of orthosis-wearing on outcome of orthotic treatment for spinal disorders and determine the wearing time necessary for best results.

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WHEELCHAIR PROVISION AND USE AMONG OLDER PERSONS

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Introduction: Disability is a major problem facing the aging US population. Assistive technology is often used to treat disability(LaPlante, Hendershot, et al. 1992). Some data indicate that often such assistive technology does not meet users needs and/or is discarded (Rogers and Holm, 1993).

Objectives: To determine how wheelchair (wch) recipients use their wheelchairs.

Methods: We identified consecutive wch recipients at the Durham VA and Duke University Medical Centers. Wch recipients were included in the study if this was their first prescription for a wch during the study period, if they lived ≤ 65 mile from the Medical Centers, were ≥ 21 years old, had a telephone and a score of ≥ 6 on the Short Portable Mental Status Questionnaire, gave informed consent, and were still using their wch 2 weeks after receipt. All study participants were interviewed within 2 weeks of wch receipt and monthly for 4 months. This report provides data on initial (≤2 weeks after receipt) wch usage by the community dwelling wch recipients.

Results: 743 persons received new manual or motorized wchs from 2/12/98 - 2/17/99. Of these, 335 (46%) were eligible for study enrollment and 202 (60%) of eligible persons were enrolled in the study (173=VA, 29=Duke). Among the 153 community dwelling subjects:

Demographics: male 92.2%, African-American 28.8%, <high school education 37.9%, <$15,000 per year income 44.1%, median age 64.7 years. *Social characteristics:* 11.1% lived alone, 81.7% no paid assistance. *Medical characteristics:* The most common reasons for wch prescription were weakness 57.5%, poor balance 56.9%, pain 87 (56.9%), and fear of falling. 34% had regularly used a wch prior to the study wch. *Environmental characteristics:* 41.8% had adapted their house to accommodate a wch. Nonetheless, 63.4% had to surmount steps to enter/exit their home and 22.9% had discontinued using one or more rooms in their house. 66% lacked transportation they could use independently. *Wheelchair characteristics:* Usual method of wch propulsion - human assistance 25.5%, motorized 18 11.8%, self-propelled 54.9%, missing 7.8%. Usual distance self-propelled - <1 block 34.6%, 1 block 10.5%, >1 block 9.8%, not self-propelled 37.3%, missing 7.8%.

	Wch use in the home in preceding 24 hours				
	Did not go	Wheeled/ assist	Wheeled/ indep	Walked	Missing
Bathroom	12 (8.5)	31 (20.3)	11 (7.2)	96 (62.7)	3 (1.3)
Kitchen	13 (8.5	39 (25.5)	8 (5.2)	92 (60.1)	1 (0.7)

Kappa coefficient wheelchair method in bath versus kitchen: 556 (449-.684_

Conclusions: Potential barriers to wheelchair use are common, both environmental (e.g., steps) and personal (e.g., human help needed for wch propulsion). The mobility methods in two commonly used locations within the home are fairly consistent across location, and wheelchair use those 2 locations is relatively infrequent.

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COUPLING STRESS ANALYSIS OF JOINTS WITH HUMAN GAIT TO IMPROVE WEAR PREDICTION IN JOINT REPLACEMENTS

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Objectives: Osteoarthritis (OA) affects over 21 million U.S. adults, many of them veterans, elderly, or both. Severe OA is treated with joint replacements. The bearing surface of these implants is often composed of polyethylene, which wears out over time. To date, efforts aimed at understanding this wear process have assumed *a priori* a particular joint loading to obtain stress and deformation, used to quantify wear. The objective of this research is to couple finite element stress analysis with a dynamic model of human gait, offering a simulation that better represents *in vivo* loading conditions.

Methods: In this study, we created a finite element model of the human femoral head, attached to rigid elements representing legs. A load simulating the head-arms-trunk (HAT) was applied to the stance leg through the hip joint. The stress distributions and deformations in the hip for one complete gait cycle were obtained.

Results: As the stance leg moves from the initial position, associated with heel strike, to the final position, representing toe off, the hydrostatic stress is observed to peak, just below the point of load application, during the mid-stance. This result is consistent with the ballistic gait framework because the rigid leg produces the greatest reaction force against the HAT at mid-stance. This result is expected to change from a single stress peak to a bi-modal stress peak, seen just after heel strike and just prior to toe-off, as the gait model is refined to more-closely match physiological gait.

Conclusions: Coupling stress analysis with human gait allows for the evaluation and improvement of existing methods for computing joint wear that presuppose joint loading. The approach advocated here offers clinical relevance because it can help lead to better implant designs by producing polyethylene wear results that better match *in vivo* wear patterns. Additionally, this research may offer insight not previously available. For example, the coupled approach allows for alterations of gait patterns to be used, which may help elucidate how humans adapt locomotion strategies (*i.e.,* limping after trauma or surgery) to minimize joint stress.

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ARTIFICIAL MUSCLES: ACTUATORS FOR LOWER LIMB PROSTHESES

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Prosthetic clinical experience indicates many veterans suffer from lack of endurance, non-symmetrical gait, and high levels of effort while simply walking at their self-selected pace. The integration of an artificial musculo-tendon actuator into a below-knee prosthesis has the potential to greatly improve amputee gait by providing the missing propulsive force of the ankle musculature.

Objective: Our objective is to test the hypothesis that a powered prosthetic limb will reduce the metabolic cost of locomotion, reduce the perceived level of effort, and improve gait symmetry as measured by kinematic and kinetic techniques when compared to conventional prosthetic limbs. Our intermediate objective is to develop an artificial muscle and tendon whose performance mimics that of the triceps surae muscle group and Achilles tendon during walking, while remaining suitable for use on a prosthetic limb.

Methods: Using published data, we developed a Hill-based model of muscle and an energy storage model of tendon to match performance specifications for an isolated, whole muscle-tendon system. These specifications were used to design the artificial musculo-tendon actuator with the aid of computer simulations. The simulation results indicate the predicted output force of the proposed design will meet or exceed the forces necessary for amputee walking. We proceeded with fabricating the device using McKibben actuators as contractile elements. To test its performance, we used a Bionix(testing instrument (MTS Systems Corp., Minnesota, U.S.A.) to measure the output force for various velocity and activation profiles enveloped by the maximum conditions expected during locomotion.

Results: Under isometric conditions, the maximum force achieved was 1600 N. During eccentric (lengthening) contractions, the output force increased with velocity and was greater than 2000 N at the maximum velocity of 300 mm/s. During concentric (shortening) contractions, the output force decreased with velocity, asymptotically approaching zero at the maximum velocity condition. Three-dimensional plots of the force, length, and velocity relationship are very similar to the triceps surae and Achilles tendon model predictions.

Conclusions: The development of an artificial musculo-tendon actuator that mimics the function of the triceps surae and Achilles tendon has been accomplished. Our next steps are to integrate the actuator into a prosthetic limb, develop a robust control system, and proceed with human subject testing. The human tests will measure the metabolic cost of locomotion, the perceived level of effort, and kinematic and kinetic measures of gait symmetry and enable testing the hypothesis that a powered prosthetic limb will improve amputee locomotion.

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LONG TERM USE OF PERCUTANEOUS FES SYSTEMS IN PARAPLEGIA

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Objectives: Percutaneous functional electrical stimulation (FES) systems were implanted in persons with T5-T12 SCI in early 1980s for exercise, standing and walking. The purpose of this report is to describe long term FES use including safety, efficacy and function.

Methods: Eleven volunteers with motor and sensory complete SCI were implanted with percutaneous intramuscular (PI) electrodes between 1982 and 1985. Up to 40 PI and 8 surface electrodes were connected to a portable microprocessor-controlled stimulator that provided stimulation patterns for exercise, standing, walking and climbing stairs.

Results: Of the eleven patients implanted, nine were able to stand, six were able to walk with a rolling walker, and three were able to climb stairs. Six patients that were able to walk remained FES users for an average of 8.5 years. Out of 1702 electrodes implanted in these six patients there were sixteen incidents of cellulitis, fourteen incidents of superficial infection, a superficial fungal infection around the electrode exit site and two incidents of a generalized cellulitis in the leg. These were treated with appropriate local and oral antibiotics. Nine electrodes (0.5%) were removed due to infection at the exit site. The fragments remaining in the body after electrode removal have been in general well tolerated. On occasion these have caused skin irritation and have been removed by forceps probing. This was done 16 times in these six subjects. Two participants have been using the FES system for 15 and 16.5 years. The first participant uses his system at home an average of 45min per week and visits the lab once a month. He stands and walks at home for exercise and minor household activities. He can stand for 18min and walk 100m at speed of 0.4m/s with a 15-channel FES system. He thinks that regular use of the system is an excellent work out and that it helps him to stand and walk better and makes his legs look better. The second participant uses his FES system at home for quadriceps exercise six days a week for one hour daily mainly to relieve muscle spasms. He walks 200m with rolling walker at the lab for exercise five days a week. He can stand for 20min and his walking speed is 0.6m/s with a 26-channel FES-only system and 0.3m/s with a hybrid system using 16-channel FES system and RGO. The PI electrode design and manufacture during the follow-up period has improved the one-year survival from 35% at the beginning of the study to 85% at present. Therefore, only one implant session was required for each participant in the past two years to maintain standing and walking function.

Conclusions: While the intent of the percutaneous FES system was a temporary use, this system has been found to be safe and effective for up to sixteen years. The most common problem was inflammation at the electrode site that was easily treated with topical antibiotics. The other complications reported involved cyst formation due to foreign body reaction but this could not be confirmed. In the two subjects who have used the system for exercise and walking for over 15 years no adverse effects have been noted to the skeletal system. Their feet, ankle, knee and hip joints appear normal in the radiographs.

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A CRUTCH SHOCK ABSORBER SYSTEM

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Background: Over the past fifty years, there have been monumental advancements in the fields of prosthetics and orthotics. Space age materials and computer aided design techniques have been used to fabricate a new generation of artificial limbs and braces which have improved the functionality of persons who have limb loss, neurological or musculo-skeletal deficiencies. In contrast, the basic design of crutches has been unchanged for millennia and the only innovation that has been a commercial success is the Canadian forearm crutch that was developed after World War II. There have been a number of investigators who have studied crutches and have developed innovations like the rocker bottom crutch and molded hand grips that help maintain the wrist in a neutral position. Moreover, there are many studies reported in the literature about the energy expenditure associated with various gaits and crutch configurations. Chronic crutch use has resulted in fatigue, repetitive stress disorders, nerve trauma and osteoarthritis. The need for devices that reduce the repetitive forces applied to the upper extremity has been further documented in studies which have shown that chronic use of crutches leads to joint damage in the upper extremity with subsequent pain and loss of function.

Methods: This project is being conducted in two phases. The first phase has focused on laboratory testing of a shock absorbing system that can be incorporated into the crutch to reduce the impact forces which load the hand and wrist at the crutch handles. The system was designed and tested in a loading jig to assess the ability of the shock absorber to reduce the forces delivered to the crutch handle. With vertical motion of the crutch handle limited to less than 6 mm, the force delivered to the crutch handle was reduced with the shock absorber at least 20% and as much as 45%. The second phase of the project involves evaluating how the reduced forces at the crutch handle affect motion of the wrist during crutch assisted ambulation. A Vicon motion analysis system is being used to monitor the flexion and extension of the wrist joint during ambulation on a smooth, flat, floor. Using crutches that have been fit with the shock absorbers, the subjects walk along the walkway to assess whether the shock absorber system can limit wrist extension to less than 20% during the gait cycle - a threshold for significantly increasing the pressure in the carpal tunnel. The effect of handle shape on limiting the flexion and extension of the wrist during impact and weight bearing is also being explored during this phase of the project.

Expected Outcomes: The project is directed toward solving a problem that impacts a large segment of the aging veteran population - veterans who chronically use crutches to assist in ambulation due to amputation of the lower extremity secondary to cancer, diabetes, or vascular disease or due to stroke. By reducing the repetitive forces that act on the hand, wrist and shoulder, the consequential damage will be reduced and chronic crutch users will be able to live longer without the disabling effects of chronic upper extremity pain. Reducing the damage done to the joints of the upper extremity by repetitive forces should lead to people who retain range of motion in the upper extremities that is required for ADL and strength that is required to maintain function and autonomy in daily living. If the proposed work is successfully completed, the number of carpal tunnel surgeries could be reduced and arthritic changes in the wrist and shoulder cause by mechanical trauma could be postponed and thus provide veterans with longer life times without the need for orthopedic surgeries. Moreover, the results of this project will be increased understanding of the force transfer from the crutch to the upper extremities of patients who use crutches and a novel design for a new generation of crutches that are biomechanically better than current crutches.

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EEG-BASED CONTROL FOR ASSISTIVE TECHNOLOGIES: APPLICATIONS TO UPPER EXTREMITY NEUROPROSTHESES

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Objective: Studies have demonstrated that individuals can learn to voluntarily control a specific frequency component of the electroencephalogram (EEG) generated by the motor cortex to operate cursor movement upon a computer screen. This has then formed the basis of an augmentative communication device for individuals with no remaining voluntary movement (i.e. amyotrophic lateral sclerosis or brain stem stroke). However, these signals could potentially be used for the operation of other devices. The purpose of this investigation was to determine if the EEG signal could be employed for use with the upper extremity neuroprosthesis. By establishing feasibility with the neuroprosthesis, it would then be possible to apply the use of this signal to other prosthetic systems.

Methods: Initial studies focused on identifying an EEG signal that could be used to operate the neuroprosthesis. Restrictions which were placed on the signal were that: 1) it must be unaffected by the electrical stimulus generated by the neuroprosthesis and, 2) it could be controlled while the individual generated upper extremity movements. Therefore, the beta rhythm (25-29 Hz) generated by the frontal cortex was selected. Six subjects (four able-bodied subjects and two neuroprosthesis users) were trained to voluntarily control this signal to operate cursor movement upon a computer screen. Training involved a one-hour session, 2 to 3 times a week over a period of six months.

Results: Five out of the six subjects were able to acquire excellent control over the frontal beta rhythm, achieving an accuracy rate of over 90% when moving the cursor to a randomly placed target. These accuracy rates were maintained while the subjects were manipulating a 0.5-kg weight with either hand and in the presence of electrical stimulation. This indicated that the signal could potentially be used to operate a neuroprosthesis. This was tested using an interface developed for the neuroprosthesis that employed the EEG as the command input. Using a switch algorithm, one subject was able to effectively control his hand grasp system to manipulate several objects, including a fork, weight and cup.

Conclusions: The results of these studies indicate that the EEG signal could have a potential application to the field of prosthetics. Also, the establishment of the fact that frontal EEG rhythms can also be voluntarily controlled could also have a potential contribution to the field of augmentative communication. However, further work needs to be accomplished on establishing how well the EEG-based controller works with the neuroprosthetic system, as well as increasing the information content of the signal to allow for more elaborate control of a prosthetic device. Work also needs to be performed on miniaturization of the controller so that it can become a cosmetically acceptable part of any prosthetic system.

Funding: This research is funded by the VA Pre-Doctoral Associated Health Rehabilitation Research Fellowship, the NIH Neural Prosthesis Program (NIH Contract NO1-NS-6-2338), the Ron Shapiro Charitable Foundation and the Movement Disorder Foundation.

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THE EFFECT OF EXERCISE ON GLYCATED HEMOGLOBIN IN TYPE-2 DIABETES IN SUPERVISED VS. HOME EXERCISE PROGRAMS

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Objectives: To test the hypotheses that home and supervised exercise interventions will both improve glycemic control better than usual care; and that improvement in glycemic control is related to improvement in cardiorespiratory fitness, regardless of weight loss.

Methods: A randomized controlled clinical trial is enrolling 150 veterans (25% drop out rate expected) with type-2 diabetes. The study design has 85% power at alpha = 0.05, to detect a 1% (absolute) difference in HbA1c. Veterans screened by Exercise Tolerance Test (ETT) are randomly assigned to a Supervised Group (SG), a Home Group (HG), or the Control Group (CG) for a three-month intervention period followed by a six-month maintenance period. Participants in both exercise groups (SG and HG) are given individualized exercise prescriptions which taper up to 30 minutes of daily walking at 70% of estimated VO_2max, based on results of the ETT. The SG comes to the VA three times a week for the walking and education. The HG is contacted weekly by telephone and comes to the VA three times over the first six weeks for training and education. Subjects in the CG receive assessments only. Baseline, 3-month, and 6-month follow-up assessments include measurements of cardiorespiratory fitness (estimated VO_2max), glycemic control (HbA1c), body fat, body mass index (BMI), waist/hip ratio, resting heart rate, and resting blood pressure. Sixty-five subjects have been randomized. These preliminary findings are based on the 49 subjects who have completed the intervention period.

Results: Only the SG showed significant improvement in estimated VO_2max (paired t-tests, P_{SG}=0.006, P_{HG}=0.06, P_{CG}=0.57). Resting heart rate improved as well (paired t-tests, P_{SG}=0.01, P_{HG}= 0.50, P_{CG}=0.64). Though we did not find a significant improvement in HbA1c in any of the groups (paired t-tests, P_{SG}=0.70, P_{HG}=0.37, and P_{CG}=0.33), a decrease in HbA1c is related to an increase in estimated VO_2max (r=-0.32, P=0.02). This relationship remains after adjusting for changes in BMI and weight (P=0.03). Decreases in HbA1c are also related to change in dosage of oral hypoglycemic agents (P=0.04), but estimated VO_2max has an independent effect.

Conclusions: The lack of significant improvement of HbA1c in the SG and HG suggests the need to further investigate behaviors related to HbA1c, such as diet and pharmacological adherence. The improved estimated VO_2max in the SG suggests exercise adherence in that group when compared to the CG. Follow-up measurements will be analyzed as subjects complete the maintenance period. In addition, behavior recall questionnaires will be implemented for future subjects. Exercise is known to improve insulin sensitivity in diabetics, but how patient adherence can be achieved is an important clinical question. A minimal intervention, if effective, would meet the needs of many veterans, especially in rural areas.

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A COMPUTATIONAL MODEL OF THE HUMAN FOOT

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Objectives: A three-dimensional, finite element model of the human foot was created. The model will provide information on the basic shape of the foot, which is currently a great deficit in our knowledge of the musculoskeletal system. Understanding the pathologic transition from normal will aid in the design of prevention strategies for foot ulcerations and deformities associated with diabetes, stroke and neuromuscular rehabilitation. Similarly, surgical and orthotic treatment strategies for various foot pathologies may be optimized with the use of this model. Exploring the axes of motion of the foot may help in the design of prosthetic feet and ankles. A detailed, biofidelic model will eventually obviate the need for most cadaveric experimentation, preserving the specimens for only the most crucial studies. Computational models will not only allow for parametric studies of the same foot but also provide data on internal stresses and strains. Finally, the foot model will serve as a means of educating VA care providers on the structure and function of the foot.

Methods: Model geometry was established from three-dimensional reconstructions of coronal computed tomographic (CT) images of a cadaveric human foot from a 67-year-old donor. Upon radiographic analysis, the specimen was found to be free of gross deformities or degenerative changes. Dissections of cadaveric specimens and photographic anatomical atlases were employed to locate the origins and insertions of the ligaments. The bones were modeled as rigid 4-noded quadrilateral surface shell elements with low-fiction contact interfaces, the ligaments as 2-noded linear cable elements, and the plantar soft tissue as nonlinear, 8-noded hyperelastic hexahedral solid elements. The plantar aponeurosis was modeled as a spring element that originated from the os calcis and separated into three branches that inserted into the first, third and fifth metatarsal heads. Material properties were derived from the literature and mechanical testing of cadaveric tissues in our laboratory. Since the bones were considered to be rigid, they were modeled as 1mm thick shell elements. To simplify the model, certain bones were grouped together, including the tibia and fibula, the second through the fifth metatarsals and associated phalanges, as well as the navicular and the three cunieforms. A preliminary model validation was conducted by applying an axial load of 150 N to the model's tibial shaft with the foot in midstance position. The resulting angular displacements of the hindfoot complex (calcaneus, talus, navicular, and cuboid) predicted by the model were compared to those obtained experimentally during previous cadaver tests. In addition, a sensitivity analysis was performed to determine which of the model's ligaments were most sensitive to changes in stiffness, revealing those ligaments for which accurate material properties would be desirable.

Results: Model validation demonstrated good correlation between predicted and experimentally measured hindfoot motions. When comparing the three-dimensional rotations of the tarsa; bones, the computational model came with one standard deviation of the cadaveric mean for 10 out of 12 rotations and within two standard deviations of the mean of 12 of 12 rotations. Sensitivity analysis of the model parameters demonstrated that model performance was most sensitive to changes in stiffness of the tibionavicular, long plantar and spring ligaments.

Conclusions: To more efficiently study the biomechanical phenomena underlying foot deformities and diabetic foot ulceration, the functional consequences of foot surgery, and the optimal design of foot orthoses, a three-dimensional, finite element model of the foot and ankle was created. This anatomically accurate, experimentally validated, foot and ankle model should ultimately provide a powerful tool for the rapid understanding, treatment and prevention of foot disease. The Veterans population is likely to have at least an equal incidence of foot problems compared to the general population.

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P-90

EFFECT OF CUSTOM ORTHOSIS ON HINDFOOT KINEMATICS

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Objectives: Foot ulcers secondary to conditions such as diabetes pose significant problems to patients, especially in combination with loss of sensation and altered bony alignment in the foot. The most common conservative treatment is the prescription of a custom orthosis to redistribute weight and reduce skin pressure on the sole of the foot. Orthoses are presumed to unload specific areas of the foot, and if sufficiently rigid, alter bony alignment. However, there does not appear to be any quantified demonstration of the mechanical role of orthoses of differing rigidities. This study was designed to determine the effect of custom orthoses of three different stiffnesses on the kinematics of four hindfoot bones.

Methods: The sample consisted of four human cadaveric feet, free of overt pathology, which were sectioned at the distal one third of the tibia. All tendons crossing the ankle were preserved. Carbon fiber rods were cemented into the calcaneus, talus, cuboid, and navicular to act as mounts for motion sensors. Each specimen was radiographed with a 100 Newton (N) load applied through the tibial shaft. A plaster cast was made that corresponded to the shape of the normal unloaded foot. From this mold, using a CAD/CAM milling machine, a set of three orthoses was manufactured. One each from polyurethane (rigid), cork (midrange), and foam (flexible). The foot was then mounted onto a loading frame with pneumatic cylinders connected to the major extrinsic tendons that cross the ankle. Quasistatic loads in heel strike and stance phases of gait, with corresponding tendon loads were applied at one quarter body weight. Relative angular rotations of the four hindfoot bones were determined using magnetic sensors attached to the carbon fiber rods. Each orthosis was placed under the foot and measurements of hindfoot motion recorded. After testing the intact condition, a flatfoot deformity was created in the following manner. The spring ligament was attenuated by sectioning fifty percent of its fibers to reduce tensile strength. The specimen was then subjected to 5000 cycles of axial loading at one hertz (Hz) with a peak load reaching twice the body weight of the donor. The specimen was then radiographed under a 100N load to determine changes in Meary's angle and talar head coverage to indicate progression to flatfoot. The specimen was placed on the test frame and motions of the four hindfoot bones measured again, with and without orthoses.

Results: The results of this preliminary study are reported as the means and standard deviations for three of the four hindfoot bones (calcaneus, talus, and navicular) tested in the stance position. Each bone was compared to the intact loaded foot. There was a trend toward eversion of each bone after the creation of the flatfoot. This was overcorrected to inversion by the rigid orthosis. The cork orthosis corrected the foot toward neutral to a lesser degree, and the foam orthosis had no appreciable effect on bone position. No consistent trend was seen for the cuboid in this sample. Data for heelstrike did not identify any consistent trends in bone position related to the orthoses. These are descriptive statistics and none of the reported values were found to be significant.

Conclusions: Although this small sample does not allow statistical comparisons, the trends noted indicate that a rigid orthosis appears to alter hindfoot bone position. The cork orthosis shows some change toward the baseline condition, but still allowed the bones to remain everted as compared to the intact foot. The foam orthosis showed no improvement toward the baseline. It would appear that the rigid orthosis can improve the flatfoot condition, but what is not known is whether the overcorrection seen might have detrimental clinical results. To gain greater insight into this question we will be testing an additional sixteen specimens recording both kinematic data and plantar pressures for each test condition. We expect that by correlating these data we can better predict the clinical implications as they relate to the use of these different orthosis materials.

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PROPULSIVE METHODS FOR CRUTCH AMBULATION

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Concepts & Objectives: It has been observed that the orientation of the trunk is often maintained in a fixed attitude with respect to the crutch/arm segment during the early part of crutch stance in "swing-through" crutch gait (Rovick and Childress, 1988). We hypothesize that trunk control could serve to help propel forward movement of the ambulator. Models of trunk and leg swing on crutches were investigated to try to understand how control of body segment orientations during the body's swing phase (crutch stance) could influence energy flow to the forward ambulation process. The goal of our work is to investigate possible propulsive mechanisms of crutch ambulation. We believe that an understanding of the biomechanics of swing-through crutch gait may make it feasible to design more efficient crutch-type mechanisms that will enable disabled veterans and other users to move about more efficiently and freely than is now possible.

Methods: Computer and physical models were developed and constructed based on the idea that propelling one's self on crutches is similar to propulsion of a child's playground swing. Children's swings (regular pendulums) are similar in dynamics to walking models (inverted pendulums), but allow continuous analysis compared to stepwise continuous models that are associated with inverted pendulum models. Physical models were used to confirm results observed in the computer models.

Results: It was found that control of the orientation of segments with respect to the hanging pendulum can be used to pump a swing. Computer-based pendulum models demonstrated this pumping action and it has been confirmed with tests on physical models. Similar computer models have been designed that correspond to inverted pendulum models of crutch ambulation crutch stance. They show that control of the orientation of the trunk can help propel the body forward. The engineering design challenge is to construct simple devices that can assist the human musculature with this "hold-and-swing" control process.

Conclusions: The results from the models have been encouraging. They provide insight into the mechanisms that are used in crutch propulsion. Design of "hold-and-swing" crutch mechanisms is ongoing in an attempt to use this propulsion method without excessive muscle activity in the trunk and upper limbs.

References: Rovick, J. S. and Childress, D. S. Pendular model of paraplegic swing-through crutch ambulation. *Journal of Rehabilitation Research and Development*. 1988; 25(4): 1-16.
Wirkus, S.; Rand, R., and Ruina, A. How to pump a swing. *The College Mathematics Journal.* 1998; 29(4): 267-275.

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P-92

ANATOMICAL BASIS OF OSSEOPERCEPTION: NEUROPEPTIDE EXPRESSION DURING OSSEOINTEGRATION OF TITANIUM IMPLANTS

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Objectives: The research objective of this program is to determine the anatomical basis of the sensory phenomena termed osseoperception that is associated with titanium fixtures implanted in bone for the support of prostheses. Preliminary studies in humans with osseointegrated titanium fixtures that anchor prostheses for hands and lower extremities have documented increased perception of the environment relative to traditional socket prostheses. Since bone is innervated by unmyelinated fibers immunoreactive for calcitonin gene-related peptide (CGRP), we chose to explore changes in this sensory peptide as a function of time after experimental osseointegration of titanium implants in rat femurs. CGRP also plays a key role in the process of bone remodeling, and we wanted to quantify its relationship to neuroimmune events that may control both osseointegration and the secondary phenomenon of osseoperception.

Methods: In 10 male Sprague-Dawley rats, a 20 mm-long, partly threaded, titanium implant with a core diameter of 1.5 mm was installed through the knee joint into the intramedullary space of the femur. The animals were housed without restriction for 8 weeks. Changes in nerve fiber density were studied with the PGP 9.5 antibody technique using fluorescent secondary antibodies and confocal microscopy. Immunohistochemical characteristics of neural elements and marrow cells in remodelled and control bone were analyzed by staining for CGRP.

Results: Application of this new experimental model was successful in that the fixtures became osseointegrated within 8 weeks. Bone remodeling occurred around the threaded end of the fixture as evidenced by the upregulation of osteoblasts at the boundary of the titanium/bone interface and their incorporation in new haversian systems. These osteons and new Volkmann's canals were filled with CGRP-positive cells. Bone marrow cells were also stained positively for CGRP at levels that greatly exceeded normal tissue. PGP expression did not appear to be significantly altered at this timepoint.

Discussion: Osseoperception is of great importance in the rehabilitation of the amputated patient since it facilitates improved feedback control of the prosthesis and may enhance psychological acceptance of the artificial limb. CGRP is generally associated with nociception, in that it is co-localized in sensory neurons with substance P. CGRP may also have a role as a neuropeptide that is related to mechanoreception. Continued studies are planned to assess changes in the expression of this neuropeptide in the dorsal root ganglia that give rise to the axons innervating rat femur. It is concluded that CGRP expression reflects both afferent and efferent responses to intramedullary titanium implants.

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LUMBAR SPINE MOBILITY UNDER IN VIVO COMPRESSIVE LOADS

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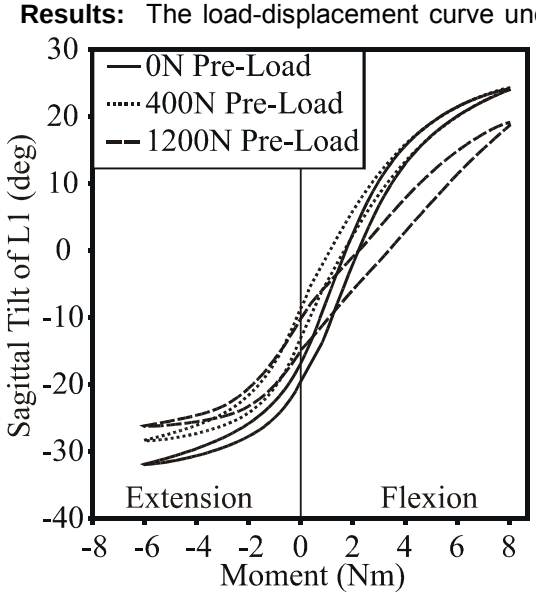
Objectives: *In vivo* compressive loads on the human lumbar spine reach 1000 N during standing and walking and exceed that level in lifting activities. In the absence of muscles, the ligamentous lumbar spine cannot support vertical compressive loads of physiologic magnitude. This has been a limiting factor in *ex vivo* testing of the whole lumbar spine under compressive pre-loads of physiologic magnitude. Patwardhan, et al. (1) showed that if the compressive load is applied along the follower load path (the path that approximates the tangent to the spinal curve), the segmental bending moments and shear forces on the mid-transverse plane of the discs are minimized. This allows the lumbar spine to support large compressive follower loads without hypermobility in a given posture. In this study we asked: "Is the increased stability of the lumbar spine under a follower load achieved at the cost of mobility?" The hypothesis was that a compressive follower pre-load does not affect the neutral zone and range of motion of the lumbar spine in flexion and extension.

Methods: The neutral zone (NZ), range of motion (ROM), and stiffness of healthy human lumbar spines (L1-sacrum) were determined in flexion-extension under compressive follower pre-loads of up to 1200 N which covers a significant portion of the physiologic compressive pre-load on the lumbar spine. A compressive follower pre-load was applied to the specimen bilaterally using cables and dead weights. The cables were attached to L1 and passed through cable guides secured to L2-S1. The specimen was tested first under zero follower pre-load by applying three complete cycles of flexion-extension moments (0-8 Nm flx-0-6 Nm ext-0). The change in L1-S1 sagittal angle was continuously recorded. This protocol was repeated with follower pre-loads of up to 1200 N.

Results: The load-displacement curve underwent a gradual change from a nonlinear to a linear curve with increasing follower pre-load magnitude. The flexion/extension stiffness of the spine increased as the compressive follower pre-load increased. The range of motion decreased with increasing follower pre-load magnitude. However, at 1,200 N follower pre-load the ROM decreased by only 24%; from a mean of 52 degrees to 39 degrees. The neutral zone was not significantly affected at 1200 N follower pre-load magnitude.



Conclusions: We believe the follower load path represents the overall effect of muscles that stabilize the spine and allow it to support compressive loads of physiologic magnitude throughout the range of motion in a dynamic task. This is in sharp contrast to previous studies that noted nearly 90% decrease in the segmental ROM and NZ under simulated actions of selected muscles. This study provides an explanation of how muscles can stabilize the lumbar spine in lifting tasks that induce large compressive loads while bending forward. It offers a new experimental technique to test the effects of spinal implants on the response of the lumbar spine under realistic *in vivo* loads.

References: Patwardhan et al., Spine 1999; 24:1003-1009.

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IRIDIUM-BASED SUBRETINAL IMPLANTS

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Objectives: To determine whether microphotodiode-based subretinal implants have improved durability and retained biocompatibility when the electrode materials is iridium/iridium oxide (IrOx) instead of gold.

Methods: Microphotodiode-based implants were fabricated using standard thin-film semiconductor techniques. Final devices were ~50 □m in thickness and 2 mm in diameter, and were comprised of an array of 20 □m x 20 □m individual microphotodiode subunits. Implants were placed in the subretinal space of normal cats using vitroretinal surgical techniques adapted to the cat eye. Throughout the postoperative period, implant function was evaluated by recording at the corneal surface the electrical response of the implant to infrared (IR) light. Implant biocompatibility was assessed by fundus appearance evaluated using indirect ophthalmoscopy and documented by fundus photography, by electroretinographic recordings made in response to white light presented in a ganzfeld, and by analysis of retinal histology.

Results: IrOx-based implants continued to generate electrical responses to IR light throughout the postoperative period, which has been extended for up to 12 months in some cases. In comparison to gold-based implants, in which the implant response diminished in amplitude over the first 6 postoperative months, the amplitude of the implant response has remained essentially unchanged. As was the case for gold-based devices, IrOx-based implants have good biocompatibility for the neural retina, with the exception of the photoreceptor layer which is lost due to the solid disk implant blocking access to the choroidal circulation.

Conclusions: The use of IrOx as the electrode layers in the design of the microphotodiode-based subretinal implant renders the device more durable in the subretinal space, where it is intended to stay permanently.

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CORRELATION OF PRESSURE AND PERFUSION MAPS OF PLANTAR FOOT SURFACES OF HEALTHY VOLUNTEERS

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Objectives: Reactive hyperemia is a basic compensatory mechanism of the skin vasculature which enhances blood flow after release of ischemia induced by skin compression. Effectiveness of this compensatory phenomenon is important to prevent potential skin damage of the plantar foot surface induced by repeated compression during standing and walking. Prior to a study of the relationship of compression forces and local blood flow in vascular insufficiency of the lower limb, we sought to characterize the correlation between these variables in a sample of normal individuals.

Methods: Ten subjects of both sexes were divided into 2 groups of 5 subjects less than 35 years old and 5 subjects greater than 50 years old. Subjects were asked to stand and then walk on a matrix of pressure sensors to record a 2-dimensional graphic display of the forces generated on the plantar foot surface. In the same session, a similar display of blood flow distribution over the plantar surface of the same foot was recorded with a laser doppler imager (LDI). LDI was implemented with a Moor Instruments imager. This instrument uses a He/Ne laser beam, which scans the area of interest in a raster pattern. The doppler shift detected in the reflected beam is related to the speed of moving particles (blood cells) in the tissue and provides a quantitative estimate of tissue perfusion. A color-coded map of perfusion of skin in the foot plantar surface is then constructed. Plantar pressures were detected with a 16x32 rectangular sensor (VistaMedical, Ltd. Winnipeg, Canada). A color-coded map of plantar pressures scaled from highest pressure = 100% to no pressure = 0%.

Results: In the absence of compression (subjects lying prone on a bed) LDI images showed maximal estimated blood flow (FLUX) in the heel, and metatarsal heads, with intermediate levels on the lateral edge of the sole and minimal values in the rest of the plantar surface. The patterns of compression (plantar pressures) during standing and walking generally reproduced the same distribution. These patterns were similar regardless of age within the healthy population used in this pilot study.

Conclusions/Clinical Relevance: A higher level of FLUX is evident at rest in the supine position in areas of skin that are exposed to compression during standing and walking. Additionally, these are areas considered to have high incidence of plantar ulceration. Conceivably, a loss of this correlation between compression and FLUX might lead to the appearance of plantar ischemic lesions. Further study of the spatial correlation between these two variables in subjects at risk of skin ulceration might help to predict the likelihood of occurrence and possible location of these lesions. These issues are further paramount for the diabetic peripheral neuropathy patient who have increased time of plantar pressures due to increased stance times and decreased swing times during gait.

Future Research: Future research directions involve describing the correlation of FLUX and plantar pressure mapping of subjects with diabetic peripheral neuropathy. Additionally, development of dynamic measures of reactive hyperemia following the application of plantar pressure are underway.

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SQUIRT SHAPE—DEVELOPMENT OF AN AUTOMATED FABRICATION TECHNIQUE TO ENHANCE PROSTHETICS CAD/CAM

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Objectives: Develop a method and device for the automated production of prosthetic sockets suitable for use with computer-aided design and computer-aided manufacturing [CAD/CAM]. The device in development—Squirt Shape—is intended to address some of the shortcomings of commercially available equipment for prosthetics CAM, namely (1) inconsistency or variability in socket fabrication; (2) reliance on a two-stage process requiring production of a positive model and a separate molding operation (i.e. sockets are not produced directly) which lead to either high technician expenses, or high costs of equipment and supplies. Further objectives of Squirt Shape are (1) the potential to produce sockets with engineered properties of stiffness and flexibility, allowing a single socket to be structurally stiff in certain regions and comfortably flexible in others; and (2) the ability to fabricate unitized limbs incorporating multiple features such as socket, pylon and foot into a single structure.

Methods: The socket is made by depositing melted plastic in thin, ring-shaped layers; one upon another. The profile shape of each layer ring corresponds to the perimeter shape of the desired socket at various height levels. The full, three-dimensional shape of the socket is achieved by the stacking of a multitude of layered rings with gradually varying profile shape. As each layer of melted plastic is deposited, it bonds to the layer below it and is then quickly cooled to a solid form. A computer controlled positioning system directs the flow of the melted plastic to achieve the desired profile shape for each layer. The temperature and flow rate of the melted plastic is also computer controlled to provide consistency in the processing parameters. A 230-mm long B/K socket will have over 300 layers of deposited plastic and can be fabricated in less than 50 minutes.

Results: A prototype of the Squirt Shape device has been constructed and evaluated. Definitive sockets can be made using this device and the resulting sockets are smoothly shaped and have uniform wall thickness. Common thermoplastic materials can be used, such as polypropylene. Mechanical testing shows tensile strength for polypropylene equivalent to hand production and estimates an "unlimited" fatigue life for typical socket stress levels. Clinical trials in excess of four years reveal no visual signs of mechanical failure.

Conclusions: The device shows promise for prosthetics CAD/CAM. Development is in a pre-commercial prototyping phase. Separate projects are underway addressing future design enhancements.

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KINEMATIC CONSTRAINTS TO RELATIVE MOTION BETWEEN THE HINDFOOT AND MIDFOOT JOINTS

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Objectives: The talonavicular and calcaneocuboid joints of the foot act together to absorb shock and adapt to the complex forces imparted during ambulation. It has been observed clinically that the midfoot is more mobile with subtalar (calcaneal) eversion, and less so with inversion. In this study, the contributions of various structures to midfoot mobility were determined by sequential sectioning, to provide understanding of flatfoot deformity.

Methods: Eight human cadaveric feet were disarticulated intact at the tibiotalar joint. Steinmann pins were placed through the base of the second metatarsal dorsal to plantar, and through the calcaneus. The foot was mounted to an apparatus with the talus as the fixed point. The calcaneus was positioned in either maximum achievable inversion or eversion for that particular specimen and was locked in that position. The midfoot was loaded to maximum dorsi flexion (combined with eversion) or plantar flexion (combined with inversion) using a 22N weight suspended 10 cm from the center of the second metatarsal on the midfoot pin. An inclinometer was mounted first on the pin through the calcaneus to record its position, and then on the pin through the midfoot to record its motion under load. The calcaneus was placed in maximum eversion, locked, and its angular position recorded. The angle achieved by the loaded midfoot in dorsiflexion, and then plantar flexion, was measured with the inclinometer. The calcaneus was then positioned in maximum inversion and midfoot motion remeasured. Then the calcaneocuboid joint capsule was dissected perpendicular to the articulation and the posterior 4 mm of the cuboid bone removed, leaving the calcaneocuboid ligament intact. Following retesting, the plantar fascia, the short calcaneocuboid ligament, the spring ligament, and the bifurcate ligaments were sectioned in that order, with measurements each sectioning step. CT scans of the intact foot were taken to visualize the congruity of the midfoot bones.

Results: *Intact joint motion:* Positioning the calcaneus in full inversion resulted in 32.9 deg (sd = 11.7 deg) of midfoot motion (dorsi to plantar flexion) under load. In contrast, with the calcaneus positioned in full eversion, midfoot range of motion increased to 41.7 deg (sd = 11.7 deg) ($p = 0.001$, $n = 7$). CT scans showed that the calcaneocuboid joint becomes close packed with calcaneal inversion, and incongruous with midfoot dorsiflexion. *Effect of sectioning:* There was a progressive increase in overall midfoot range of motion with progressive sectioning of components. With the calcaneus everted, midfoot motion increased from 52.5 deg to 55.3 deg with cuboid removed, to 64.6 deg with fascia sectioned, ($p<0.05$, $n = 5$) 69.2 deg with the spring ligament sectioned, and 74.5 deg with the bifurcate ligament removed.

Conclusions/Relevance: (i) When the calcaneus is positioned in inversion, midfoot motion decreases, probably due to close packing of the subtalar and midfoot bones, and conversely increases with eversion. (ii) The cuboid and soft tissues, when resected, progressively allowed greater midfoot dorsi-plantar flexion (up to 142% of that of the intact midfoot). This basic information provides insight into foot mechanics in flatfoot deformity and methods of its correction.

P-98

PERFORMANCE OF IMPLANTED EPIMYSIAL ELECTRODES IN THE LOWER EXTREMITIES OF INDIVIDUALS WITH SPINAL CORD INJURY

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Objectives: This paper describes the reliability and effectiveness of implanted epimysial electrodes in the lower extremity muscles of persons with spinal cord injury (SCI).

Methods: Forty-one epimysial electrodes have been implanted in various muscles of the lower extremities of six volunteers. Each of these electrodes was surgically installed and connected to the CWRU/VA receiver/stimulator as part of a fully implanted system to restore standing or stepping function in individuals with SCI. The standing system uses electrodes implanted bilaterally in Vastus Lateralis (VL) for knee extension, Gluteus Maximus (GMAX) for hip extension, and Adductor Magnus (PADD) or Hamstrings (HAMS) for additional hip extension. The stepping system also uses these extensor muscles, and hip and ankle flexion is accomplished through electrodes implanted bilaterally in Tibialis Anterior (TA) for ankle dorsiflexion, Sartorius (SART) for hip flexion and Tensor Fasciae Latae (TFL) for additional hip flexion. After implantation, a six-week period of restricted activity promotes healing of the tissue and encapsulation of the implanted components. One week post-implant, voltage potentials are recorded on the surface of the skin along the path of the electrode leads to monitor electrode integrity. These potentials are recorded again at the completion of the rehabilitation training, and at one-year follow-up, or at the onset of a suspected problem. Pulse-width activation thresholds are recorded four weeks post-implant, and monthly thereafter to monitor electrode stability. The hip and knee joint extension moments are measured on a Biodex isokinetic dynamometer at the onset of standing training, at the completion of the rehabilitation training, and at one-year follow-up.

Results: The pool of epimysial electrodes has accumulated over 75 electrode-years of operation, with an average observation time of two years per electrode. Thirty-six of the 41 electrodes (87.9%) produce joint moments adequate for standing and stepping, and remain stable up to three years post-implant. Peak joint moment produced by these electrodes range from 5 to 45Nm for hip extension, and 25 to 45Nm for knee extension. Three of the 41 electrodes (7.3%) are stable, but produce joint moments insufficient for standing, and one electrode (2.4%) exhibits signs indicative of a mechanical failure. Behavior of one of the 41 electrodes (2.4%) indicated, through lower voltage potentials and elevated activation thresholds, a mechanical failure. This was confirmed during replacement of this electrode, where it was discovered that the stimulating disk had separated from the electrode lead. The size, weight and high activity level of this individual, along with the location of this electrode (GMAX), may have been contributing factors.

Conclusions: Epimysial electrodes are reliable and effective in producing joint moments adequate for standing and stepping even after three years of operation. The effectiveness of these electrodes at producing joint moment can be improved through refinement of the surgical installation. The reliability data indicate that these electrodes are suitable for use in fully-implantable neuroprosthetic standing and stepping systems.

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P-99

DEVELOPMENT OF AN EXTERNALLY POWERED PROSTHETIC HAND FOR PERSONS WITH PARTIAL HAND AMPUTATIONS

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Objectives: We are developing an externally powered prosthetic hand for persons with transmetacarpal amputations that result in loss of all digits. In this case, all except the very simplest function of the hand is lost. However, the wrist is usually still functional and its motions, flexion-extension, radial-ulnar deviation, and supination-pronation are extremely valuable in positioning the hand in space. There are no commercially available externally-powered partial-hand prostheses. Although there exists a wide range of devices, ranging from: passive cosmetic replacements; to body-powered hands or fingers; to purely functional passive work prostheses; there are few partial hand prostheses that are functional yet cosmetic. The indications for partial hand prostheses are cosmesis, protection of sensitive skin, and function [Michael, 1992]. Our device will provide function with cosmesis and in addition, the stabilizing socket for the device will provide protection for sensitive skin.

Significance: There are 102,000 people with upper extremity absence or loss according to Report 7, Disability in the United States, 1992, published in 1996 by the Disability Statistics Rehabilitation Research and Training Center at the University of California, San Francisco. The most common loss is partial hand amputation with the loss of one or more fingers (61,000); next most common is loss of one arm (25,000). Based on these data and data from Le Blanc, who estimated that 10% of upper-limb amputations are wrist or partial hand amputations, we believe that an externally powered prosthesis for partial hand amputations has the potential to benefit upwards of 6000 persons with wrist and hand amputations in the USA (Veterans and Civilians). The device should be particularly advantageous for persons with bilateral loss due to land mines or other explosives. A powered finger hand has application primarily for persons with partial hand amputation of all digits at or more proximal to the level of the metacarpophangeal joints, including wrist disarticulation amputations. Persons with higher level upper-limb amputations could also benefit because the hand has been designed in a modular fashion to allow connection to conventional upper-extremity sockets.

Results/Methods: We are in the process of finishing the first prototype hand. This hand uses three motors operating in synergy to provide reasonable overall force and speed capability. In a 'synergetic' motor system one motor is dedicated to providing high torque at low speed while another is dedicated to providing high speed at low torque. Together it is possible to have a system that is capable of achieving reasonable torque and speed. For this hand the thumb is fixed and only the fingers move. There is a motor in the index and middle fingers to provide force, and a third motor lying in the line of the knuckles to provide speed. The knuckle motor provides speed for the opening of the fingers. The hand is expected to have a pinch force of at least 12 lbs_f, a width of opening in excess of 3½" and a maximum speed in excess of 2 radians/sec. The preferred method of control is through myoelectric signals from superficial intrinsic muscles of the hand. Through the use of carbon-graphite mounting components and the availability of small DC motors we believe that an aesthetically pleasing lightweight prosthetic hand is readily achievable.

Funding: This project is funded through funds administered by the VA Chicago Health Care System - Lakeside Division Merit Review Grant No: A2263-RC and Rehabilitation Research Career Development Award (B0928CD).

P-100

THE EFFECT OF CUTTING FLUTE DESIGN ON THE INSERTION AND PULLOUT PROPERTIES OF SELF-TAPPING BONE SCREWS

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Objectives: Self-tapping cortical bone screws are commonly used for internal fixation of long bones. However, oftentimes the cutting flutes of these screws induce soft tissue irritation and patient discomfort. With the intent of reducing patient discomfort, this study investigated how changes in cutting flute design would affect the ease of insertion and holding power of these screws. We hypothesized that changes in cutting flute length and/or number of flutes would result in changes in the mean insertion torque and pull-out strength of the screw.

Methods: Six cortical bone screw designs were studied, each with a different flute number and/or flute length. The number of flutes varied from zero to four, and the flute length was either zero, 1.7 mm (one-third length), or 5.1 mm (full length). Screws were inserted bi-cortically from lateral to medial in the diaphyses of human cadaveric femurs. Each femur was scanned using dual-xray absorptiometry and regional bone mineral density (BMD) values were measured. Screws were inserted at seven locations along the diaphysis of each femur. The insertion torque was measured with a custom digital torque transducer and pull-out strength was measured using a servo-hydraulic load frame. Insertion torque and pull-out strength were normalized by dividing by the respective regional BMD values. The mean normalized insertion torque and normalized pull-out strength data were each statistically analyzed using a single factor analysis of variance and a Fischer's post-hoc test with a level of significance of 0.05.

Results: The mean normalized insertion torque of the screw design with four full-length flutes was significantly ($p<0.05$) lower than that of the one design with three full-length flutes, and the two designs with one-third length flutes. The mean normalized pull-out strength of the screw design with four full-length flutes was significantly ($p<0.05$) greater than that of all designs with fewer than three flutes.

Conclusions: The primary advantages of self-tapping screws include a decrease in 1) the number of instruments needed during surgery, 2) the number of surgical steps, and 3) the operation time. This study was designed to investigate the possibility of reducing the cutting flute length, while still maintaining the insertion and pull-out properties of similar screws with longer flutes. We found that the normalized insertion torque significantly increased and there was a trend toward a decrease in normalized pull-out strength as the number of flutes decreased. These results give insight into the effect of flute length and number on bi-cortical bone screws. The data suggest that screws with four, one-third length cutting flutes may be appropriate when attempting to minimize soft tissue irritation, but there is some compromise to screw performance.

Acknowledgements: This study was funded in part by Depuy-Ace Medical and the RR&D Center of the Veterans Affairs Palo Alto Health Care System.

SPINAL CORD AND RELATED NEUROLOGICAL DISORDERS

Abstract #
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S-101

PHYSIOLOGIC COMPARISON OF YAMAHA JWII POWER ASSISTED AND TRADITIONAL MANUAL WHEELCHAIR PROPULSION

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Objective: This study sought to examine the difference in metabolic energy efficiency during manual wheelchair propulsion with and without the JWII power assist hub.

Research Plan: Subjects were recruited to perform wheelchair propulsion trials of varying speeds and resistances in a controlled laboratory environment. Physiologic data was collected during propulsion.

Methods: 4 female and 6 male full-time manual wheelchair users (9 SCI T2-T9, 1 MS, age 22-50) were recruited from the laboratory's database. Subjects were asked to propel both their own chair and a Quickie GP equipped with the JWII on a computer controlled wheelchair dynamometer. Propulsion speed was 0.9 and 1.8 m/s with the dynamometer set on normal, slight and moderate resistances. The order of chairs, speeds and resistances was randomized. Oxygen consumption (VO_2) was measured with Sensormedics Metabolic Measurement Cart and heart rate (HR) was measured with a heart rate monitor. Three minutes of physiologic data were collected for each trial. Since the data was not normally distributed, Wilcoxon signed ranks test was used for statistical analysis.

Results: The JWII had significantly lower ($p<0.05$*) mean and peak VO_2 values in all 5 conditions, while mean and peak HR was significantly lower in 3 of 5 trials with the JWII than the traditional chair.

	VO_2			HR		
MEAN VALUES	Mean ± SD with JWII	Mean ± SD without JWII	P	Mean ± SD with JWII	Mean ± SD without JWII	P
1.8 m/s, normal resistance	7.79 ± 1.57	10.76 ± 2.84	0.022 *	112.67 ± 22.75	128.92 ± 27.31	0.059
1.8 m/s, slight resistance	7.98 ± 1.39	13.00 ± 2.84	0.005 *	111.37 ± 20.19	134.4 ± 24.22	0.005 *
0.9 m/s, normal resistance	5.47 ± 0.83	6.86 ± 1.20	0.005 *	95.06 ± 16.06	104.79 ± 20.27	0.022 *
0.9 m/s, slight resistance	5.93 ± 0.96	7.31 ± 1.51	0.005 *	98.32 ± 21.14	106.01 ± 19.15	0.066
0.9 m/s, moderate resistance	5.93 ± 1.30	7.51 ± 1.83	0.005 *	99.84 ± 18.51	106.31 ± 23.54	0.037 *

Clinical Relevance: JWII power assist wheelchair hub reduces the physiologic demand of wheelchair propulsion. This is beneficial for most wheelchair user veterans, particularly the aging or those in transitional status between manual and powered chairs. In addition, it eases long distance propulsion by facilitating longer maintenance of higher speed.

Funding Acknowledgement: The JWII power assist hubs used in this study were provided by Yamaha Motor Corporations, USA. Funding was also provided by the Center of Excellence for Wheelchairs and Related Technologies, VA Rehab R&D Service, U.S. Department of Veterans Affairs.

S-102

EFFECT OF ANABOLIC STEROID THERAPY ON HEALING OF LONG-STANDING PRESSURE SORES: NINE CASE REPORTS IN VETERANS WITH SCI

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Long-standing pressure sores are a frequent and debilitating problem for individuals with spinal cord injury (SCI). Anabolic steroids combined with increased protein intake have been successful in promoting weight gain, reversing catabolism and increasing the rate of skin healing in patients with burns (Demmling et al., J Trauma, Injury, Infection, and Crit Care, 1997). Pressure sores are appreciated to bear a similarity to burns. Based on improved skin healing in patients with burns, we treated nine inpatients on the SCI ward who had non-healing pressure sores with the anabolic agent, oxandrolone (20 mg/d; Oxandrin™, BTG Pharmaceuticals, Iselin, NJ) and the nutritional supplement, glutamine (20 g/d; Cambridge Nutraceuticals, Boston, MA). The previous pressure ulcer histories included: 2 patients with seven ulcers each, 2 patients with four ulcers each, 2 patients with three ulcers each, 2 patients with two ulcers each and 1 patient with one ulcer; self-reported healing time was weeks to months; flap surgeries consisted of 3 patients with none, 4 patients with single and 2 patients with multiple. Characteristics of the patients and current pressure sore(s) are presented below. After treatment, 4/9 patients healed, 4/9 patients showed significant signs of healing and 1 patient remained unchanged.

Characteristics			Current Pressure Ulcer(s) Status						
S's	DOI (y)	SMK Hx	Tot. No.	Age of Ulcer	Pre Tx Healing Progress?	Recent Wt. Loss	Surgery Status	Mo. of Tx	Status
1	46	Quit	1	4 mo.	no change	19 lb.	n/a	2	healed
2	1	Never	1	1 yr.	no change	none	n/a	2	healing
3	9	Current	1	2 mo.	some	none	n/a	1	healed
4	3	Current	5	2 mo.	some	none	flap	4	healed
5	34	Quit	3	1 yr.	some	20 lb.	n/a	4	healed
6	18	Quit	1	5 yr.	deterioration	none	flap	1	healing
7	30	Never	1	2 mo.	some	10 lb.	n/a	1	no change
8	2	Quit	3	9 mo.	deterioration	none	n/a	4	healing
9	30	Never	1	1+ yr.	deterioration	none	flap	1	healing

Nutritional supplementation and oxandrolone appeared to be efficacious because the chronic pressure sores presented prior to treatment did not heal on conventional therapy but healed or improved on anabolic steroid intervention.

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S-103

UPREGULATION OF A PREVIOUSLY SILENT SODIUM CHANNEL GENE IN AXOTOMIZED DRG NEURONS

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Hyperexcitability of DRG neurons, following nerve injury and SCI, contributes to chronic pain in these disorders. Recent studies have demonstrated the emergence of a rapidly-repriming, tetrodotoxin (TTX)-sensitive sodium current which may contribute to this hyperexcitability in axotomized DRG neurons, but its molecular basis is unexplained. Axonal transection leads to an up-regulation of sodium channel III transcripts, which are normally undetectable in DRG neurons, in adult rats. We show here that TTX-S currents in axotomized DRG neurons reprime more rapidly than those in control neurons throughout a range of -140 to -60 mV, although small (<25 (m dia.) neurons exhibit substantially greater changes than medium (40-45 (m dia.) neurons. We also show that small and medium DRG neurons display increased brain type III sodium channel immunostaining at 7-9 days post-axotomy. Type III sodium channel staining is present within somata and neurites of axotomized neurons studied *in vitro*. Axotomized DRG neurons *in situ* also exhibit enhanced type III staining compared to control neurons, including an accumulation of type III sodium channels in the distal portion of the transected sciatic nerve. These observations are consistent with a contribution of type III sodium channels to the rapidly-repriming sodium currents observed in axotomized DRG neurons, and suggest that type III channels may at least partially account for the hyperexcitibility of these neurons following injury. Selective blockade of type III channels may offer a new therapeutic approach to neuropathic pain. [Supported by Rehabilitation Research and Development Service and Medical Research Service, Department of Veterans Affairs]

S-104

MAINTENANCE OF TISSUE HEALTH THROUGH LONG-TERM USE OF NEUROMUSCULAR ELECTRICAL STIMULATION

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Objectives: Neuromuscular electrical stimulation (NMES) can potentially be employed as a therapeutic method for the long-term intrinsic improvement of tissue viability in paralyzed muscle. Maintenance of tissue health in veterans with spinal cord injury will help to prevent or reduce the risk of pressure sores.

Methods: A four channel system employing percutaneous electrodes is implanted bilaterally in the gluteus maximus. Following muscle conditioning to improve the strength and fatigue resistance of the chronically paralyzed muscles, the NMES system is used daily in the wheelchair. Stimulation parameters are set to provide active muscle contractions which mimic pressure-relief maneuvers. Tissue viability status is monitored regularly using transcutaneous oxygen measurements to assess regional blood flow, interface pressure monitoring to determine pressure variations and CT scans to determine muscle thickness.
Study participants have a significant history of pressure sore occurrence and have upper motor neuron spinal cord lesions.

Results: Two participants have currently been recruited for this study. One is scheduled to receive the stimulation system. The other participant has been using the system for over two years. During this time he has had no incidences of skin breakdown or pressure sores. Prior to entering the study, he had a history of at least one significant sore per year. Assessment of tissue viability status has indicated that regional blood flow increases and pressure distributions improve following muscle conditioning. These positive changes are further improved and maintained with regular long-term use of NMES. Withdrawal of the daily stimulation regime led to reversal of the observed gluteal hypertrophy such that tissue viability status returned to near baseline values after ceasing stimulation for 12 weeks.

Conclusions: The long-term therapeutic application of NMES has a positive effect on regional tissue health, implying that risk of pressure sore development is reduced. Results to date indicate that this technique may provide a useful adjunct pressure relief technique for individuals who cannot move independently. Current indications are that regular use of NMES stimulation is likely to be necessary in order to achieve optimal benefit to tissue health.

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S-105

ASSESSMENT OF PARASPINAL MUSCLE FUNCTION IN PATIENTS WITH LOW-BACK PAIN DURING DYNAMIC ACTIVITIES

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Objectives: Healthcare specialists working with low back pain (LBP) patients need objective measures for assessing muscle impairment. Clinical research studies by our group and others have demonstrated that the Back Analysis System (BAS), a surface electromyographic (EMG) technique developed through VA Rehab R&D funding, is able to non-invasively and objectively identify the presence of muscle impairments in patients with LBP. Despite these favorable results, the technique suffers from two primary limitations which prevent widespread use in the VA Healthcare System: 1) the technique has been derived and validated only for static, constant-force contractions; and 2) it's size and cost are prohibitive. This project describes recent innovations to record and process surface EMG signals from dynamic contractions which make it possible to expand the considerable benefits of the BAS to a more versatile and useable system for back pain assessment.

Methods: Signal processing algorithms based on time-frequency analysis procedures were developed to derive spectral estimates of the EMG signal for dynamic contractions. This technique was used to process signals from control subjects (n=10) and patients with LBP (n=4) during a standardized repetitive lifting protocol. Subjects lifted a weighted box (10-20 lbs) from mid-shank to waist height for a duration of 4 minutes, at a duty cycle of 12 lifts per minute. The biomechanics of the task was studied (using a stereophotogrammetic system and/or goniometers) and the EMG data were processed taking into account the periodicity of the task. Specifically, the EMG analysis was performed for the same portion of the lifting cycle over successive cycles. The portion to be used for the EMG assessment was chosen according to the repeatability of the biomechanics over successive cycles.

Results: The time frequency analysis procedure was successful in deriving EMG spectral parameters that indicated distinct periods of localized fatigue and recovery during the lifting protocol for controls, but not LBP patients. The LBP patients demonstrated very little shifts in EMG spectral parameters which suggest muscle substitution or inhibition secondary to pain. These findings were directly related to the degree of clinical impairment and disability of the patient. Further analysis is underway using mechanical models to establish whether LBP and fatigue modify the lifting strategy in a way that can increase the likelihood of injury.

Conclusion: The preliminary findings support the hypothesis that recent innovations in EMG signal processing can extend the BAS technique to dynamic "real-world" tasks such as lifting.

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S-106

CHANGES IN THE DEMOGRAPHICS OF SPINAL CORD INJURY: 1942-1997

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Objective: This study was designed to examine trends in demographic and injury-related information of individuals with spinal cord injury (SCI) treated over a 55 year period in the VA Health Care System.

Methods: Data were retrieved from the medical records of SCI patients treated at the VAPAHCS SCI Center. A total of 656 patient charts were reviewed with data from 646 of them used for this analysis. Efforts were made to retrieve information on all patients ever seen at the SCI Center, however data analysis was performed only on those patients currently alive. Data were analyzed in approximate ten year intervals by date of injury; 1942-1955, 1956-1965, 1966-1975, 1976-1985, and 1986-1997. Descriptive statistics were performed on demographic and injury-related characteristics, and changes over time were evaluated.

Results: The number of SCI patients increased by 10% per decade from 1965-1997. The average age at the time of injury doubled from the 1942-1956 cohort (23.3 years) to the most recent cohort (46.0 years). The average age of all surviving patients was 60 years old (range: 19-88 years). The vast majority of patients were male and Caucasian. The current population is represented by 48% quadriplegic and 52% paraplegic individuals. Prior to 1966, over 70% of SCI resulted in paraplegia. Over the next three decades, the proportion of quadriplegic injuries has doubled to where 60% of new injuries result in quadriplegia. The proportion of patients with SCI classified as Frankel/ASIA A (i.e., complete motor loss) decreased over time while the proportion of those classified as Frankel/ASIA D (i.e., motor function at least partially intact) more than doubled from 11% to 24%. The majority of spinal cord injuries were caused by motor vehicle accidents (45.5%); additional causes of SCI were falls (15.5%), gun shot wounds (9.6%), diving incidents (8.4%), surgery (6.7%), medical reasons (6.8%), and other (13%). Little change was noted with time in the cause of SCI except that surgery accounted for nearly no SCI before 1986 but a substantial proportion (15%) after that.

Conclusions: These results represent the current population treated at the SCI Center and illustrate the changes in demographic and injury-related characteristics over the past 55 years. There are more patients with SCI, increased age in those sustaining SCI, and more quadriplegic and incomplete injuries than previously. Surgery accounts for more cases of SCI currently which also contributes to the increased age at injury.

Clinical Relevance: The health care needs of this population are changing - requiring more and different health care than in the past. Understanding demographic and injury-related trends in the SCI population will help with health care planning, cost projections and allocation of resources. Health care workers need to become familiar with the changes in SCI characteristics in order to provide adequate care for this population.

Acknowledgment: VA Rehabilitation R&D Merit Review Grant #A2014-RA.

S-107

ACUTE CARDIOVASCULAR RESPONSES TO STATIC AND DYNAMIC ELECTRICALLY STIMULATED LEG EXERCISE COMBINED WITH ARM CRANKING IN SPINAL CORD INJURY

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Objective: The objective of this study was to compare acute cardiovascular responses to maximal and submaximal arm crank exercise alone and in combination with static and dynamic functional electric stimulation (FES) in individuals with spinal cord injury (SCI).

Methods: Eight males with tetraplegia and six males with paraplegia participated in this study. All subjects had at least minimal spasticity and all subjects' lower extremity musculature responded to FES. All subjects performed submaximal and graded maximal arm crank exercise tests in three different exercise protocols. These were: (1) arm crank exercise alone (ACE); (2) arm cranking combined with FES applied simultaneously to opposing muscle groups of the lower limbs to create isometric co-contractions (Static Hybrid); (3) arm cranking combined with FES applied to leg muscles to produce cycling (Dynamic Hybrid). Cardiorespiratory responses including heart rate, VO_2, VE, RER, and submaximal cardiac output were measured. Differences in maximum heart rate, peak VO_2, VE, RER, and submaximal cardiac output across exercise protocols were measured using a repeated measures ANOVA.

Results: No differences were found between arm cranking alone, static hybrid and dynamic hybrid in peak VO_2 (12.8(5.4, 13.1(4.7, and 13.7(5.1ml/kg/min for ACE, static hybrid, and dynamic hybrid respectively, p=0.79). Likewise, there were no differences found in maximum heart rate between the three exercise protocols (136.4(32.5, 134.6(27.4, 147.7(26.4 bpm, p=0.69). Submaximal steady state cardiac output testing was also similar between protocols (13.3(2.1, 13.2(2.6, 12.5(2.3 L/min, p=0.62). Further, no differences were found in RER and VE between protocols.

Conclusion: While there is evidence from training studies of increased cardiovascular responses to static and dynamic hybrid exercise compared with ACE alone, our results demonstrate that differences do not exist in cardiovascular responses to these three exercise protocols acutely. Our findings indicate that the contribution from untrained lower extremity musculature is insufficient to alter cardiovascular responses during acute hybrid exercise.

Clinical Relevance: While a slight increment in metabolic activity might have been expected these results do not indicate a measurable contribution from FES. This should not be taken as a negative indicator of the long term benefits of hybrid exercise. Cardiovascular and pulmonary adaptations that are not seen with acute exercise bouts are nonetheless expected to develop as the lower extremities adapt to regular use of FES. Currently, we are investigating the benefits of static and dynamic hybrid exercise in a 12 week training study. These results will allow us to evaluate the potential for hybrid exercise to modify heart disease risk factors and will be applicable toward informed cost-benefit decisions for implementation of exercise training programs for individuals with SCI.

Acknowledgement: VA Rehabilitation R&D Merit Review Grant #B2110-RA.

S-108

GENETICALLY ENGINEERED SCHWANN CELLS SECRETING BDNF BUT NOT NT-3 PROMOTE THE REGROWTH OF TYROSINE HYDROXYLASE IMMUNOREACTIVE AXONS FOLLOWING SPINAL CORD INJURY

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Functional impairment following spinal cord injury is mainly due to the disruption of axonal integrity at the lesion site. Attempts have been made to study the effects of different neurotrophic factors (NTFs), including brain-derived neurotrophic factor (BDNF) and neurotrophin-3 (NT-3) on the regeneration of neurons following injury in various trauma-models. It appears that among all the NTFs studied so far, BDNF and NT-3 have a greater potential for enhancing the regrowth of injured axons.

Objective: The purpose of the present study was to evaluate genetically engineered Schwann cells secreting BDNF and NT-3 on the regrowth of axons in general, with special emphasis on the regeneration of catecholaminergic sensory axons following contusion injury to the spinal cord.

Methods: Rats were anaesthetized and sustained severe contusion injury at T8 level. Carbon filaments co-cultured with genetically engineered Schwann cells secreting BDNF and NT-3 were implanted at the lesion site. The procedural controls consisted of animals sustaining injury only, and animals which received implantation of carbon filaments co-cultured only with Schwann cells not engineered to secrete any NTFs. At 14-weeks post-trauma, all the animals were evaluated histologically. Immunocytochemical analysis of phosphoneurofilaments (NF) and tyrosine hydroxylase (TH) was performed on the sections of spinal cords at lesion site.

Results: Although the regrowth of NF-positive axons was evident in all the groups with only Schwann cells, cells secreting NT-3, and cells secreting BDNF, the effect of BDNF-secreting cells was relatively more prominent. In addition, animals implanted with BDNF-secreting Schwann cells exhibited stronger immunoreaction for TH-positive sensory axons than any other groups.

Conclusion: Regenerative effects of BDNF-secreting Schwann cells were much more pronounced than those of NT-3 secreting cells or Schwann cells alone following contusion injury to the spinal cord.

Acknowledgement: Supported by Rehabilitation R&D Services, DVA.

Clinical Relevance: Uninterrupted supply of selected neurotrophins via genetically engineered cells may provide a strategy to treat spinal cord injury.

S-109

RESTORATION OF ELBOW FUNCTION BY FNS

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We are restoring active elbow extension with neuroprostheses by stimulating triceps in individuals with C6 or C5 tetraplegia. We are investigating methods of maximizing the strength and controllability of elbow extension, so that it can be restored to the largest number of people and provide the greatest amount of function. These techniques should allow the largest range of both elbow flexion and extension strength, with a system that is potentially totally implantable. We are also studying the biomechanics of weight shift and transfer procedures to develop methods of providing these important functions to individuals who can not perform these maneuvers independently.

In individuals with weak C5 tetraplegia, stimulation of the long head of triceps must be avoided, since it produces strong shoulder adduction that interferes with arm elevation. This has been achieved in one individual by carefully placed implanted electrodes, but was not achieved in a similarly disabled individual implanted previously.

The feasibility of fully and selectively activating individual heads of triceps and selected shoulder muscles by optimal placement of implanted electrodes, or by nerve cuff electrodes is being investigated by an anatomical study of nerve lengths, diameters and electrode implantation sites. Based on two cadavers studied to date, full selective stimulation should be achievable for nearly all desired muscles, including possibly using nerve cuffs.

In the past, we have used constant triceps stimulation to extend the arm, with voluntary flexion counteracting the stimulated extension for intermediate postures. In our current studies, we have demonstrated that the biceps EMG can be measured during stimulation and used to reciprocally reduce triceps stimulation during elbow flexion. This reciprocal control is stable, increases the range of elbow flexion and extension strength, and reduces the overall stimulation. EMG control with a totally implantable system offers a reliable cosmetic solution.

Finally, we have measured the strength of voluntary elbow flexion and extension in one individual with C7 tetraplegia. We have also measured the kinematics and kinetics of a sliding board transfer, which he performed independently. His maximal voluntary elbow extension strength (~10 Nm) was comparable to the extension strength achieved by electrical stimulation in some other individuals who can not transfer, indicating that increasing extension strength is probably not the most important factor limiting the ability to transfer.

The significance of this research is that restoring proximal arm function will greatly enhance a person's ability both to grasp and manipulate objects in the environment, and to assist in self care by performing weight shifts and transfers. Thus the person will be able to work more independently in an unstructured environment, and will have expanded employment opportunities.

Supported by the Rehab. Res. and Devel. Program of the Department of Veterans Affairs.

S-110

RESTORATION OF BLADDER AND BOWEL FUNCTION USING ELECTRICAL STIMULATION AFTER SPINAL CORD INJURY

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Objectives: To evaluate the effects of sacral nerve stimulation and posterior sacral rhizotomy on bladder and bowel function in human subjects with spinal cord injury.

Methods: In patients with suprasacral spinal cord injury, electrodes were implanted surgically on the sacral nerves and connected to a stimulator implanted under the skin of the chest or abdomen. The stimulator was powered and controlled by radio transmission from an external controller operated by the user. Rhizotomy of the posterior sacral nerve roots was carried out intradurally on the same occasion in all but two subjects. Bladder and bowel function were evaluated pre-operatively and at 3, 6 and 12 months follow-up, using subjects as their own controls. Micturition was evaluated urodynamically and urinary continence was evaluated by a one-month diary which also documented the occurrence, duration and techniques used for bowel evacuation. Medications, appliances, complications, costs and user satisfaction were also documented.

Results: The majority of subjects use the stimulation system routinely at home for producing micturition on demand with low residual volumes of urine and reduced urinary tract infection, and also use the system to assist with bowel evacuation. Subjects report significant reductions in urinary incontinence, autonomic dysreflexia, usage of anticholinergic medication, and usage of catheters and other appliances. Upper urinary tracts have been well preserved and complication rates have been low. Subjects use fewer suppositories, laxatives and stool softeners and the time taken for bowel care is reduced. Subjects report reduced costs of bladder and bowel care and improved satisfaction and quality of life. The stimulation system has now received FDA approval for producing micturition on demand with reduced residual volumes of urine and for assisting with bowel function in patients with complete suprasacral spinal cord injury.

Conclusions: Electrical stimulation of the sacral nerves using an implanted neural prosthesis is a safe and effective method of producing micturition and assisting defecation in patients with suprasacral spinal cord injury. Posterior sacral rhizotomy is effective in reducing detrusor hyper-reflexia and its complications. The combination of the two techniques is projected to reduce significantly the costs of bladder and bowel care after spinal cord injury.

Funding: Rehabilitation Research and Development Service of the Department of Veterans Affairs

S-111

CHARACTERIZATION OF PERFORMANCE AND FUNCTION AFTER STROKE

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Purpose: Acute stroke survivals (ASS) are typically evaluated in terms of their physical impairment. The objective of this paper is to characterize ASS through physical performance-based tests, measures of functional and cognitive outcomes, and to describe the correlations among these measures.

Subjects: Nine male acute stroke patients with a mean age of 59 years (range: 44 to 75) who had a stroke from 8 to 21 days prior to testing voluntarily agreed to participate in the study, providing signed informed consent. All participants were admitted to the Rehabilitation Medicine Service at the Veterans Affairs Medical Center in Houston, Texas.

Methods: Functional outcomes were evaluated utilizing the Functional Independence Measure (FIM) scale and the disability level by the National Institutes of Health (NIH) Stroke Scale. Characterization of cognitive impairment was done by the Mini-Mental State Examination (MMSE). Physical performances tests included: gait endurance (END) total distance in meters (m) covered over 5 minutes; gait energy cost (COST)in terms of the total oxygen consumption (mlO_2/kg/min) observed during the END; gait efficiency (EFF) COST over END; gait speed (SPEED) time to cover 5 meters (m/sec). Peak oxygen consumption ($PeakVO_2$) was evaluated utilizing a bike ergometer protocol and an open circuit method. Gait ability (GA) was evaluated using a Functional Ambulation Category (FAC) scale, with scores ranging from 0 (patient cannot walk or requires the help of 2 people) to 5 (patient walks independently).

Results: Mean values and standard deviations are as follows: FIM: 79.5 ± 15.14; NIH: 4.33± 2.29; MMSE: 27 ± 2.39; END: 34.79 ± 42.34 m; COST: 36.33 ± 9.21 mlO_2/kg/min; EFF: 3.57 ± 7.00 mlO_2/kg/min/m; SPEED: 0.19 ± 0.20 m/sec; $PeakVO_2$: 8.52 ± 1.43 mlO_2/kg/min. GA ranged from 0 to 2. The correlation of END to COST and SPEED were 0.87 and 0.78 ($p<0.05$). COST and SPEED presented a correlation of 0.75 ($p<0.05$). Correlations of GA to END, COST, EFF and SPEED were moderate, ranging from 0.51 to 0.63 although not statistically significant. FIM scores were trivially correlated with END, EFF, and SPEED (0.27, 0.10, and 0.13 respectively). NIH did not correlated well to FIM, nor to GA, END, EFF, and COST. $PeakVO_2$ presented no significant correlation to any other measure of performance, FIM, NIH, MMSE or GA (ranged from 0.12 to 0.56). However, metabolic criteria for peak oxygen consumption were never attained with these subjects as tests were interrupted due to exaggerated inotropic responses and safety-imposed limitations (blood pressures).

Conclusion: Measures of performance in the study were more strongly correlated among themselves than they were to gait ability as judged by the FAC. Aerobic capacity may be more easily evaluated by gait-based tests than by bicycle-based tests.

Acknowledgment: This work was supported by the Rehabilitation Research and Development Center of Excellence on Healthy Aging with Disabilities, by Texas Woman's University School of Physical Therapy, Houston, TX, and by CAPES-Brazil.

S-112

RESPONSE OF PROLONGED FLACCID PARALYSIS TO FUNCTIONAL NEUROMUSCULAR STIMULATION REHABILITATION TECHNIQUES

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Objectives: The purpose of this study was to investigate the response of chronic flaccid paralysis (after stroke) to treatment with two types of functional neuromuscular stimulation (FNS): 1) commercially available surface-stimulation; and 2) investigational multi-channel FNS using intra-muscular (IM) electrodes (FNS-IM).

Subject: JJ was a veteran, age 72, and one year post stroke at entry into the study. He had a left hemisphere infarct with dense right hemiparesis, flaccid during passive range of movement.

Methods: A single subject research design was used for this time-intensive, new procedure. Treatment One was 4 months of surface stimulation by a commercially available electrical stimulation device for 40 minutes per day, 5 days per week on tibialis anterior and distal hamstring muscles. Treatment Two was FNS-IM treatment. Implantation of electrodes was performed using a hypodermic needle insertion technique, positioning the electrodes beneath the skin at the motor point of each of the tibialis anterior, short head of the biceps femoris, and distal portion of the biceps femoris (long head). JJ followed the same treatment frequency and duration with the FNS-IM system as he had used with the surface-stimulation system. During walking, the patient competently triggered his individualized walk pattern by pressing a finger switch. Outcome measures were both volitional and FNS-driven, active ankle dorsiflexion and knee flexion; Fugl-Meyer coordination scale; and the gait component measures of knee flexion at toe-off, peak-swing knee flexion, peak-swing ankle dorsiflexion, ankle dorsiflexion at heel strike. A *t*-test was performed to compare the volitional gait pattern before and after treatment and to compare the FNS-gait versus the volitional gait (plus AFO).

Results: During the 4 months of conventional surface-stimulation treatment, there was no change in measures of volitional movement capability nor in measures of coordination. Following treatment with the FNS-IM system, there were gains in coordination and in volitional movement capability for knee flexors and ankle dorsiflexors; there was no change in volitional movement capability for untreated muscles. There was no difference between JJ's volitional (plus AFO) gait and his gait with surface-stimulation. However, there was a significant difference between JJ's volitional (plus AFO) gait and his gait while using the FNS-IM system ($p = .037$).

Conclusion And Relevance: The return of volitional motor control in response to rehabilitation can occur long after the stroke, even in the case of prolonged flaccid paralysis. This result supports the concept that treatment targeted at impaired motor function can result in restoration of volitional function even for severe deficits. This study suggests that FNS-IM can influence restoration of volitional motor function.

Supported by Veterans Administration, Rehabilitation Research and Development Service Grant; FES Center, a consortion for functional neuromuscular stimulation research.

S-113

BACTERIAL INTERFERENCE FOR PREVENTION OF UTI IN SCI PATIENTS

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Objectives: Urinary tract infection (UTI) is the most common infection in spinal cord-injured (SCI) patients. Benign bacteria that colonize the bladder without causing symptoms of infection may provide some protection against symptomatic infection with more harmful bacteria. The objective of this ongoing study was to assess the concept of using bacterial interference to prevent symptomatic UTI in SCI patients.

Methods: A prototype strain, *Escherichia coli* 83972, that had been shown previously to cause asymptomatic bacteriuria for extended period of time was used to deliberately colonize the bladder. SCI patients who had suffered from frequent symptomatic UTI ($\geq$ 2 episodes during preceding year) received twice-a-day bladder inoculations with *E. coli* 83972 for 3 days. Participants whose bladder was not successfully colonized after one set of inoculations were eligible to receive two additional 3-day sets of bladder inoculations.

Results: A total of 39 SCI patients have been enrolled so far in this ongoing study. Median age of participants was 43 years (range, 25-74 years) and method of bladder management included intermittent catheterization (19 patients), suprapubic catheter (11 patients), transurethral catheter (2 patients) and external collection device (7 patients). The 39 patients received a total of 86 bladder colonization attempts (each consisting of a 3-day set of inoculations). Overall, long-term ($\geq$ 1 month) bladder colonization with *E. coli* 83972 was successfully achieved in 28/39 (72%) patients and after 37/86 (43%) inoculation attempts. The mean rate of symptomatic UTI in patients while colonized with *E. coli* 83972 (0.038 episodes/patient-year) was about 100-fold less than that prior to enrollment in the study (3.7 episodes/patient year). The genetic and phenotypic properties that may contribute to the persistence of *E. coli* 83972 in the urinary tract were delineated.

Conclusions: The preliminary findings of this ongoing study indicate that the application of bacterial intereference in SCI patients can reduce the rate of symptomatic UTI. The role of this innovative approach is best examined in a prospective, randomized, placebo-controlled, multicenter clinical trial.

S-114

IMPLANTABLE FES SYSTEMS FOR STANDING AND TRANSFERS

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Objectives: A surgically implanted neuroprosthesis employing functional electrical stimulation (FES) for exercise, standing and upright mobility in persons with low cervical or thoracic level SCI is currently undergoing Phase II clinical trials. The purpose of this report is to describe the initial results and functional performance of the implanted system in the first 5 subjects enrolled in a multicenter study to determine its safety, efficacy and functional utility.

Methods: Five adult subjects with long-standing (avg. 4 yrs) motor complete SCI received the implanted system consisting of the CWRU/VA implanted receiver-stimulator and 8 epimysial or intramuscular electrodes in the trunk, knee and hip extensor muscles. Baseline measurements of impairment, disability, and perception of general health were obtained prior to surgery and repeated at 6 and 12 months post-discharge both with and without stimulation. Satisfaction was assessed at the same follow-up intervals with a structured questionnaire, and logged usage patterns. Safety and system integrity were determined via repeated stimulus thresholds and x-rays of the joints and implanted materials.

Results: After completing a program of exercise and rehabilitation, total motor scores with stimulation were 16 to 23% greater than without FES. All subjects were able to stand and perform pivot transfers to higher surfaces with FES, and several were able to swing-to over short distances or release one hand from a walker to retrieve and manipulate objects. Stimulated knee extension strength approached or exceeded 30 Nm with sufficient endurance to maintain 50% maximal output after 40 minutes of cyclic contractions. Indicators of tissue viability (gluteal thickness, transcutaneous O_2) improved along with seated pressure distribution, implying a reduced risk of pressure sores. Standing duration varied from subject to subject (2 to 20 minutes) depending on posture and body size, and upper extremity support forces to maintain balance were typically less than 20 percent of body weight. Implanted components were reliable, electrode thresholds and stimulated responses were stable and no radiographic abnormalities or adverse incidents were observed. Subjects uniformly expressed satisfaction with the neuroprosthesis, and had no regrets about receiving it. Users found the system most valuable for exercise and derived an improved sense of well being from it.

Conclusions: These preliminary results indicate that a surgically implanted neuroprosthesis for standing and transfers is safe and effective in reducing the impairment and disability associated with low cervical or thoracic SCI. The system appears to be well accepted and positively impacts overall health while providing options for transfers or other maneuvers that would otherwise be difficult or impossible without significant personal assistance or extensive bracing. Multicenter trials and transfer of the technology to other clinical sites is currently underway.

Acknowledgements: Support for this project was provided by the Rehabilitation Research & Development Service of the Department of Veterans Affairs, and the Office of Orphan Product Development of the US Food and Drug Administration.

S-115

TELE-MONITORING PHYSICAL ACTIVITY AND EXERCISE

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Objective: We wish to develop and evaluate a wireless Personal Status Monitor that may be used to monitor the functional activity and exercise compliance of individuals in their home environment. It will be particularly useful for aging veterans undergoing rehabilitation and who require physical exercise. But it will be generally useful for providing presently unavailable information about the physical activity pattern of individuals with physical disabilities. This information has the potential for dramatically improving the management of these patients by providing data that can be used to guide the patient treatment.

Benefit to the VA: The primary benefit of the proposed personal-status monitor to the aging veteran and the VA health care mission is that it will augment clinical service by making the home a more effective place for geriatric rehabilitation. Such outcomes will reduce costs to the VA since fewer home visits will be necessary to establish compliance, and adherence to exercise should translate into lower recurrence rates or follow-up visits.

Expected Outcomes: The Personal Status Monitor will consists of a miniature wireless sensor attached to the skin above muscles of interest, a wireless data transceiver also worn on the body and which relays the signals to a base station located in the near environment. The base station will process the data and send the information, via telephone wires or Internet to a remote location where it is accessible by an attending physician and/or care giver and nay be stored. The sensor detects, conditions, and transmits the electromyographic (EMG) signal emanating from contracting muscles. It will be no more obtrusive than a small Band-Aid. The technological achievements embodied by the sensor will revolutionize the manner in which biosignals are currently collected.

Results: The most complex part of this project, the wireless EMG sensor, has been under development for under a separate contract from the Army for the past two years. A working prototype of the electrode has been built and tested successfully. The circuitry is now being designed into an ASIC electronics chip so that it can fit in the Band Aid size of the EMG electrode. Investigations into identifying EMG signal patterns, which uniquely correspond to physical activity and tasks performed by individuals, have already begun. The results are very encouraging.

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S-116

NaN: A NOCICEPTIVE SODIUM CHANNEL

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Previous studies have shown that sodium channel □-subunit NaN is preferentially expressed in small diameter sensory neurons of dorsal root ganglia and trigeminal ganglia. These neurons include high threshold nociceptors that are involved in transduction of pain associated with tissue and nerve injury. In this study, we show that mouse NaN is a 1765 amino acid peptide which is predicted to produce a current that is resistant to tetrodotoxin (TTX-R). Mouse and rat NaN are 80% and 89% identical at the nucleotide and amino acid levels, respectively. The Scn11a gene encoding this cDNA is organized into 24 exons. Unlike some □-subunits, Scn11a does not have an alternative exon 5 in domain I. Introns of the U2 and U12 spliceosome types are present at conserved positions relative to other members of this family. Scn11a is located on mouse chromosome 9, close to the two other TTX-R sodium channel genes, Scn5a and Scn10a. The human gene, SCN11A, was mapped to the conserved linkage group on chromosome 3p21-24, close to human SCN5A and SCN10A. The co-localization of the three sodium channel genes supports a common lineage of the TTX-R sodium channels. The selective expression of NaN in c-type DRG neurons suggests that it participates in nociception, and that it may contribute to chronic pain. [Supported by Rehabilitation Research and Development Service and Medical Research Service, Department of Veterans Affairs]

S-117

ADAPTATION OF HYBRID III TEST DUMMY TO REPRESENT SPINAL CORD INJURED POPULATION

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Objectives: To modify an automobile industry standard Hybrid III test dummy to replicate a spinal cord injured person for use in low speed, low impact power wheelchair obstacle collisions. The 50th percentile Hybrid III test dummy represents an average able-bodied male. Steps must be taken to reduce trunk stability and weight from the lower extremities to more closely match a person with a spinal cord injury.

Methods: The bladder of the test dummy was removed to allow more motion in the lumbar region. A standing "pedestrian" pelvis with a straight lumbar spine was employed in place of the rigid seated pelvis. A custom spine base and load cell adapter plate were fabricated on a CNC milling machine. The components enabled existing instrumentation to be used with the design changes. In addition, the medial/superior portions of the left and right vinyl coated foam buttocks were trimmed to allow for a non-interference fit with the pelvic structure during seated posture.

Results: The changes made enabled the dummy to both stand and sit in 90 degrees of flexion. The smaller trunk offered less rigidity in the lumbar region of the spine. The changes resulted in improved biomechanical and anthropometric characteristics while maintaining reproducibility.

Conclusions: There is an increasing trend in power wheelchair accidents annually. The modified test dummy is part of a research project that will investigate the causes and nature of these accidents. Currently, no low speed, low impact dummy exists for crash studies. A reliable and accurate dummy is necessary for valid results and ultimately the reduction in accident frequency and severity.

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S-118

MAXIMUM CONTRACTION MEASUREMENT AT THE WRIST

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Objective: Repetitive motion of manual wheelchair propulsion (MWP) may influence development of wrist pain. Aljure (1985) noted carpal tunnel syndrome (CTS) in 63% of people with paraplegia. Proposed causes include changes in the volume of the carpal tunnel that increase tunnel pressure levels such as changes in the wrist flexor tendons. Yamaguchi (1996) found 87% of CTS subjects demonstrated tendon thickening. Quantification of the flexor activity at the wrist via electromyography (EMG) indicates the relative exertion of the flexors during MWP. Inter-subject EMG measurements can only be compared via percent of maximum voluntary contraction (MVC). Thus, the purpose of this study was to develop and statistically evaluate a method for determining MVC of the wrist flexors muscles: flexor carpi radialis (FCR), finger flexors (FF), and the flexor carpi ulnaris (FCU).

Methods: Nine unimpaired subjects provided informed consent prior to participation. Surface biopolar electrodes were placed bilaterally over wrist flexor muscles (Basmajian, 1980). Maximum contraction was recorded while the subject was seated in a wheelchair and grasped the pushrim and flexed at the wrist, flexed/radially deviated and then flexed/ulnar deviated. This sequence was repeated three times to determine whether a learning effect occurred. MVC were performed at 11, 12 and 1 o'clock positions on the pushrim. The data was evaluated to determine whether a significant difference existed between the first, second and third repetitions of the contraction sequence and the different positions on the pushrim by using a repeated samples ANOVA. Mean maximums from the three repetitions of the contraction sequence and the three pushrim positions were determined. Pearson correlation were also found for each muscle between the three repetitions of the contraction sequence and the three pushrim positions.

Results: High Pearson correlation values were found between each of the repeated contraction sequences. A repeated measures ANOVA demonstrated significant difference between the repeated contraction sequences only with the left hand in the 1 o'clock position (FF $p=.039$, FCR $p=.038$). The same ANOVA analysis did not identify significant differences between the three pushrim positions. In addition, each muscle demonstrated high Pearson correlation between the three pushrim positions (lowest $r=.796$, $p=.01$).

Conclusions: Repeated measures ANOVA results showed a significant difference between the three trials of the contraction sequences for the left arm while in the 1 o'clock position. This difference may be due to handedness. The lack of general significance indicates a learning effect did not occur. Additional repeated measures ANOVA tests did not demonstrate a difference in mean maximum wrist flexor activity between the three positions on the pushrim. The lack of a significant difference indicates that any three of the pushrim locations may be used to record maximum voluntary contractions.

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S-119

WHEELCHAIR SEATING DEVICES: UTILIZATION AND SATISFACTION FOLLOWING CEREBRAL VASCULAR ACCIDENT

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Objectives: The primary objective of this study is to determine the extent to which wheelchair seating devices prescribed during rehabilitation following a stroke are still in use by veterans who have returned to the community. A second objective is to determine the level of satisfaction with the wheelchair-seating device in terms of its functional, mechanical, and safety performance. Other parameters, such as functional independence, medical and psychological status, social integration and quality of life were explored.

Methods: Participants were selected from a convenience sample of veterans admitted for rehabilitation following a stroke between 1996 and 1999. Demographic and medical information were obtained by interview. Participants completed an investigator-constructed structured questionnaire regarding their use of and satisfaction with the recommended seating device, modifications made to the device, and the activities performed when using the device. In addition, participants completed other assessments including Functional Independence Measure (FIM), Geriatric Depression Scale (Short Form), Health Status Questionnaire and Craig Handicap Assessment and Reporting Technique (CHART)

Results: 28 individuals, 24 males and 4 females are enrolled currently. Mean age is 61 years (range: 39-79) and mean duration of stroke is 2 years (range: 1 month to 12 years, 7 months). Fourteen are Caucasian, 13 are African-American, and 1 is Hispanic. Seven persons have totally discarded their wheelchairs and 21 continue to use them with varying frequency (range: 10 hours/day to 1 hour/month). Of those still using their wheelchair, most are very satisfied with its mechanical and functional performance. The most frequently sited reason for discarding their wheelchair is "improved physical function". There is wide variability in utilization of retained wheelchairs following rehabilitation hospitalization of persons who have had a cerebral vascular accident. Participants were grouped within ranges of utilization time for analysis purposes. The ranges are 1) >8 hours/day; 2) 4-8 hours/day; 3) 1-4 hours/day; 4) 2-4 hours/week; 5) 1-6 hours/week; and 6) <1 hour/week. Preliminary data indicate that wheelchair seating device utilization does not impact on social integration or mobility at home or in the community. However, functional independence (mobility) was related to the occupation domain of the CHART. Individuals who scored higher on the FIM mobility items were more likely to engage in activities such as homemaking, work, volunteer work, or recreation. In addition, there was a relation between depression and social integration: individuals who were more depressed were more likely to be socially isolated. Although there was no statistically significant relations between depression and mobility, participants reported high levels of depression and social isolation regardless of wheelchair use and retention.

Conclusions: Mobility, social integration and ultimately quality of life may be influenced by factors other than utilization of a wheelchair-seating device. These issues were identified through direct interview with veterans and may support the notion of a structured follow-up program for veterans who have had a stroke.

Funding Acknowledgment: This project is funded by the VA Rehabilitation Research and Development Service, Center for Healthy Aging with Disabilities.

S-120

SHIFTS IN SHOULDER JOINT POWER DURING WHEELCHAIR PROPULSION IN MANUAL WHEELCHAIR USERS

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Objective: The shoulder has been identified as the primary source of joint power for wheelchair propulsion[1]. Since fatigue during wheelchair propulsion is associated with injury risk[2], shifts in shoulder power due to fatigue may be a mediator of injury. This study characterized changes in upper extremity joint power during wheelchair propulsion to fatigue in MWCU.

Methods: Nineteen MWCU, 16 to whom had SCI (3 with other diagnoses) participated in the study. Sixteen of the participants were male (3 female) with an average age of 44±11 years and time of wheelchair use of 17±10 years. Propulsion mechanics were measured during a submaximal exercise test to exhaustion (inability to maintain target velocity of 3 km/hr) on a prototype wheelchair ergometer. Load for the test corresponded to 75% of the peak VO_2 that occurred during a previous maximal exercise test. The wheelchair ergometer was instrumented with force/torque transducers in its wheel hubs to detect 3D forces and moments (Bertec Corp., Worthington, OH). A potentiometer monitored wheel position. Shoulder, elbow, wrist and trunk motion were measured by 3 Peak 3D CCD cameras (Peak Performance Technologies, Colorado Springs, CO). Linear displacements of markers placed on joints were measured and differentiated to obtain movement kinematics. From 3D kinematic (60 Hz) and handrim kinetic (360Hz) data, joint kinetics were calculated using a 3D linked segment model which employed an inverse dynamics approach. Kkinetic data were averaged over three cycles during fresh and fatigued states. Peak joint poer (joint moment multiplied by the angular velocity) differences between the shoulder, elbow and wrist occurring during wheel contact were determined to identify power shifts with fatigue. Power differences were compared during fatigue states using an ANOVA ($p<0.05$).

Results: There was a significant shift in power away from the shoulder which was redistributed to the elbow and wrist with fatigue as reflected in the shoulder which was redistributed to the elbow and wrist with fatigue as reflected in the shoulder-elbow ($p<0.04$) and shoulder-wrist ($p<0.05$) power differences.

Conclusions: The shoulder has been identified as the primary source of joint power during wheelchair propulsion. With fatigue, shifts in power away from the shoulder reflect a compromised ability to generate the force necessary for propulsion, placing it at greater risk for injury. Concomitantly, the elbow and wrist assume the power production lost at the shoulder thereby placing these joints at greater risk for injury. Since muscular contraction is a primary generator of joint power and since shoulder muscles are not predominantly oxidative, and therefore fatigue resistant, endurance training of shoulder muscles may be beneficial.

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S-121

GLUCOSE TOLERANCE AND BODY COMPOSITION IN SPINAL CORD INJURY

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Problem: Spinal cord injuries (SCI) predispose to glucose intolerance and insulin resistance, presumably due to changes in body composition and skeletal muscle dysfunction, placing SCI individuals at greater risk for diabetic retinopathy, nephropathy, gastropathy, neuropathy and coronary artery disease. In the able-bodied, marked improvements in glucose tolerance have been reported in response to aerobic exercise, with variable changes in insulin sensitivity. Resistance training has also improved glucose tolerance, and to a greater extent, insulin sensitivity in the able-bodied. The purpose of this pilot investigation was to determine the relationship between glucose tolerance and body composition in SCI Adults.

Hypothesis: Glucose intolerance is directly related to % Body Fat (%BF) in SCI adults, and inversely related to Fat-free Body Mass (FFM).

Objective: The primary objective of this pilot investigation was to assess oral glucose tolerance in persons with C7-T4 Motor Complete SCI and to determine its relationship with body composition.

Methods: 5 persons with C7-T4 Motor Complete SCI were admitted overnight to the U of Kentucky GCRC. 3-hour Oral Glucose Tolerance Tests were performed from 0800-1100 after an 8-hour fast, with glucose and insulin levels determined at rest and 30-minute intervals. Body composition was assessed in each individual by 4-Compartment modeling using hydrodensitometry, DXA scan, and Bioelectrical Impedance Analysis.

Results: Mean Glucose Area Under the Curve (AUC) for SCI was significantly elevated (1,105(228 mg%•min) compared to Able Body Controls (679(18 mg%•min). Glucose Area Under the Curve (AUC) was significantly correlated (r^2=0.84, $p<0.05$) with %BF, and the glucose:insulin ratios appeared elevated compared to able-bodied (AB) controls.

Conclusion: The strong relationship between glucose intolerance and body composition implies that reducing %BF in veterans with SCI may improve glucose intolerance, reducing morbidity and mortality associated with diabetes in this special population.

Acknowledgements: This research was supported by American Heart Association Grant-in-Aid #9806232, and USPHS M01RR02602, Subproject #33.

S-122

HIGH RESOLUTION EEG IN THE DETECTION OF CORTICAL REORGANIZATION; RECORDING MOVEMENT RELATED ORTICAL POTENTIALS IN SPIAL CORD INJURY AND STROKE

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We have applied the new technology of High Resolution EEG, Co-Registered with MRI, to identify brain plasticity after Spinal Cord Injury and Stroke. Movement-Related Cortical Potentials (MRCPs) were recorded in 60 patients with SCI and 20 with Stroke, utilizing an array of 120 electrodes (Neuroscan). Eight electrodes were used to monitor eye movements and the EMG. Dipole sources were analyzed using the Curry program. There were 25 normal volunteers.

SCI: The Motor Potential (MP) component of the MRCPs was recorded in a significantly more posterior position with finger or toe movements than in the controls. This location was supported by the results of Dipole Source Analysis. The MP was posterior in 90% of tetraplegics but in only 40% of paraplegics. Preliminary data indicates the prognosis for recovery may be better in paraplegics who have posterior MPs.

Stroke: The MP was recorded in 20 patients with infarcts of at least three months duration. All had made some degree of recovery. Patients with left hemiparesis had evidence of ipsilateral control of finger movements. Patients with right hemiparesis had MPs and dipole sources displaced to the ischemic rim of the infarct.

S-123

DETECTION AND INHIBITION OF BLADDER HYPER-REFLEXIA BY NERVE ROOT RECORDING AND ELECTRICAL STIMULATION

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Spinal cord injury, multiple sclerosis, and stroke often lead to impairment of the lower urinary tract. Paralysis of the bladder, bladder hyper-reflexia, in which the bladder contracts at low volume, and loss of the synergic relationship between contraction of the bladder and relaxation of the urethral sphincter lead to incontinence, frequent urinary tract infections, and damage to the upper urinary tract. Electrical stimulation of the sacral nerve roots innervating the bladder has proven to be an effective means to empty the bladder. Presently, the dorsal sacral nerve roots are transected to treat bladder hyper-reflexia and bladder-sphincter dyssynergia. The purpose of this project was to explore an alternative to transection to abolish bladder hyper-relfexia. Specifically, we sought to determine whether reflex bladder contractions could be detected by electrical recording from the sacral nerve roots and if reflex bladder contractions could be inhibited by stimulation of sacral afferents. Six male cats were anaesthetized with alpha-chloralose and bipolar cuff electrodes were used to measure sacral nerve root electroneurograms (ENG) during slow bladder filling, during rapid injections of fluid into the bladder, and during quasi-periodic reflex bladder contractions. The rectified and time-averaged activity of the S1 extradural root increased by 0-5% above the baseline during bladder filling. Rapid injections caused a sudden increase in bladder pressure, and a 3-36% increase over baseline in the S1 nerve activity. At the onset of a reflex bladder contraction, there was a 7-38% increase over baseline in the S1 nerve activity. This activity increase was sustained for the duration of the contraction and decreased during bladder relaxation. The onset and the duration of reflex bladder contractions could be detected consistently from these changes in nerve activity. Contractions were detected within 6±8 s after the onset of the contraction, and at the time of detection the bladder pressure had increased by only 9±8 cm H_20. Further, it was demonstrated that an ongoing reflex bladder contraction could be inhibited by rectal distension or by electrical stimulation of the dorsal sacral root S1. The results demonstrate that afferent sacral root nerve activity can be used to detect hyper-reflexive bladder contractions at low bladder pressures. Such a signal might be used to trigger bladder inhibition via electrical stimulation of specific sacral afferents, and thus provide an alternative to dorsal sacral nerve root transection for treatment of bladder hyper-reflexia. When combined with sacral nerve root stimulation, this technique may prove an effective method for bladder management in individuals with disorders of the lower urinary tract.

Acknowledgment: This study was supported by the Johnson and Johnson Focused Giving Program, the U.S. Department of Veterans Affairs Rehabilitation Research and Development Service Center of Excellence in FES, The Danish National Research Foundation, and The Danish Research Council.

S-124

ALTERATION OF THE RESPONSES OF SERTOLI CELLS TO FSH AND TESTOSTERONE IN THE RAT AFTER SPINAL CORD INJURY

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Objectives: Our previous studies demonstrated that regression of spermatogenesis in rats subjected to surgically induced spinal cord injury (SCI) was paradoxically enhanced by FSH. This series of experiments investigated normalcy of the functions of Sertoli cells, the supporting cells for spermatogensis, after spinal cord injury (SCI).

Methods: (1) SCI was induced in adult rats by surgical transection of the spinal cord at the level of the 9th thoracic vertebra. (2) SCI and sham control rats were treated with FSH, testosterone, or combination of both, for 7 to 14 days. (3) Normalcy of Sertoli cells was determined by Northern blot measurement of changes in the levels of mRNA transcript for Sertoli cell speccific proteins after hormone treatments.

Results: (1) In sham control rats, administration of exogenous FSH or testosterone for 2 weeks resulted in a general decrease in the levels of mRNA transcripts Sertoli cell specific proteins including androgen binding protein (ABP), transferrin (trf), inhibin *a* (Inh) and sulfated glycoprotein (SGP)-2. (2) In SCI rats, identical hormone treatments resulted in a general increase in the levels of mRNA transcripts for the aforementioned Sertoli cell specific proteins. (3) These effects may be related to signal events initiated by androgen receptor (AR) and FSH receptors (FSHR), as levels of AR and FSHR mRNAs were decrease in sham control rats but increase in SCI rats after hormone treatments.

Conclusion: Current results demonstrated that SCI is associated altered Sertoli cell responses to FSH and testosterone. Such changes may alter functional integrity of Sertoli cells thus resulting in abnormal spermatogenesis. These findings open a new direction of research that may lead to further understanding of mechanisms responsible for male infertility after SCI or other causes. Such information will facilitate the prevention and treatment of service-related male infertility in veterans such as after SCI or exposure to chemicals.

Acknowledgement: This study is supported by VA RR&D Service Grant #B885-2RA.

S-125

PULMONARY FUNCTION TESTING IN SPINAL CORD INJURY: EFFECTS OF ABDOMINAL MUSCLE STIMULATION

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Objective: Expiratory muscle weakness or paralysis in patients with a spinal cord injury (SCI) results in decreased peak expiratory flow rate (PEFR), forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC). The objective of this study was to assess the effects of applying transcutaneous electrical stimulation to upper motor neuron paralyzed abdominal muscles during pulmonary function testing (PFT). The hypothesis to be tested was that FVC, FEV_1, and PEFR could be increased over purely volitional levels by applying electrical stimulation to abdominal muscles during the performance of a standard PFT.

Method: Eight male patients with SCI were studied. The selection criteria included volitional (unassisted) FVC $\leq$ 90% of predicted, anatomical level of injury between C4 and T7, upper motor neuron paralysis of the abdominal muscles, visible abdominal muscle contraction upon application of electrical stimulation, tolerance of the electrical stimulation, and no current pulmonary complaint. The study was approved by the Hospital's Human Studies Subcommittee and written informed consent was obtained from each patient. Electrical stimulation was delivered via eight surface electrodes on the lower abdomen. The stimulus pulse train was 8 s in duration, with constant amplitude, frequency, and pulse width. Patients performed PFTs with and without electrical stimulation delivered to abdominal muscles.

Results: Expiratory flows and volumes were enhanced in seven of the eight patients. The patients with the lowest predicted expiratory volumes and flows demonstrated the greatest improvement when electrical stimulation was delivered during forced expiration.

Conclusion: The results indicate that electrical stimulation of the expiratory muscles during forced expiration can significantly improve expiratory volumes and flows in some patients with SCI.

Clinical Relevance: Pulmonary complications are the leading cause of death in persons with a SCI. In the future, it may be possible to allow individuals with a SCI to electrically stimulate their abdominal muscles when they need to cough. This may help reduce the incidence of these complications. This study provides evidence that electrical stimulation of abdominal muscles can be effective in improving standard measures of pulmonary function in patients with a SCI.

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S-126

IMPROVING STEPPING-OVER RESPONSES IN THE ELDERLY USING SIMULATED OBSTACLES

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Objectives: The goal of this project is to design and evaluate clinical interventions to train elderly individuals at high risk for falling. These interventions employ techniques to monitor stepping-over performance and response times. The specific objectives are to develop a clinical system to measure and improve stepping-over performance, train effective movement strategies, and to demonstrate clinical efficacy of the system in a randomized, controlled intervention study.

Methods: Subjects will participate in one of three interventions: stepping over 1) real, 2) imaginary, and 3) virtual objects.

Subjects will be asked to step over a course of ten foam obstacles, or Subjects will be instructed to "step higher" and "step longer" while walking on a motorized treadmill, or A composite video image of the subjects' lower body and virtual obstacles will be presented in a head-mounted display. Subjects will be asked to step over the virtual obstacles while walking on a motorized treadmill. Shoe mounted vibro-tactile stimulators will provide feedback of "collisions" with the virtual obstacles.

Results: The pilot work has led to the following preliminary results: The most successful technique for presenting virtual objects involved displaying a side-view of stepping on a treadmill while the viewer repeatedly negotiated computer-generated obstacles. Similar stepping strategies are employed in all three interventions. A small group of elderly subjects were better able to negotiate an overground obstacle course after three training sessions using computer-generated obstacles.

Conclusions: Clinical trials are currently underway with a population of Veterans over the age of 60 who have mild to moderate respiratory disease. The completed study will identify the relative merits of the three interventions with this population.

Funding Acknowledgement: VA Merit Review (E2167-2RA)

Clinical Relevance: The United States Public Health service identified the reduction of falls as a national health priority in it's "Healthy People 2000: National Health Promotion Disease Prevention Objectives". The ability to step over objects is an essential component of ambulation that enables a person to reduce the risk of falling. The frail elderly, a growing Veteran population, would benefit from this research which will identify efficacious approaches to improving stepping-over responses.

S-127

PARETIC LIMB PERFORMANCE OF HEMIPARETIC SUBJECTS USING A SPLIT-WHEEL CAR-STEERING SIMULATOR FOR UPPER LIMB THERAPY

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Objectives: This study examines the ability of a novel upper limb therapy device, Driver's Simulation Environment for Arm Therapy (Driver's SEAT), to enable subjects with hemiplegia to initiate and actively engage their paretic limb in a functional bimanual exercise task. Driver's SEAT is a 1 degree of freedom robotic device that incorporates a modified PC-based driving simulator to create simple and motivating steering tasks.

Research Plan: Via Driver's SEAT, subjects with hemiplegia can focus on steering coordination and their ability to regulate the force effort between their paretic and non-paretic limbs. Regulation of force effort is made possible via our unique split steering wheel design, which allow us to measure the tangential forces applied to the wheel by each limb. Three therapy modes, designed to complement the three main stages of stroke recovery, were implemented. They differ by the level of programmed resistance torque experienced at the wheel by the subject. A subject's ability to successfully complete the road-tracking tasks was coupled to their ability to modify the forces generated on the steering wheel with each limb. The main therapy mode implements a bimanual steering task that constrains the non-paretic limb and encourages the paretic limb to control the road-tracking task. The diagnostic mode does not constrain either limb so both can control the road-tracking task.

Methods: To explore whether the main therapy mode encouraged subjects to increase their paretic limb force output, we studied 8 subjects with hemiparesis (age > 50 years). Each subject performed unilateral and bilateral steering tasks in the three steering modes of Driver's SEAT. Force, position, surface EMGs and video data were collected.

Results: The study showed that the main therapy mode does enable subjects to more actively engage their paretic limb. The level of torque output from paretic limb was greater in the main therapy mode than in the diagnostic mode. These findings support our hypothesis that in a bimanual task without constraints, i.e. our diagnostic mode, subjects with hemiplegia will choose to use their non-paretic limb over their paretic limb to control the outcome of the task but in a bimanual task with constraint, i.e. the main therapy mode, they would be motivated to switch to their paretic limb as the primary controller of the task.

Conclusions: Subjects with hemiplegia can be encouraged to modify their bilateral force efforts using Driver's SEAT.

Funding Acknowledgment: This project was supported by VA Rehabilitation R&D Grant B2257PA and NASA Grant No. 2-52208.

Clinical Relevance: Hemiplegia, a common post-stroke condition affects many of the 400,000 stroke survivors per year in the U.S. Upper extremity return of function of both limbs is important for many activities of daily living. If these preliminary results are confirmed in a larger study, then Driver's SEAT has potential to augment and improve current upper limb therapy.

S-128

COMBINATORIAL TREATMENT STRATEGIES IMPROVE RUBROSPINAL MOTONEURON REGENERATION AFTER PARTIAL SPINAL CORD INJURY

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Testosterone (T) is a neurotrophic factor that is able to enhance the regeneration of injured peripheral motoneurons by upregulating regeneration-associated genes, including II-tubulin. The rubrospinal tract represents a population of central motoneurons that express androgen receptor and are injured following spinal cord injury (SCI) in rodents. T is able to attenuate the downregulation of II-tubulin mRNA normally observed in injured rubrospinal motoneurons (RSMN). Adding a peripheral nerve graft at the site of a SCI stimulates a sustained outgrowth of processes from injured RSMN that ultimately migrate through the graft. Using II-tubulin as a marker of regeneration, this study examined the effect of a peripheral nerve graft on the intrinsic injury response of rsmn, and determined whether T administration could augment that intrinsic response. Adult gonadectomized male hamsters were subjected to right peroneal nerve crush above the mid-thigh level. One week later, the same hamsters were subjected to a right dorsolateral aspiration lesion of the spinal cord at the C7 vertebral level, with the contralateral side serving as uninjured control. Immediately following SCI, a 3mm segment of the predegenerated peroneal nerve was excised from the leg and autografted into the spinal aspiration cavity. One end of the nerve segment was sutured flush against the proximal end of the injury site, while the other end remained free. Half the animals received testosterone propionate implants at the same time of injury. Postoperative times included 2, 7, and 14 days. *In situ* hybridization was performed using a [^{33}P]-labeled cDNA probe specific to II-tubulin. Slides were dipped in emulsion and processed for autoradiography, and quantitative analysis was performed using a computer-assisted image analysis system. Final analysis revealed that both testosterone treatment and peripheral nerve grafting individually increased the levels of II-tubulin mRNA relative to levels observed after injury alone in a similar manner. However, RSMN in those animals that had received a peripheral nerve graft plus testosterone treatment exhibited an increase in II-tubulin mRNA levels that were higher than those levels following either treatment alone. These data suggest that the introduction of an environment that is permissive to neuronal growth in combination with a known neurotrophic factor can result in the heightened upregulation of genes that are critical in sustaining a regenerative effort by injured spinal-projecting motoneurons. The additive effect observed from an axonally transported factor originating from the graft, coupled with an exogenously applied gene-targeting hormone, suggests the existence of multiple pathways for the potential regulation of regeneration-associated genes following SCI. Supported by VA grant V05-940A (KJJ).

S-129

INVESTIGATION OF BONE STRENGTH PARAMETERS, SKELETAL SITE, AND ASSESSMENT TECHNIQUES IN FRACTURE PREDICTION

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Objectives: In recent years, considerable progress has been made toward accurate, noninvasive determination of long bone strength. Typically, bone mineral mass or density is measured at specific skeletal sites using densitometry or computed tomography, but there has been considerable attention to the need to also assess distribution of bone tissue for optimal prediction of strength. Debate continues, however, regarding which bone strength parameter, skeletal site, and assessment technique is most appropriate for the prediction of fracture risk in a clinical setting. Our objectives were to: (i) determine the parameter(s) which best predict whole bone fracture and (ii) determine the best skeletal site at which to make measurements.

Methods: Thirteen pairs of cadaver femora were scanned using dual energy x-ray absorptiometry with radiographic images obtained concurrently. From these data, the following bone strength parameters were calculated along the length of the femoral shaft: bone mineral content (BMC); cross-sectional area, polar moment of inertia and polar section modulus using radiographic measurements and a concentric annulus model; cross-sectional area, cross-sectional moment of inertia, and polar section modulus obtained directly from raw absorptiometry data using custom written software; and a strength indicator (SI) parameter based on beam theory which incorporates both BMC and polar section modulus. The left femurs were subsequently tested to failure in torsion. Correlation analysis was performed between torsional failure load and each parameter measured at the midshaft and fracture sites.

Results: All parameters showed the same basic pattern of variation along the femoral shaft. Geometric and structural properties were maximized in the proximal region and minimized in the distal region. The correlation between failure load and parameters measured at the fracture site was generally low. The correlation between failure load and parameters measured at midshaft were considerably higher, with parameters that incorporated both amount and distribution of mineral showing the strongest association with failure load.

Conclusions: In most of the specimens, bone failure did not occur in the region where both structural and geometric properties were minimized, and data obtained at the midshaft were more accurate in predicting fracture than data obtained at the actual site of fracture. Parameters that incorporated both mass and distribution of bone mineral had the strongest predictive power; however, BMC alone provided a reasonable prediction of fracture risk. With currently available assessment technology, the added time and effort needed to calculate cross-sectional properties may not be justified for a relatively small gain in predictive power.

Clinical Relevance: Although it is well accepted that bone mass is not the only determinant of bone strength, we were only able to demonstrate a small advantage in prediction of whole bone failure by inclusion of geometric properties in our assessment. Further, we found that the midshaft assessments were more accurate in predicting whole bone failure than measurements taken after the fact at the site of fracture. These findings indicate that standard bone densitometry is robust as a clinical assessment technique. Future work needs to investigate what other properties may be measured relevant to bone failure, such as material properties, tissue-level defects, anisotropy, and bone shape.

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S-130

CLENBUTEROL AS A REHABILITATIVE AGENT FOLLOWING EXPERIMENTAL SEVERE CONTUSION INJURY TO THE SPINAL CORD

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One of the major goal of rehabilitation following spinal cord injury (SCI) is recovery of motor function, building muscle strength and endurance and preventing osteopenia. Clenbuterol, a beta 2 agonist, has been shown to ameliorate denervation-induced muscular atrophy, therefore is considered to have a therapeutic potential in the treatment of muscle wasting. In addition, clenbuterol has also been found to have a neuroprotective effect on central nervous system neurons, promoting neuron survival after injury.

Objective: This study was designed to evaluate the potential for clenbuterol treatment to reverse muscle atrophy after chronic injury to the spinal cord (SCI). And to determine whether the enhanced musculature be correlated with increase in motor activity.

Methods: Fisher 344 rats were anesthetized and sustained a severe contusion injury at the T8 level. The animals were divided into three groups. The injury only group (n=10) was compared with non-lesioned group (n=5). Ten week post-trauma, a third group of animals (n=10) received clenbuterol treatment orally through liquid food at a dose of 10 mg/kg/day, for another ten weeks. The effectiveness of this treatment was evaluated by electrophysiological and behavioral testing, by measuring body weight weekly during the experimental period, and by weighing individual leg muscles after sacrifice. The weight of the hearts were obtained to eliminate the possibility of hypertrophy of cardiac muscle by clenbuterol. The dry/wet weight ratios of the muscles were also determined.

Results: Repeatable baseline SSEPs and MEPs were obtained from all animals pre-operatively. Following injury, the SSEP responses to stimuli requiring transmission across the lesion site were extinguished. There was no electrophysiological evidence of sensory transmission across the lesion in untreated, as well as clenbuterol treated animals. However, MEPs recovered in the clenbuterol treated animals, although the amplitude was reduced and the mean latency of the response to cortical stimulation was increased. Clenbuterol treatment also restored the muscle wasting following chronic SCI, in addition to muscle protein which was lost following SCI was restored in the treated group. Recovery of muscle mass also resulted in improve motor activity as measured by behavioral testing in these animals.

Conclusion: The results of this study indicate that clenbuterol appears to be a potentially useful drug for the treatment of muscular consequences of SCI.

Acknowledgment: Supported by American Paraplegia Society and Rehabilitation R&D Services, DVA.

Clinical Relevance: The long term goal of proposed research is to establish the beneficial effects of clenbuterol as therapeutic agent for the management of SCI patients. To accomplish this goal, it is necessary to establish if clenbutral can improve the muscle endurance and improve motor function following SCI. This type of animal data can serve as a baseline for future functional outcome testing at the clinical level. Individuals who sustain SCI develop weakness and wasting of muscle below the level of lesion. It is estimated that the muscle volume is reduced by 30 -35% in the first few weeks after the injury. The prevention or reversal of muscle wasting is extremely important, because residual strength and muscle volume determine the degree of independence achieved by individuals with SCI. In addition, the trophic influence of clenbuterol on injured spinal cord neurons has great potential for enhancing functional recovery following SCI. If successful, besides the psychological boost for the patient of maintaining a more normal appearance of the inactive limbs, even minimal recovery of neuromuscular function based on the reconnection of a few axons with viable muscle units, could translate into a greatly enhanced quality of life for these individuals.

S-131

CLINICAL EVALUATION OF A SECOND GENERATION IMPLANTED UPPER EXTREMITY NEUROPROSTHESIS

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Objectives: The goal of this research is to provide hand and arm function to individuals with upper extremity paralysis. This is accomplished using a combination of surgical reconstruction techniques and implanted neuroprosthetic technology.

Methods: Neuroprostheses use electrical stimulation of paralyzed muscles to produce movement in spinal cord injured individuals. The individual can control the stimulation through retained voluntary movements, such as wrist or shoulder motion. Grasp patterns are produced through coordinated stimulation of multiple muscles in the forearm and hand. A first generation neuroprosthesis has undergone a prospective multi-center clinical trial, has received FDA approval, and is commercially available. A second generation implanted neuroprosthesis has now been developed which can provide enhanced grasp and control for C5 and C6 level tetraplegic individuals. The primary feature of this second generation system is that both the stimulator and the control source are implanted. These systems are now undergoing clinical evaluations. Second generation neuroprosthetic systems utilize either a joint angle transducer implanted in the wrist, or myoelectric control generated by voluntary wrist extensors or neck muscles. The signal generated by the implanted sensor is transmitted out of the body through a radio frequency link. This same link is used to transmit the command signals back into the implanted device in order to produce stimulation on the appropriate electrodes. In addition to the implanted control source, the second generation device has ten to twelve channels of stimulation. Seven or eight channels are needed to provide lateral and palmar grasp patterns, and the additional channels of stimulation are used to provide improved grasp opening through stimulation of the finger intrinsic muscles, elbow extension through stimulation of the triceps, and/or forearm pronation through activation of the pronator quadratus. The impact of the neuroprosthesis was evaluated by measuring pinch strength, stimulated range of motion, grasp-release function, and performance in activities of daily living. In addition, a survey of user satisfaction was used to assess general satisfaction, device usage, device impact, occupation, and external assistance required.

Results: Four C6 tetraplegic individuals have undergone the first stage of implementation involving implantation of the stimulator and ten electrodes. Functional systems for home use have been provided at this stage by using a control sensor mounted externally on the wrist. Two patients have completed the second stage, in which the control sensor is implanted in the wrist. The complete system has now been used at home and in the community for over one year. The initial results indicate a high level of daily home usage among all four patients. The device provides a significant increase in grip strength. All four patients demonstrate increased independence in activities of daily living when using the neuroprosthesis compared to their performance without the neuroprosthesis. Three of four patients were able to gain overhead reach through triceps stimulation, and the fourth gained this function through surgical reconstruction. Two of the four patients also gained additional function through surgical reconstruction procedures on their contralateral limb.

Conclusions and Clinical Relevance: Neuroprostheses provide spinal cord injured individuals with improved functional capacity beyond that which can be obtained through conventional rehabilitation techniques. Compared to the first generation neuroprosthesis, this new system is easier to don and doff and provides more refined hand function.

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S-132

HEALING OUTCOMES OF LONG BONE FRACTURES IN PERSONS WITH SPINAL CORD INJURY

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Objectives: Long bone fractures in persons with spinal cord injury (SCI) are characterized as slow-healing, often resulting in malalignment and nonunion, with disorganized "exuberant" callus a common feature. Our clinical observations have been otherwise. This study was undertaken to examine a large series of long bone fractures occurring after SCI in order to determine timing and quality of fracture healing. Specifically, we evaluated the association between fracture location and morphology and healing outcome.

Methods: Systematic reviews were performed on available radiographic records of 170 long bone fractures in patients seen at the Spinal Cord Injury Center. Sequential xray films were evaluated for location and type of fracture, presence and appearance of callus, anatomic alignment, and healing outcome. Fracture morphology was determined according to an hierarchical classification system which codes bone, anatomic location (proximal, midshaft, distal), and fracture type and complexity. In addition, we developed a Healing Index in order to quantify the presence and extent of callus formation and healing endpoint (0=no callus, 1=callus present in one projection only, 2=callus present in more than one projection, 3=bony bridging, 4=remodeling). Bony union was defined by a healing score of 3 or 4.

Results: Overall, a high proportion of successful healing was observed in lower limb long bone fractures; 90% achieved bony union. The majority of non-unions occurred in the femur, but no bone segment was more likely to heal improperly. Overall, 57% of leg fractures healed in normal alignment with malalignment less frequent in the healed fractures of the tibial midshaft (33%) and distal tibia (27%). Approximately one half of the fractures healed with some degree of shortening with compaction more common in femoral than tibial fractures. Callus was apparent by 3 weeks for all bone segments, except the proximal tibia where it was observed as early as 10 days and the midshaft tibia where it was not observed before 5 weeks. Bridging bone was present by 4-6 weeks in all segments, except the proximal femur where it was observed at 10 weeks. Normal callus formation occurred in the majority of lower limb fractures appearing along stress lines. Exuberant callus was observed in less that 10% of all tibia fractures, in 30% of femoral midshaft and distal fractures, and in 60% of proximal femoral fractures although these were the least common fracture type.

Conclusions: In patients with SCI, fracture healing is rapid and bony union is usually achieved before 2 months. Contrary to common belief, exuberant callus formation is found infrequently and normal callus formation occurs along stress lines. This bone formation does not seem to require a program of mechanical loading (i.e., graded weight-bearing) considered necessary for optimal healing in able-bodied fracture patients.

Clinical Relevance: With an improved understanding of the normal healing sequence, a more appropriate evaluation pathway can be implemented to effectively monitor SCI patients who sustain long bone fractures. If patients are scheduled for radiographic evaluation at prescribed intervals relevant to expected healing patterns, decisions can be made regarding continuation or cessation of treatment, and non-optimal healing may be identified and corrected. Further, treatment regimes can be implemented and monitored according to an outcome-based clinical evaluation system, rather than according to observation and clinical judgment , as these may vary with the experience of the personnel.

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S-133

AUTOMATIC EMG-BASED CONTROL OF SHOULDER MUSCLE STIMULATION PATTERNS IN C5 TETRAPLEGIA

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Objective: There were two primary objectives of this project. The first was to devise a strategy for using EMG recordings from voluntary shoulder muscles in individuals with C5-C6 spinal cord injuries to automatically control the stimulation to paralyzed shoulder muscles in a task-appropriate yet natural manner, thus resulting in significant improvements in shoulder function. The second objective was to determine the minimum number of stimulated muscles and recorded EMG signals needed to implement this approach.

Methods: An artificial neural network (ANN) was devised to use electromyographic (EMG) recordings from shoulder muscles with retained voluntary to predict the functional electrical stimulation (FES) patterns needed in paralyzed muscles to automatically produce the movements intended by the user. Training and evaluating the ANN using data from human subjects would require recording EMG signals from a large number of voluntary muscles and stimulation of many different combinations of paralyzed muscles, as well as the collection of enormous amounts of experimental data. As an alternative, this study used a computer-based musculoskeletal model of the shoulder and elbow, adjusted to reflect C5 tetraplegia, to substitute for human subjects. Inverse model simulations indicated the muscle activation patterns required to hold the arm in various postures while balancing loads applied to the hand in different directions. The C5-adjusted model was augmented by 1-6 “paralyzed” muscles to indicate the performance that would be gained by addition of stimulated muscles. Furthermore, the activation patterns of several of the “voluntary” muscles were then used to predict the activation patterns needed in “paralyzed” muscles. The “voluntary” activations were used as inputs to the ANN, and the outputs were the needed activation (stimulation) to the “paralyzed” muscles. The number of “voluntary” muscles was varied from 1-13, and the number of added “paralyzed” muscles was varied from 1-6.

Results: In general, adding more stimulated “paralyzed” muscles resulted in better arm function, as measured by the external loads that could be resisted. However, most of the additional strength was due to just two muscles (pectoralis major and latissimus dorsi). Likewise, the ANN was able to predict the needed stimulation of these muscles with highest accuracy when more muscles were included. However, more than 90% of the predictive ability was obtained using 4 muscles as inputs and almost 70% from just two muscles.

Conclusions: A simple shoulder neuroprosthesis consisting of two stimulation channels, controlled automatically using EMG recordings from two muscles, is likely to successfully improve shoulder function in individuals with C5 tetraplegia. The proposed control strategy will automatically adjust stimulation levels to match the task, providing a greater range of motion to the user, while imposing little or no cognitive burden onto the user.

Funding for this project was provided by NIH HD32653, with additional support from the Cleveland VA Rehabilitation Research and Development FES Center of Excellence.

S-134

TRANSPLANTATION OF OLFACTORY ENSHEATHING CELLS OR SCHWANN CELLS RESTORES RAPID AND SECURE CONDUCTION ACROSS THE TRANSECTED

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Long tract axons in the mammalian spinal cord do not normally regenerate for an appreciable distance within the denervated host tract after they are transected. However, a number of experimental approaches have been reported to improve elongative regeneration of axons in the transected mammalian spinal cord. Recent attention has focused on transplants of cultured olfactory ensheathing cells (OECs) into ablated cortico-spinal tract axons and nerve bridges in the spinal cord to enhance regeneration. OECs have several unique properties which provide a rationale for their potential to enhance CNS axonal regeneration. OECs are specialized cells which support axons that leave the olfactory epithelium and project through the peripheral nervous system into the olfactory bulb of the central nervous system; they are pluripotential cells which can show Schwann cell or astrocyte-like cell properties. Interest has focused on these cells because olfactory epithelial neurons are continuously replaced and regenerate axons in the. It has been reasoned that the unique properties of OECs may allow them to guide and enhance regenerating CNS axons through a normally growth inhibitory environment. Olfactory ensheathing cells or Schwann cells were transplanted into the transected dorsal columns of the rat spinal cord to induce axonal regeneration. Without transplantation of cells no impulse conduction was observed across the transection site, but following cell transplantation impulse conduction was observed for over a centimeter beyond the lesion. Cell labeling indicated that the regenerated axons were derived from the appropriate neuronal source, and that donor cells migrated into the denervated host tract. As reported in previous studies the number of regenerated axons was limited. Conduction velocity measurements and morphology indicated that the regenerated axons were myelinated, but conducted faster and had larger axon areas than normal axons. These results indicate that the regenerated spinal cord axons reconstitute electrophysiological function, an important requirement for an intervention therapy to enhance axonal regeneration after spinal cord injury, but there is a preferential regeneration of large myelinated and rapidly conducting axons. Therefore, while the number of regenerated axons induced by cell transplantation is limited, a rapidly and securely conducting new information line is established which may contribute to the observed behavioral recovery of function. Supported in part by the Rehabilitation Research and Development and the Medical Research Services of the VA.

S-135

SYNAPTIC REORGANIZATION IN THE SUBSTANTIA GELATINOSA FOLLOWING PERIPHERAL NERVE NEUROMA FORMATION: ABERRANT INNERVATION OF LAMINA II NEURONS BY A(AFFERENTS

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A number of degenerative and regenerative changes occur in the central terminal regions of primary afferent neurons after their peripheral axons have been injured. Characteristic of these changes is a structural reorganization of central terminals in the dorsal horn of the spinal cord, which may modify sensory input to the central nervous system (Woolf et al., Nature, 355: 75-78, 1992). In this study, intracellular recording and extracellular field potential (FP) recordings were obtained from spinal cord dorsal horn neurons (laminae I-IV) in a rat transverse slice preparation with attached dorsal roots. To study changes in synaptic inputs following neuroma formation, the sciatic nerve was sectioned and ligated 3 weeks prior to *in vitro* electrophysiological analysis. HRP labeling of dorsal root axons indicated that A(fibers sprouted into laminae I-II from deeper laminae following sciatic nerve section. FP recordings from dorsal horns of normal spinal cord slices revealed long latency synaptic responses in lamina II and short latency responses in lamina III. The latencies of synaptic FPs recorded in lamina II of the dorsal horn following sciatic nerve section were reduced. The majority of monosynaptic EPSPs recorded with intracellular microelectrodes from lamina II neurons in control slices were elicited by high-threshold nerve stimulation, whereas the majority of monosynaptic EPSPs recorded in lamina III were elicited by low-threshold nerve stimulation. Following sciatic nerve section and ligation, 31 of 57 (54%) EPSPs recorded in lamina II were elicited by low-threshold stimulation. The majority of low-threshold EPSPs in lamina II neurons after axotomy displayed properties similar to low-threshold lamina III EPSPs in control slices. These results indicate that reoccupation of lamina II synapses by sprouting A(fibers normally terminating in lamina III occurs after sciatic nerve section and ligation, and that the lamina II neurons receive inappropriate sensory information from low-threshold mechanoreceptor after sciatic nerve section and ligation. These results emphasize that central rewiring can occur after injury and have implication for rehabilitation strategies. Supported in part by the Rehabilitation Research and Development and the Medical Research Services of the VA.

S-136

MEASURING CONTROLLABILITY DURING VOLUNTARY MOVEMENT

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Objectives: Voluntary movement is a result of muscle activation which is volitionally generated by the central nervous system (CNS). A CNS impairment such as spinal cord injury (SCI) results in altered motor control. However, objective methods to assess the degree of remaining motor control are lacking. Altered motor control of SCI subjects has been assessed using surface electromyography (sEMG) of lower limb muscles in a protocol called brain motor control assessment (BMCA). This paper introduces a challenging expansion of the BMCA protocol and a method to measure controllability and to detect the limits of voluntary movement using cross correlation in ten healthy subjects.

Methods: While in a comfortable supine position, subjects were asked to perform unilateral and bilateral alternating ankle dorsal and plantar flexion for 5 s at 4 different speeds followed by continuously increasing, slow to fastest possible speeds for 10 s. An alternating high and low tone was presented as a target for dorsal and plantar flexion respectively. During this protocol, sEMGs were recorded from 10 lower limb muscles (quadriceps, adductor, hamstring, tibialis anterior and triceps surae for both legs). Ankle movements were recorded by a magnetic position sensor. Cross-correlations between windowed movement and target signals (1s-width sliding window) were obtained and plotted in 3D contour graphs (Fig. 1).

Results: The peak of the cross correlation between movement and target represented the movement phase delay. Fig. 1. shows that the subject could track the target signal reasonably well up to target speeds of about 3Hz. Beyond this critical frequency, the cross correlation values were lower, consistent with the subjects' inability to follow faster targets.

Conclusion: Based on this analysis, the maximum movement frequency and motor control strategy can be estimated. This simple movement task demonstrates the consequence of challenging the limits of controllability. The proposed method offers the promise of improved discrimination of controllability for studies in SCI subjects as well as other upper motor neuron dysfunction (post-stroke, Parkinson's disease etc.)

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S-137

CLINICAL AND BASIC SCIENCE STUDIES OF THE DELTOID-TO-TRICEPS TENDON TRANSFER AFTER TRAUMATIC SPINAL CORD INJURY

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Objectives: The posterior deltoid muscle is surgically transferred to the triceps insertion to replace lost elbow extension in patients with C5 and C6 level tetraplegia [1,2]. Considering the large range of motion of both the elbow and shoulder joints, a risk exists for overstretching the repair sites, exceeding the range over which the muscle can operate. The purpose of this study was to quantify the magnitude of tendon slippage after postoperative deltoid-to-triceps tendon transfer and to mathematically model the transfer based on detailed architectural study of deltoid and triceps muscles from cadaveric specimens.

Methods: Twelve patients (10 males and 2 females; mean age 26, range 20 - 35 years) had thirteen tendon transfers of the posterior deltoid-to-triceps brachii muscle secondary to traumatic spinal cord injury. The posterior deltoid was mobilized and the interval between middle and posterior deltoid identified. The distal tibialis anterior was cut at its insertion, the tendon was then cut proximally at the myotendinous junction and removed through an anterior incision on the distal portion of lower leg. A subcutaneous tunnel was created from the level of deltoid insertion to the distal triceps tendon via a dorsal incision to the level of olecranon. A distal deltoid tendon and tendon graft were placed with an overlap of 5 cm and sutured to each other using 5-0 Ethibond. Patients were separated into groups based on using or not using a protective armrest. Subsequently, 10 deltoid and triceps muscles were harvested from cadaveric specimens for detailed quantification of fiber length and cross-sectional area using methods previously developed for upper extremity muscles [3].

Results AND Discussion: Total distance between markers measured approximately 6 months postoperatively was 23.1±4.8 mm for patients without arm rests while the corresponding value measured with armrests was significantly lower (8.4±3.0 mm, $p<0.05$). The fiber bundles of the posterior deltoid were significantly longer than any of the three heads of the triceps (123.1±7.8 *vs*. 72.1±4.2 mm, $p<0.05$). Translated to the functional realm, these data indicate that the excursion of the posterior deltoid greatly exceeds that of any of the triceps heads. As expected, the cross-sectional area of the posterior deltoid was significantly less than the total triceps area ($p<0.001$) and would be expected to provide only ~20% of the maximum isometric tension of the combined triceps heads. Based on the observation that the fiber length of the posterior deltoid is very long and would be predicted to have a moderate force-generating capacity, we suggest that this transfer is an excellent choice to restore lost elbow extension function.

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S-138

SUPPORTED TREADMILL AMBULATION TRAINING (STAT) FOR STROKE PATIENTS

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Objectives: Using a new gait training technique, STAT, for patients with recent (within 6 weeks) unilateral stroke to: a) establish the safety of body-weight supported ambulation b) observe its impact on gait speed, endurance, and efficiency c) determine its effect on outcomes, especially transfers and locomotion d) compare its efficacy to conventional gait training.

Methods: Participants who satisfied the inclusion and exclusion criteria were randomized to either a control group with regular comprehensive inpatient stroke rehabilitation, or to a STAT group where the usual 20 minutes of conventional gait training was substituted by body-weight supported treadmill ambulation. Support with an overhead harness, initially 40% of body weight, was progressively decreased as the participant improved in ability to facilitate proper trunk-limb alignment, and transfer of weight to the paretic limb. Initial treadmill speed of 0.1 mph, was increased when a usual step-length was performed at a higher speed. Physical therapists assisted with reciprocal stepping and weight shifting, heart rate and blood pressure monitoring before, during, and after each session.

Gait outcomes were assessed by:
a) Functional Ambulation Category, from 0 (totally dependent) to 5 (independent)
b) Walking Speed for a 5 meter distance
c) Walking Endurance viz. distance walked as fast as possible, and
d) VO2 consumed as measured by a portable gas analyzer, during a 5 minute walk
Functional outcomes were assessed using the Functional Independence Measure (FIM) at admission, and on discharge from inpatient rehabilitation. Re-evaluations of these parameters will be conducted at 2 and 6 months after hospital discharge.

Results: Due to randomization, there were only three participants in the STAT group versus six controls to date, hence meaningful comparisons could not yet be made. However, all participants successfully completed their training without any adverse complications. All demonstrated definite improvements in gait parameters studied, and in FIM scores by the time of discharge. Further data including from follow-up testing will soon be available.

Conclusion: STAT is a safe and effective technique for gait training after acute unilateral stroke.

Clinical relevance and implications for the Veteran population and future research: STAT may permit earlier initiation of gait training resulting in enhanced mobility and independence, with subsequent reduction in morbidity for Veterans with stroke. Better functional outcomes are expected with decreased burden of care on the family, overall health status improvement, subjective well-being, and reduced cost of care. Future research will include expanded numbers of subjects for the two groups to enable statistical analysis. The aerobic capacity at the same time intervals will also be studied in both groups using a cycle ergometer. The follow-up period will be extended to one year.

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S-139

ROBOT-ASSISTED UPPER LIMB MOVEMENT PROMOTES IMPROVED MOTOR FUNCTION IN POST-STROKE HEMIPARESIS

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Objectives: World War II veterans constitute the largest proportion of persons eligible for health care in VA facilities, and most of these veterans are at increased risk for stroke. With the dramatic reduction of inpatient rehabilitation length of stay following stroke, efficient and effective interventions have become critical. The objectives of this project are to establish the therapeutic efficacy of robot-assisted movement in subjects with chronic stroke, and to understand the mechanisms by which this therapy promotes motor recovery.

Methods: A clinical trial is underway to evaluate the therapeutic efficacy of robot-assisted movement for recovery of shoulder and elbow motor function. Chronic stroke subjects (> 6 months post-stroke) are randomly assigned to a robot or control group. Both groups receive 24 one-hour sessions over two months. A typical robot group session includes tabletop tracing of circles and polygons, and a series of 3-dimensional targeted reaching movements, all assisted by a Puma 560 robot arm. Four modes of assistance are used. In passive mode, the subject relaxes as the robot moves the limb in a predetermined pattern. In active-assisted mode, the subject triggers initiation of the movement with force toward the target and then "works with the robot" as it moves the limb. In active-constrained mode, the robot provides a viscous resistance in the direction of movement and spring-like restoring forces in all other directions. In bimanual mode, the subject attempts bimanual mirror-image movements while a 6-DOF digitizer measures movement of the contralateral limb and the robot moves the paretic limb to the mirror-image position with minimal delay. A typical control group session includes NeuroDevelopmental Therapy (NDT) targeting upper limb function, and 5 min of exposure to the robot with target tracking tasks. All subjects are evaluated pre and post treatment with clinical and biomechanical measures.

Results: Data from the 10 robot group subjects and 9 control subjects who have completed the study indicate robot-assisted movement may have advantages over conventional NDT-based therapy. In terms of the upper limb portion of the Fugl-Meyer exam (FM) of motor function, there is a trend towards greater improvements in the robot group compared to controls, but this trend is not yet significant. However, when considering only the shoulder and elbow portions of the FM, robot group improvements are significantly greater than control group improvements ($p<0.05$). There is evidence that the improvements in robot trained subjects are due to increased activation of paretic muscles and decreased antagonist co-contraction.

Conclusions: If it can be shown that robot-assisted movement has significant therapeutic value, robotic systems can be integrated into clinical practice, potentially improving outcomes and increasing the efficiency of the clinical staff. Therapists could supervise setup of patients in the robotic system and instruct on the movements and modes to be practiced. An extended period of unsupervised exercise would proceed, with automatic feedback of data to motivate performance. Patients could thereby increase the amount of therapy received in the clinic, with the robotic system facilitating many of the exercises that require labor-intensive manual manipulation.

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S-140

PREVALENCE AND CHARACTERISTICS OF CHARLES BONNET SYNDROME IN A VETERAN POPULATION

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Objectives: Determine the prevalence of Charles Bonnet Syndrome and photopsias in severely visually impaired veterans.

Research Plan: This study determines the prevalence of Charles Bonnet Syndrome (formed visual hallucinations after adventitious vision loss without evidence of psychological or psychiatric problems) and photopsias (subjective perception of flashes, sparks or flickering light) by interviewing veterans participating in the VICTORS Regional Low Vision Rehabilitation program.

Methods: Subjects were asked in a friendly, open-ended, non-judgmental manner if they had ever "seen something that they knew wasn't really there." Information gathered included age, eye diagnosis, visual acuity, date of onset and description of the visual phenomena, reaction to visual phenomena and if the subject had told anyone about these visual phenomena.

Results: One hundred and ten subjects participated in this study. The median age of the subjects was 75 with a range from 26 to 89. Eye diagnoses included age-related macular degeneration (66%), diabetic retinopathy (13%), optic nerve atrophy (4%), glaucoma (3%) and other (14%). Best corrected visual acuity ranged from 20/20 (subject with hemianopsia) to finger counting. Thirty-six percent (40/110) of these subjects were legally blind (20/200 or worse). Sixty-six percent (73/110) saw formed images and/or experience photopsia. Of those who experience photopsia and/or formed images, 15% (11/73) saw formed images without photopsia, 67% (49/73) only had photopsia and 18% (13/73) experienced both photopsia and formed images. Almost 50% (35/73) of subjects experience photopsia and/or formed images daily The visualization of formed images and/or photopsia ocurred under dim illumination conditions in 49% (35/72) of the subjects, while 38% (27/72) saw the images or photopsias at anytime of day. It's interesting to note that 1 subject only saw images when driving, 4 saw images when watching TV and one saw images or photopsias when reading. Although 25% (18/73) of subjects admitted to being disturbed or frightened by the images, only 8 of these veterans spoke to a friend, spouse or doctor about it. Of the 73 subjects who saw images and/or photopsia, 49 (67%) did not talk to anyone about them.

Clinical Revelance: A high percentage of veterans with chronic severe visual impairment experience formed visual hallucinations and/or photopsias in the absence of psychological or psychiatric problems. Because vision loss is associated with age, many veterans with visual impairment who experience photopsias or formed images may be concerned about the possibility of dementia or Alzheimer's disease. Unfortunately, the majority of these patients do not talk about their formed images or photopsias. Geriatricians, optometrists and ophthalmologists should question their patients regarding these phenomena and provide reassurance counseling. Further research is needed to determine the etiology of Charles-Bonnet Syndrome and possible treatment options.

S-141

DESIGN OF A FOLDING COMMODE-SHOWER WHEELCHAIR

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Collaborating manufacturer: Everest & Jennings

Objectives: Because bowel care procedures can take several hours, proper seating posture and comfort is necessary in order to prevent pressure ulcers, a serious threat in standard commode-shower chairs. This new chair will incorporate patented features (a new seat, a foot-lift, contoured footrests, large hand-rims) of a rigid "Commode-shower wheelchair" designed by the authors. However, the new chair will fold to be stored away when not in use.

Research design and methodology: An iterative process of design, prototype fabrication and evaluation is used to design the chair:

1. Design/development
   Development of sketches based upon the performance criteria for the chair.
   Manufacturing of prototypes with the collaborating manufacturer.
   Testing of prototypes with applicable ISO-ANSI/RESNA wheelchair standards.
2. Clinical Evaluation
   Assessment by veterans with SCI and caregivers of the chair's ability to fold/unfold, to transfer to and back from the chair and finally access for toileting and showering, etc.
3. Design modifications & final evaluation
   If necessary modification will be made with the collaborating manufacturer, followed by a final evaluation of the redesigned prototypes with veterans and caregivers.

Findings: The first two prototypes have recently began clinical evaluation at the Milwaukee and Tampa VAMC. All indications/feedback received so far indicate that both seated and standing individuals are able to fold-unfold the chairs without problems. Additionally the chairs have been found to fit conveniently over toilets and its other features, footrests, foot-lift, wide hand-rims are functioning properly.

Clinical relevance: There are over 200,000 persons with spinal cord injuries in the United States, requiring bowel care an average of three times a week. The new folding commode-shower chairs will significantly impact on their user's quality of life and safety. It will prevent falls and pressure ulcers. At the time it will improve efficiency of caregivers who assist in performing bowel care procedures in the home or hospitals.

Funding: DVA, Rehabilitation R&D Service.

S-142

ELECTROMYOGRAPHIC RESPONSES IN MANUAL WHEELCHAIR USERS DURING WHEELCHAIR PROPULSION TO FATIGUE

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Objective: Fatigue induced alterations in wheelchair (WC) propulsion have been associated with overuse injury risk.[1] Mechanisms mediating fatigue during WC propulsion must be understood in order to identify specific causes of injury. The objective of this study was to characterize electromyographic (EMG) responses of four muscles that are key generators of propulsion moment during a submaximal WC exercise test to fatigue.

Methods: Manual WC users (n=25) were tested for peak capacity and fatigue testing using a prototype WC ergometer. Mean age for subjects was 39 yrs (25-64 yrs) and disabilities included paraplegia (12), quadraplegia (3), spina bifida (3), cerebral palsy (1), Guillian-Barre syndrome (1), and arthrogryposis (1). After informed consent, subjects were medically screened for absence of cardiovascular contraindications for exercise. Subjects then completed a WC ergometer graded peak exercise tolerance test. This was followed by a fatigue test using 60% peak workload. Subjects propelled the ergometer at constant velocity (32-RPM) until they could no longer maintain the velocity. Bipolar surface EMG activity was recorded from bilateral anterior deltoid (AND), flexor carpi ulnaris (FCU), clavicular portion of the pectoralis major (PEC) and long head of the triceps brachii (TRI) muscles at 960 Hz. EMG was normalized to maximum voluntary isometric contractions for each muscle. RMS amplitudes, time to peak, onset and offset activity, total muscle on-time, and median power frequencies (MPF) were determined for the fresh state (at min 3) and the fatigued state (at the last test min). All variables were normalized to the WC propulsion cycle (rim contact2 – rim contact1 = 100%). Data was analyzed using ANOVA with repeated measures and Tukey's test for multiple comparisons.

Results: Average fatigue time was 19.5$\pm$12 min. There were no significant differences in the EMG parameters between the fresh and the fatigued states. There were significant differences between sides for the MPF of the FCU, and for the RMS maximum amplitudes for three muscles (AND, FCU, TRI), but these differences were not significantly related to fatigue. Only 15% of the subjects had EMG changes that would be expected with local muscle fatigue during submaximal exercise (amplitude increases and MPF decreases).

Conclusion: Preliminary results indicate that the submaximal exercise test used in this study did not result in EMG evidence of localized peripheral muscular fatigue. Subjects could have shifted their muscular efforts from side to side throughout the test to minimize peripheral fatigue. Other mechanisms may have mediated test cessation (e.g. neurological central drive). Changes in temperature and kinematics with fatigue may also have altered the EMG signal. Fatigue testing is one paradigm used to elicit pathomechanics during functional tasks such as WC propulsion. Further study is warranted to determine whether local muscle fatigue contributes to test cessation during WC propulsion to exhaustion.

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Reference: Rodgers MM, et al. Arch Phys Med Rehabil 1994;75:85-93.

S-143

VITAMINS AND PRESSURE ULCERS IN PERSONS WITH CHRONIC SPINAL CORD INJURY

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Objectives: To investigate the dietary intake and serum levels of vitamins A, C, and E and the relationship of these vitamins to the incidence of pressure ulcers in persons with chronic spinal cord injury (SCI) from various ethnic backgrounds.

Methods: 155 persons with chronic (2.4 - 47.0 years post injury) SCI (93 Caucasians, 35 African-Americans, 27 Hispanic-Americans) participated in the study. The dietary intake of vitamins was determined from written three-day food records using the Food Intake Analysis System, University of Texas, School of Public Health. The results were compared to the results of the National Health and Nutrition Examination Survey(NHANES). The serum levels of vitamins were measured using standard High Pressure Liquid Chromatography techniques and was compared to able-bodied reference ranges determined by Mayo Clinic. Analysis of variance was used to determine the statistical significance of the differences between means. P-values less than 5% were considered statistically significant.

Results: The mean serum levels of vitamins A, C and E were suboptimal in persons with SCI compared to able-bodied population. Similarly, the mean dietary intake of vitamins A and C was also slightly lower in persons with SCI compared to the general population. Among persons with SCI, pressure ulcer was associated with significantly (p=0.001) lower serum levels of vitamin A and slightly lower levels of vitamins C and E. Caucasians had significantly (p=0.005) higher vitamin A in their serum than did African-Americans. Caucasians with pressure ulcer also had significantly (p= 0.01) lower vitamin A in their serum compared to those without ulcers. Similarly, Caucasians had significantly higher vitamin A (p=0.01) and E (p=0.03) intake than African-Americas. Further studies will be necessary to clarify the possible relationship of these vitamin levels to the development of pressure ulcers.

Conclusions: Overall, the intake of vitamins was almost the same in persons with SCI and the able-bodied population. Although serum vitamins were suboptimal in persons with SCI, the differences were non-significant. It is noteworthy, that African-Americans had the highest incidence of pressure ulcers (43%), compared to Caucasians (20%) and Hispanic-Americans (26%), and the lowest intake levels of all three vitamins. Pressure ulcers remain a major health problem not only for persons with SCI, but also for others with limited mobility such as many elderly persons. The fact that 25% of the SCI population develop at least one pressure ulcer each year emphasize the importance of pressure ulcer prevention. Elucidating the relationships between vitamin metabolism and pressure ulcer incidence may suggest appropriate, non-invasive interventions designed to prevent pressure ulcers.

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S-144

CHANGES IN BLOOD FLOW WITH EXERCISE IN INDIVIDUALS WITH SPINAL CORD INJURY

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Objectives: In this study, we evaluate changes in blood flow in individuals with spinal cord injury (SCI) participating in arm crank exercise alone or in conjunction with lower extremity functional electric stimulation (FES). Our objectives were to assess the distribution of upper and lower limb blood flow both before and after maximal exercise and to determine whether the hemodynamic response was enhanced by the addition of lower extremity FES.

Methods: Arterial diameter and flow velocity were measured by duplex doppler ultrasonography in seven male subjects with SCI. Subjects were characterized by level of injury (3 tetraplegic and 4 paraplegic) and habitual activity (5 active and 2 sedentary). Hemodynamic measures were taken in the subclavian and femoral arteries at rest and immediately after a session of maximal exertion exercise in one of three exercise protocols. The exercise protocols included: 1) arm crank exercise alone (ACE); 2) arm cranking combined with FES applied simultaneously to opposing muscle groups of the lower limbs to create isometric co-contractions (Static Hybrid); and 3) arm cranking combined with FES applied to leg muscles to produce cycling (Dynamic Hybrid).

Results: Upper extremity arterial diameter increased by 12% (from 7.35 to 8.24 mm) and upper extremity blood flow increased nearly 4-fold (from 336.3 to 1299.3 ml/min) after maximal exercise. No change was observed with exercise in either arterial diameter or blood flow in the lower extremity. The change in upper limb blood flow was much greater in paraplegic than tetraplegic subjects, as expected. The difference in upper limb arterial diameter was detectable only in paraplegic but not tetraplegic subjects. There appeared to be a greater effect on upper extremity blood flow in active compared with sedentary subjects although this was not significant due to a high variance. While there was a trend toward greater upper limb blood flow increment in the dynamic hybrid protocol, there were no significant differences in hemodynamic response among exercise protocols.

Conclusions: Arm cranking exercise elicits an increase in upper extremity blood flow in both paraplegic and tetraplegic individuals, but upper extremity arterial diameter is only increased in paraplegic individuals. We were unable to discern a statistically significant benefit attributable to the addition of FES although the dynamic hybrid protocol appeared to elicit a greater blood flow response. No effect was observed in the lower limb with exercise.

Clinical Relevance: The adaptive capacity of the arterial system is compromised in individuals with SCI. Hypokinesis in the lower extremities results from blood pooling secondary to a lack of sympathetic tone and diminished or absent venous "muscle pump." This puts individuals with SCI at risk for blood clots, increased fatigueability, and decreased cardiovascular fitness. If hybrid exercise can be demonstrated to increase blood flow, this will have important implications for improved cardiovascular health and aerobic potential. The current pilot study has only evaluated the influence on blood flow of an acute bout of exercise. Future studies will evaluate whether an exercise training program can improve hemodynamic function in individuals with SCI.

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S-145

DEVELOPMENT OF A SECOND GENERATION WEARABLE ACCELEROMETRIC MOTION ANAYSIS SYSTEM

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Objectives: The goal of this project is to design, fabricate, and test a system for accurately assessing balance and mobility impairments. Using new technology, a fast, small, lightweight, wearable digital system is being developed to replace older analog sensor technology.

Methods: The next generation wearable accelerometric motion analysis system measures linear accelerations in the ±10g range using four sets of triaxially mounted digital accelerometers. The accelerometers are mounted in both corners of an eyeglass frame and the left and right sides of a waist belt to measure head and trunk accelerations, respectively. The digital accelerometers' output pulse frequencies are proportional to the measured accelerations and are fed into twelve 16-bit counters. At the end of each sample interval the counters transfer their data to internal registers. These registers are read by the embedded computer system, transformed to milli-gs, checked for thresholds in value, slope, magnitude, and angle, and stored onto a PCMCIA flash memory card for post-processing analysis. The system also provides for sensory (visual, tactile or speech) output triggered by timing and/or threshold criteria, and for communication with an operator unit and/or other sensors and data processors via serial radio-frequency links.

Results: Currently a functional desktop version of this system has been developed and successfully bench tested. A wearable version is being fabricated and will be tested using the same methods as the original system for sensor drift, sensitivity, misalignments, etc. Data from this new system will be compared to the first generation database and to conventional measures of human body motion including force platforms and goniometry.

Conclusions: The technology used in this effort allows for great versatility in the device. The EPROM-based programmability allows the device to be customized for specific activities with minimal changes to the hardware.

Clinical relevance: A wearable accelerometric motion analysis system provides a means of diagnosing and reducing risk of falls, formulating individualized therapies, and monitoring patients' progress. Video analysis and force plate systems, the current quantitative balance and motion assessment methods, are expensive and are not portable. The system is expected to be essential to new clinical proposals for prevention of pressure sores and mobility therapy for Parkinson's disease.

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S-146

ETIOLOGY AND MORPHOLOGY OF LONG BONE FRACTURES AFTER SPINAL CORD INJURY

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Objectives: Long bone fractures pose serious health concerns to individuals with spinal cord injury. There are no established consensus guidelines on treatment and little understanding of mechanisms of bone failure. Our objectives were to identify risk factors and causes of long bone fractures in these individuals and to evaluate the morphology of these fractures in relation to their causes. We also evaluated the sequelae of these fractures in terms of complications and care needs.

Methods: Demographic and medical data were collected on 700 patients with spinal cord injury ever seen at the VA Palo Alto Health Care System, and fracture history was determined. In patients who had sustained long bone fractures since their injury, detailed data collection regarding fracture cause, morphology, and patient-related outcomes was conducted by medical chart review, review of radiologic records, and interviews.

Results: A total of 252 fractures in 181 patients were identified; these occurred 16.1 years (SD= 10.8) after spinal cord injury (range: 0.5 - 53.9 years). The fractures were distributed as follows: 117 (46%) femur, 112 (44%) tibia/fibula, 16 (6%) radius/ulna, and 7 (3%) humerus. Comprehensive study was completed on 170 fractures, with focus was on fractures of the lower extremity. In the femur, 25% occurred proximally, 33% in the midshaft, and 43% distally. In the tibia, the distribution of fractures was 45% proximally, 28% in the midshaft, and 26% in the distal segment. Most of the proximal and distal femur and tibia fractures were extra-articular. The majority of femur and tibia shaft fractures (64%) were simple (ie, not wedge or complex). The most common cause of fracture for both femur and tibia in all segments was falls (48%, not including falls during a transfer). Other common causes included 20% transfer activities and 10% range of motion and activities of daily living. The majority of fractures required hospitalization, and 67% of the patients who sustained fractures needed extra assistance with their daily activities for some time afterward. The highest percentage of patients who required extra assistance were those with distal femur fracture (78%) followed by those with tibia midshaft fractures (75%). Overall, the occurrence of complications was low.

Conclusions: Over 25% of all patients ever seen at our facility have experienced at least one long bone fracture with an average of 2.7 fractures per patient. The majority of these occurred around the knee joint and most resulted from falls and transfer activities. Long bone fractures had a significant impact on independence in a high proportion of patients which has financial implications when the need for extra assistance involves care provided by an attendant.

Clinical Relevance: This study provides new information about patterns of fracture in patients with SCI and how fractures affect individuals with SCI and their daily functioning. These data will assist us in determining preventable causes of fractures and setting up guidelines in order to implement prevention. Results from this study should also be useful in projecting costs and health care needs for fracture care in the spinal cord injury population.

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S-147

MOTOR UNIT FIRING PATTERNS IN POST-STROKE HEMIPARESIS

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Objectives: Stroke and resultant hemiparesis involves over 500,000 new cases in America each year and is a frequently encountered clinical problem in the VA Health Care System. A prominent characteristic of post-stroke hemiparesis is weakness. Consequently, a primary focus of rehabilitation is improvement of muscular strength and task dependent control of muscular force. To date, no particular therapeutic approach has produced superior functional outcomes. Importantly, the neuromuscular mechanisms impaired in post-stroke hemiparesis have not been well characterized. Thus, a sound, scientific basis for effective rehabilitation approaches is lacking. In an effort to develop more effective rehabilitation interventions, the aim of this research is to characterize the physiologic basis of impaired muscle function in persons with post-stroke hemiparesis.

Methods: Leg extension force and motor unit (MU) discharge activity are simultaneously measured from the vastus medialis during isometric (ISO) contractions to 40% of maximal voluntary force and during isometric contractions facilitated with either flexion (FF) or extension (FE) of the contralateral leg. Two groups of hemiparetic subjects demonstrating near complete (Brunnstrom 5-6, CVA-I) and moderate recovery (Brunnstrom 3-4, CVA-II) from hemiparesis are compared with young control subjects. Forces are obtained using strain gauge force transducers. Motor unit discharge activity is obtained using a quadrifilar needle electrode and identified using custom-written spike recognition software. MU discharge rates (MUDR) are measured and instances of recruitment and derecruitment identified

Results: For isometric contractions, CVA-II subjects demonstrate significantly higher MUDRs than control and CVA-I subjects (20 pps vs. 10 pps, $p < .05$). With contralateral flexion, control and CVA-I subjects increase ipsilateral force, primarily by recruiting additional MUs. In contrast, CVA-II subjects reduce ipsilateral force, primarily by reducing MUDR. With contralateral extension, control and CVA-I subjects reduce ipsilateral force, primarily by reducing MUDR. CVA-II subjects also reduce ipsilateral force and MUDR, but with a longer latency.

Conclusions: Results to date demonstrate remarkable impairment in force regulation mechanisms in hemiparetic individuals attributable to both supraspinal and spinal segmental levels of the neuraxis. These data will serve to identify impaired physiologic mechanisms to be targeted in future studies developing more effective rehabilitation interventions.

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S-148

RELATING ARM STIFFNESS AND REACHING ABILITY AFTER CERVICAL SCI

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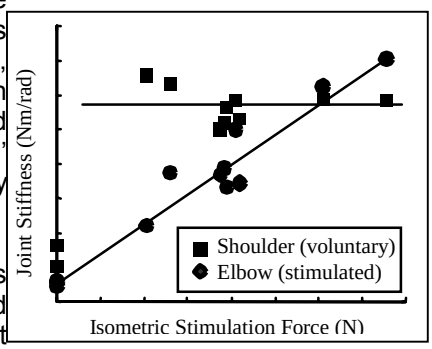
Objectives: The objectives of this work are to develop a method for quantifying postural arm stability and to determine if this method predicts functional reaching performance in individuals with cervical spinal cord injuries (SCI). SCI related motor impairments significantly limit the workspace where individuals can maintain stable hand positions, thereby restricting their independence. Functional arm control requires both strength and stability to complete tasks and to reject external disturbances. Successful rehabilitative efforts for restoring arm function must therefore restore both strength and stability. Strength is easily measured, but stability is difficult to quantify. A technique for efficiently quantifying arm stability and predicting how rehabilitation efforts will affect this stability and the corresponding function would greatly increase the benefits afforded by these interventions.

Methods: Two subjects with C6-level SCI have been studied to date; each has an implanted triceps neuroprosthesis to restore elbow extension. In these experiments, the neuroprosthesis was used to modulate arm stability via changes in triceps stimulation. Estimates of endpoint stiffness were used to quantify stimulation-related changes in stability. *Stiffness* is the relationship between externally imposed displacements and the resultant forces; *endpoint stiffness* describes how the arm reacts to external loads applied at the hand, and hence, is thought to be related to arm stability. Endpoint stiffness was estimated using a 2-joint robotic manipulator that applied position disturbances to the hand and measured the resultant force responses at 5 different levels of constant triceps stimulation. Functional consequences of changing endpoint stiffness were investigated using two reaching tasks, differing only in the amount of postural stability, not strength, required for completion.

Results: The stiffness of the elbow and shoulder joints can be directly obtained from endpoint stiffness estimates. The figure shows how joint stiffnesses were affected by the stimulation protocol, indicating that triceps stimulation can modulate elbow stiffness which directly effects changes in endpoint stiffness. Elbow-mediated changes in endpoint stiffness were directly related to subjects' functional reaching performance in tasks that were critically dependent upon maintaining a stable arm posture.



Conclusions: Triceps stimulation modulated both endpoint stiffness and functional reaching performance in tasks requiring increased postural stability. This suggests that rehabilitation interventions that increase endpoint stiffness are also likely to improve functional reaching, and also implies that quantitative estimates of endpoint stiffness can be used to predict qualitative changes in function. Hence, endpoint stiffness may be useful for evaluating existing rehabilitation strategies and for designing more effective interventions such as tendon transfer surgeries, orthoses, and neuroprostheses. These outcomes are expected to impact veterans significantly, who are over-represented in the SCI population.

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S-149

SUPPORTED TREADMILL AMBULATION TRAINING AFTER SPINAL CORD INJURY

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Objectives: A new approach to gait training following a spinal cord injury uses a support system to partially unload the lower extremities and a treadmill and assistance to stimulate stepping patterns. The purpose of this study was to conduct a pilot study of weight supported ambulation training after incomplete spinal cord injury.

Methods: Subjects: Three subjects with incomplete (2 American Spinal Cord Injury Association (ASIA) classification D and 1 ASIA classification C), chronic, thoracic spinal cord injuries volunteered to participate.

Intervention: Subjects participated in 12 weeks of training assisted by 2 physical therapists. The training consisted of walking on a treadmill (TM) while supported by a harness and a pneumatic suspension device. Body weight support (BWS) started at 40% of body weight and a TM speed of 0.1 mph, and was progressed by reducing BWS and TM speed and TM walking time. Training was conducted for 1 hour per day, 5 days per week. TM walking occurred for 20 – 30 minutes during the sessions.

Main Outcome Measures: Measures were taken at baseline, after 1, 2, and 3 months of training. Gait speed was calculated in m/sec from the time to walk 5-meters. Gait endurance was measured as the distance walked in 5 minutes. Oxygen costs of gait were obtained from a portable oxygen analyzer worn by the subject during a 5-minute walk. Oxygen consumption each minute was summed to provide milliliters of oxygen per kilogram body weight for 5 minutes.

Data Analysis: Data were analyzed with a Wilcoxon signed rank test.

Results: Mean gait speeds were 0.12, 0.15, 0.20, and 0.32 m/sec for each of the 4 observations. Mean gait endurance was 20.3, 26.5, 35.0, and 63.5 m, respectively. Mean oxygen costs were 1.96, 2.79, 1.51, 1.33 ml/kg/5 minutes for each month. Each value improved significantly ($p < 0.05$) during the course of the intervention.

Conclusions: Supported treadmill ambulation training increased gait speed, walking endurance, and decreased the oxygen costs of walking for each of the 3 subjects with chronic, incomplete injuries. Further investigation with more subjects is warranted.

Acknowledgments: This study was funded by the Rehabilitation Research and Development Center of Excellence on Healthy Aging with Disabilities, Houston, TX.

S-150

A LONGITUDINAL STUDY OF PERCEIVED STRESS IN INDIVIDUALS WITH SPINAL CORD INJURY

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Objectives: Stress has been associated with physical and psychological well being. Perception of stress is hypothesized to be a mediator between objective stressors (e.g., life events) and well-being. Two studies were undertaken to (a) compare levels of perceived stress for men and women with spinal cord injury (SCI) living in the community to each other and to their counterparts in the general population, (b) determine the stability of perceived stress over long time periods, and (c) assess correlates of perceived stress.

Methods: One sample was randomly selected from a sampling frame of 661 persons with chronic SCI and consisted of 71 men and 26 women who were assessed at 3 (women) or 4 (men) points over a period of 9 years. The other sample included 25 men and 4 women with recent SCI who were assessed 4 times during the first year following initial discharge. Participants completed numerous standardized questionnaires at each measurement point. Areas assessed included perceived stress, daily hassles, life events, life satisfaction, social support, and depressive symptomatology

Results: Women perceived more stress than men at all time points. Both men and women with SCI had higher perceived stress than their counterparts in the general population. For the recently injured group, stress peaked at 3 months following discharge. For the chronic SCI group, perceived stress remained relatively stable over time and was related to self-assessed health, level and completeness of injury, daily hassles, life events, depressive symptomatology, life satisfaction, control over one's life, social integration and social support. Frequently reported sources of stress included financial worries, health and health care, and personal assistance.

Conclusions: Perceived stress is a significant problem for many people with SCI, particularly women. Perceived stress is related to poorer physical and psychological well-being. We need to find ways to assist persons with SCI to manage their stress to avoid the negative impacts on physical and emotional health. Conversely, we must maximize health and wellness to reduce stress.

Clinical Relevance: Assessing the prevalence of stress and its correlates provides evidence of a need for interventions to assist persons with disabilities to reduce or effectively manage their stress to avoid associated health problems. This information also may suggest possible innovative approaches to the problem of stress. Studies of stress and stress management in the veteran population with disabilities are needed.

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S-151

COLLAGEN METABOLITE EXCRETION IN PERSONS WITH SPINAL CORD INJURY OR AMYOTROPHIC LATERAL SCLEROSIS

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Objectives: Persons with amyotrophic lateral sclerosis (ALS) rarely develop pressure ulcers in spite of the fact that, as their disease progresses, they are confined to bed. On the other hand, persons with a spinal cord injury (SCI) are highly susceptible to the development of pressure ulcers. In SCI, a correlation has been shown between increased excretion of some collagen metabolites and the appearance of pressure ulcers. We have shown that a glucosylgalactosyl hydroxylysine (GG) excretion above 100 micromoles per gram of creatinine when accompanied by a ratio of GG to galactosyl hydroxylysine (G) above 3.5, increased the risk of developing a pressure ulcer 4.5-fold. The principal objective of this study was to explore whether there are differences in the rate of urinary excretion of GG and G in persons with ALS and SCI.

Methods: Twenty-four hour urine samples were collected from 18 ALS patients, 10 hospital control subjects with other neurologic or muscular diseases, and 10 age- and sex-matched healthy controls. Informed consent was obtained from all subjects. All subjects were free of pressure ulcers. Samples were analyzed for creatinine content by the alkaline picrate method, and for GG and G concentration by a previously published method developed in this laboratory using an HPLC system with dabsyl chloride as the color reagent. The results of these analyses are compared to results obtained in a previous study of persons with SCI.

Results: The ratio of the concentrations of GG to G were 0.73+/-0.37, 2.12+/-0.79, and 2.14+/-0.40 in ALS patients, hospital controls and healthy controls, respectively. The ratio was significantly lower in the ALS patients than in either control group. In a previous study, 36 SCI patients with intact skin had a ratio of 2.0+/-0.5. While the ratio in ALS patients was negatively correlated with duration of illness, the ratio in persons with SCI was not correlated to time since injury.

Conclusions: The results suggest that collagen metabolism in ALS is altered in a very different way than it is altered following SCI. There is a need to conduct further research to explore the relationship of collagen metabolism to risk of developing pressure ulcers and the possibility of lowering the risk by altering collagen metabolism and perhaps skin structure. Since pressure ulcers are one of the most onerous complications following SCI, their prevention would result in decreased hospitalizations, lowered costs, and improved quality of life for persons with SCI.

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BACK EXERCISE PRESCRIPTION AND IMPLEMENTATION BY SURFACE ELECTROMYOGRAPHIC PROCEDURES

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Objectives: The purpose of this project was to evaluate a low back pain (LBP) exercise procedure for restoring muscle impairments classified by the Back Analysis System (BAS). The BAS is a computerized diagnostic device that combines surface electromyography (EMG) with dynamometry and force-feedback to evaluate the fatigability, strength, and control of back extensor muscles. This study was intended to advance the BAS technique to include the prescription and implementation of muscle-specific, individualized exercises to improve strength and endurance.

Methods: Phase I of the study focused on modifying the BAS to utilize force and EMG feedback to implement isometric exercises for back extensor muscles. This phase of the study also concentrated on developing isometric and isotonic exercises for use outside of the BAS for selectively muscle activation. Phase II of the study evaluated the effectiveness of exercise by comparing treatment outcomes in patients with LBP randomly assigned to either an experimental exercise group, a generalized strengthening exercise group, or a control group without supervised exercise. Clinical measures of pain, strength, and LBP- related disability were assessed. Testing was conducted at baseline and follow-up at discharge.

Result: Phase I: A back exercise protocol using a portable EMG system for biofeedback was developed for implementing spinal stabilization exercises. The protocol was based upon EMG recordings from twelve trunk muscles in 10 subjects during progressive spine stabilization exercises. The EMG findings can be used as a look-up table by physical therapists to objectively select an exercise that selectively activates groups of paraspinal muscles inhibited by pain or avoidance behavior. Phase II: collective analysis of the data resulted in the following key findings: (1) The modified BAS device functioned effectively in enabling patients with LBP to more easily activate specific muscle groups; (2) significant correlations ($p<0.05$; $r=0.45$-0.75) between EMG median frequency parameters and outcome measures such as VAS pain scores, pain drawings, and Oswestry disability scores; (3) significant improvement in EMG-based impairment measures at discharge compared to baseline for patients assigned to the treatment groups but not the control group; (4) the amount of asymmetry between contralateral paraspinal muscle groups was sensitive to change in clinical status following exercise; (5) successful reversal of the EMG asymmetry after exercise intervention was most evident in those patients who either had the most severe BAS-determined impairments or those patients who had access to BAS results.

Conclusion: The findings support the clinical usefulness of the BAS for objectively measuring baseline and follow up paraspinal functioning, and as an adjunct to exercises to reverse paraspinal weakness and muscle favoring.

Acknowledgment: This project was funded by the VA Rehabilitation Research & Development Service; Project No. B2029-RA.

S-153

^{31}P-MAGNETIC RESONANCE SPECTROSCOPY OF FES STIMULATED MUSCLE IN SCI SUBJECTS

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Objectives: Exercise induced by functional electrical stimulation (FES) in SCI subjects leads to greater cardiovascular and local blood flow responses than similar exercise performed by able body (AB) subjects. We tested the hypotheses that this difference was due to a greater metabolic impact of FES exercise on paralyzed muscle and that prolonged training with 2 FES cycling sessions per week could reverse this phenomenon.

Research Plan: 5 neurologically complete SCI subjects, and 12 able-body age-matched controls (AB) participated in the study. ^{31}P-Magnetic Resonance Spectroscopy (^{31}P MRS) was performed in every subject at rest (BL), during exercise (EX), and 20 min after the end of exercise. Training was performed in 30 min sessions, twice weekly on a REGYS I computer-controlled FES cycle ergometer (Advance Technologies Inc.) ^{31}P MRS was performed at three time points in SCI subjects: before training started, and after 3.5±0.65 weeks (INT 1) and 25±5.15 weeks (INT 2) of training.

Methods: ^{31}P MRS was performed on a 1.5-tesla General Electric system using a surface coil centered at the middle thigh of the activated limb. Muscle intracellular pH was estimated from the chemical shift of the inorganic phosphorus (Pi) resonance as $pH= 6.77+\log((\Delta Pi-3.29)/(5.68-\Delta Pi))$. FES was performed using an EMS+2 stimulator (Staodyn Corp., Longmont, CO) with pulse duration = 0.3 msec, pulse frequency= 60 Hz, train duration= 10 sec, and train frequency= 2/min. Stimulus intensity was adjusted to produce 30° knee extension with a 2 lb load. Stimulating electrodes were positioned on the midthigh, above and below the surface coil.

Results: In EX, intracellular muscle pH of AB subjects was 7.13±0.024, while in SCI subjects it reached significantly lower values of 6.94±0.084, P=0.04 when tested before training, and 6.88±0.025, P= 0.018 at INT 1. The pH value at INT 2, 7.10± 0.025, was not significantly different from AB controls. The ratio of Phosphocreatine peak (PCr) in EX over PCr in BL was significantly lower than 1 in SCI before training (0.845±0.021, P= 7.1×10^{-13}), and at INT 1 (0.795±0.041, P= 6.5×10^{-7}), but not at INT 2 (0.92±0.044, P= n.s.).

Conclusions/Clinical Relevance: This study indicates a greater intracellular acidification and PCr depletion of muscle during FES exercise in SCI subjects than in AB subjects performing voluntary contractions at comparable relative loads, a phenomenon likely responsible for the reduced muscle efficiency in FES induced exercise. A training adaptation in SCI subjects was induced by prolonged FES cycle ergometry (25 weeks) resulting in less acidification and PCr depletion during FES-induced knee extension. This study demonstrates that there is a potential for improvement of muscle performance under FES but that it requires prolonged training. These findings aid in characterizing FES, an intervention of potential benefit to veterans with spinal cord diseases.

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S-154

FUNCTIONAL ELECTRICAL STIMULATION INDUCED CYCLING DECREASES THE AMPLITUDE OF THE TIBIAL H-REFLEX

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Objectives: This Study tested the hypothesis that functional electrical stimulation induced lower extremity cycling (FESILEC) could attenuate the tibial H-Reflex, an index of spasticity.

Research Plan: H-Reflex waves amplitude and duration were measured under standardized conditions in six men with chronic spasticity of moderate to severe degree (Ashworth scale= 2-4) resulting from a traumatic spinal cord injury. Measurements were performed just before and within 1 hr after a FESILEC session of 30 min duration and on a control condition consisting of subjects seating on the ergometer with stimulating electrodes and bracing in place but without actual stimulation. Measurements were taken on three sessions over eight week intervals.

Methods: FESILEC was performed on a REGYS I computer-controlled FES cycle ergometer (Advanced Technologies Inc.). H-Reflex was recorded from electrodes placed over the soleus muscle, midpoint between the popliteal crease and the rostral flare of the medial malleolus. Stimulating electrodes were placed over the popliteal crease overlying the tibial nerve (cathode) and 2 cm proximal to it (anode). Skin temperature of the popliteal fossa was measured with a hand-held infrared temperature scanner. Means of base to peak (BP), peak to peak (PP) and through to peak (TP) amplitudes of the H-reflex waveform were calculated for the conditions before and after FESILEC. Analysis of variance and contrasts between means (Student's test, 2 tailed) were performed. Statistical significance was declared for $P<0.05$.

Results: FESILEC induced a statistically significant decrease in all parameters of the H-reflex waveforms (mV, Mean ± S.E.); Before FESILEC: BP= 3.55±0.32, PP= 4.53±0.36, TP= 5.54±0.36; After FESILEC: BP=2.73±0.21, PP=3.13±0.22, TP= 4.39±0.36. H-Reflex latency decreased after FESILEC (Difference before-after FESILEC, = 1.29±0.13 msec, $P<0.0001$) but not after the control condition (0.07±0.069, P= n.s.). Further analysis indicated that H-Reflex latency co-varied with popliteal fossa temperature (ANCOVA F= 7.51 $P<0.01$).

Conclusions: FESILEC reduced the amplitude of the tibial H-Reflex, an index of spasticity. The decrease in reflex latency observed with FESILEC is most likely a consequence of enhanced nerve conduction velocity induced by the temperature increase in the lower extremity associated with muscle work.

Clinical Significance: FESILEC might be of help for SCI patients when spasticity is detrimental to rehabilitation. This issue is important to the VA Healthcare System due to the prevalence of spinal cord disease patients. The ability of FESILEC to reduce spasticity over longer periods of time needs to be explored.

Funding Acknowledgment: Supported by the Department of Veterans Affairs Rehabilitation Research and Development. Project Nr B2002-R.

S-155

SURFACE EMG AS A MEASURE OF SPASTICITY IN SUBJECTS WITH SPINAL CORD INJURY: MEDICATION WITHDRAWAL STUDY

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Objectives: The overall purpose of our program is to develop new assessment tools for studying motor dysfunction following spinal cord injury (SCI). We have previously demonstrated the ability to monitor surface electromyographic (sEMG) activity in SCI subjects in a repeatable fashion. The purpose of this study is to develop information regarding the meaning of the indices developed from the sEMG data with respect to the increasing manifestations of spasticity induced by medication withdrawal, and to compare those values with scores obtained from clinical evaluations and subject self-reports.

Methods: Subjects are drawn from in and outpatients who received cervical or upper thoracic spinal cord injuries more than six months prior to the study, who are currently using antispasticity medications, moderate to severe spasticity, and good general health. Two baseline assessments are performed three days apart. Medications are withdrawn in steps, one at a time, with 3-4 days between steps, with assessments at each step. Assessment procedures include a comprehensive clinical examination (voluntary motor power, sensory level and degree of completeness of SCI, lower extremity tone, deep tendon reflexes, clonus, and plantar reflexes), patient self-assessment and neurophysiological aspects of motor control using surface electromyography (sEMG) in a protocol called brain motor control assessment (BMCA). For the BMCA, electrodes are placed over quadriceps, adductor, hamstrings, tibialis anterior and triceps surae muscles bilaterally. sEMG signals are amplified using NeuroScan SynAMPS 32 channel system with a 10-500 Hz bandpass, and gain of 1000. Data are continuously recorded for the approximately one hour BMCA protocol, beginning with five minutes relaxation followed by reinforcement maneuvers, voluntary maneuvers, passive maneuvers, tendon taps, clonus, application of vibration and finally plantar stimulation. All components offer insight into the subjects' state.

Results: From 36 total subjects, 21 were withdrawn from Baclofen, 16 from Valium and the remainder with other medications, having undergone between three and 14 assessments. The assumption that subjects became more "spastic" as medications were withdrawn permitted evaluation of clinical and electrophysiological scores. Ashworth scores showed a general tendency to increase with medication withdrawal, but not consistently, and with ceiling effects. Addition of other clinical measures and self-report scores could improve sensitivity. Indices were developed from averaged sEMG data for passive maneuvers. These indices demonstrate the expected sensitivity to medication withdrawal but without the ceiling effect observed for clinical scores. Increased activity was generally evident with medication withdrawal although not monotonically, and averaging over multiple muscle groups gave generally "better" results.

Conclusions: The sEMG methods employed in this study have proven reliable and robust indicators of altered motor control in subjects with spasticity after SCI. Further development of these methods should provide the basis for a sensitive, quantitative assessment of functional change after any intervention.

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S-156

PHYSIOLOGIC AND ANATOMIC DETERMINANTS OF EXERCISE RESPONSE IN SPINAL CORD INJURY

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Objectives: The purpose of this investigation was to evaluate the physiologic and anatomic determinants of the exercise response in individuals with spinal cord injuries (SCI).

Methods: Participants included fourteen males with SCI (8 tetraplegic, 6 paraplegic), aged 28-56 years (mean 45). Subjects were further categorized by habitual activity level: 7 sedentary and 7 active (aerobic activity >30 min/day, at least 3x/wk). Individualized graded maximal exercise testing was performed using Monark arm crank ergometry. Cardio-respiratory responses including VO_2, VE, and RER were assessed with a MedGraphics Cardio2 system. Cardiac structural analysis was determined via transthoracic M-mode echocardiography. Regional body composition was derived from whole body densitometry by use of Hologic QDR-1000/W. Relationships between variables were assessed by use of linear regression analysis. Analysis of variance with post hoc Scheffe testing was used to evaluate differences in physiologic and anatomic components due to level of lesion (tetraplegia vs. paraplegia) and activity status. Alpha levels of 0.05 were used to test for significance.

Results: Although VE_{max} was a moderately strong predictor of peak VO_2 in spinal cord injured individuals (R^2=0.85) when not separated by lesion level, there was a near perfect association in paraplegic individuals (R^2=0.98) with a much weaker association in tetraplegic individuals (R^2=0.49). While no differences were attributable to lesion level, active individuals showed significantly greater left ventricular diameter during diastole. However, there was not a significant relationship between diastolic dimensions and peak VO_2. Individuals with paraplegia had significantly greater percent upper extremity lean tissue than those with tetraplegia. Lean tissue mass was moderately predictive of peak VO_2 (R^2=0.59) and this relationship was not substantially different in those with paraplegia than tetraplegia.

Conclusions: The reduced association observed between maximal ventilation and peak VO_2 in individuals with tetraplegia is attributed to decreased innervation of muscles of respiration in individuals with tetraplegia versus those with paraplegia. Inactive individuals have decreased left ventricular diastolic dimensions as compared with their active counterparts. Active individuals may maximize physiologic mechanisms to increase preload to the left ventricle thus increasing left ventricular diameter during diastole. As expected, the amount of metabolically active tissue is correlated with the amount of physiologic work a SCI individual is capable of performing. In tetraplegic individuals, there is no significant relationship between percentage of lean tissue and activity level. However, in paraplegic subjects, percent of lean tissue increases with higher activity level.

Clinical Relevance: Differences in physiologic and anatomic determinants of exercise due to habitual activity are indicative of effects that are seen in training programs. In the absence of organized training programs, SCI individuals may still have significant cardiovascular and structural benefits from increases in habitual activity alone. Health care providers should therefore encourage and facilitate persons with spinal cord injuries to increase habitual activities to improve cardiovascular responses.

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S-157

IMPROVEMENTS IN DIAPHRAGM WIDTH AND PULMONARY FUNCTION FOLLOWING ANABOLIC STEROID THERAPY IN VETERANS WITH TETRAPLEGIA

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Paralysis from cervical spinal cord injury is associated with reduced lung function. Anabolic steroids increase muscle mass. Oxandrolone is an anabolic agent with low androgenic side effects. We hypothesized that treatment with oxandrolone would improve body weight, diaphragm width and pulmonary function in subjects with tetraplegia. Diaphragmatic width (DW) was measured by ultrasonography (as described by McCool et al., Am J Respir Crit Care Med, 1997). Pulmonary function tests (PFTs) were measured by spirometry (SensorMedics, Inc. Yorba Linda, CA). Oxandrolone (BTG Pharmaceuticals, Iselin, NJ) was administered (20 mg/d) for four months to 16 healthy subjects with tetraplegia (cervical 4-7). Average percent change from baseline was calculated for all variables. Results are reported as mean±SD. Average weight gain was 1.6±2.1 kg, $p<0.05$. PFTs improved for FVC (7±6%, $p<0.0005$), FEV1 (6±7%, $p<0.005$), FEF25-75% (8±11, $p<0.01$), FIVC (9±7%, $p<0.0001$), FIV1 (14±15%, $p<0.0005$), MIP (12±21%, $p<0.05$), and MEP (26±43%, $p<0.05$). DW improved 9±10%, $p<0.005$ (0.22±0.27 mm). The mean percent change in the inspiratory flow parameters was positively correlated with improvement in DW ($r=0.51$, $p<0.05$). The average of the expiratory flow parameters showed a positive, but nonsignificant trend, with increasing DW. In conclusion, VC, expiratory and inspiratory muscle strength improved. The increase in inspiratory muscle function can in part be attributed to increased diaphragmatic mass.

Acknowledgements: Eastern Paralyzed Veterans Association and an unrestricted grant from BioTechnology General Inc. Pharmaceuticals

S-158

HEALTH STATUS AND LIFE SATISFACTION AMONG INDIVIDUALS WITH SPINAL CORD INJURY: DO VETERANS DIFFER FROM NONVETERANS?

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Objectives: The goals of this study were to a) examine self-reported physical health, mental health, and life satisfaction among a sample of veterans with Spinal Cord Injury (SCI) and b) compare these results to those of two established nonveteran databases on persons with SCI.

Methods: Veterans who received outpatient services at the Houston VAMC Spinal Cord Injury Service were contacted and asked to participate in the Healthy Aging with Disabilities Registry. One-hundred sixty-four male veterans with SCI agreed to participate. Participants answered questions about the nature and extent of their injury and completed life satisfaction and health status measures via telephone interview. The measures administered included the Diener Satisfaction with Life Scale and the Short Form–12 Health Survey (SF-12). Data from this VAMC sample were examined in relation to published data on nondisabled persons and then compared to data from two previously established databases on patients with SCI. Because of demographic differences between the VAMC data and the two comparison databases, only males aged 35 and over were included in the comparison groups. The first comparison sample consisted of 88 community-dwelling men from a 13-county health services area surrounding Houston, TX. The second consisted of 182 men from around the nation who participated in the SCI Model Systems Database. The mean age for the Houston VAMC sample, the Houston community sample, and the national sample was 54.31 (SD=11.68), 50.10 (10.57), and 46.96 (10.01), respectively. The percentage of persons classified as tetraplegic was 50.4%, 46.6%, and 53.8% for the three samples, respectively.

Results: As expected, veterans with SCI scored lower than national norms for nondisabled populations in physical health, mental health, and life satisfaction. In addition, they reported significantly poorer physical health than both nonveteran SCI comparison samples [Means = 30.73 (21.22), 46.73 (9.98), and 36.69 (23.70) for the Houston VAMC, Houston community, and national sample, respectively]. Despite poorer self-reported physical health, the sample of veterans with SCI did not report poorer mental health or less satisfaction with life than the comparison samples. In fact, the veterans reported significantly higher scores on the SF-12 Mental Health subscale than the nationwide sample from the SCI Model Systems Database [Means = 63.70 (25.46) for the VAMC sample, 52.01 (10.47) for the national sample]. There were no differences on the Mental Health subscale between the Houston VAMC sample and the community sample from the Houston area [Mean = 67.13 (23.55)].

Conclusions: While there is a growing body of literature on the physical and mental health of nonveterans with SCI, there is currently very little data on veterans with SCI. It is vital that we explore the health and well-being of veterans with SCI in order to better understand their needs. It is only through greater understanding that we can adequately address those needs and work to enhance the quality of life of veterans with SCI. Data from this study suggest that veterans with SCI are in significantly poorer physical health than nonveteran samples; thus, caution is suggested in applying research from nonveteran populations to veterans with SCI.

This study was supported by the Veterans Affairs Rehabilitation R&D's Center of Excellence on Healthy Aging with Disabilities and the National Institute on Disability and Rehabilitation Research.

S-159

DEVELOPMENT OF PRINT AND WEB-BASED PATIENT EDUCATION MATERIALS ON FUNCTIONAL ELECTRICAL STIMULATION (FES) OPTIONS

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Objective: In order to understand, identify, and pursue appropriate Functional Electrical Stimulation (FES) treatment options, persons with spinal cord dysfunction and their family members need specialized information about FES including how it works, who it is for, how much it costs, what the alternatives are, and where to go for treatment. The objective of this project is to develop and disseminate educational materials that allow individuals to evaluate FES options.

Methods: The FES Information Center collects, organizes, and disseminates information on electrical stimulation for people with disabilities. In response to a needs assessment based on historical information and referral data, we have developed the *FES Resource Guide for individuals with spinal cord injury or multiple sclerosis*, a wire-bound manual that includes a tutorial on FES, a referral directory, resource listings including references, professional organizations and product information, and a glossary. We are in the process of revising the print edition and developing *FESWebGuide*, a web-based publication that provides easy access for users who need the information and easy updating for those responsible for maintaining the information.

Results: We surveyed more than 700 clinicians and researchers across the world serving people with spinal cord injury or multiple sclerosis to determine what FES applications are available to which populations. A format to display data from more than 70 responses has been designed. A survey of manufacturers of electrical stimulation equipment is underway to describe product availability. Beta testing on the World Wide Web has commenced.

Conclusions: An educational tool is under development that allows veterans and others with disabilities to explore functional electrical stimulation as a treatment option. Access to the tool is available in a printed format or via the World Wide Web. The utility of the tool to various user populations will be assessed.

Relevance To Veterans: In medically appropriate cases, FES can maximize health and function for veterans with spinal cord injury or dysfunction by restoring upper and lower extremity mobility, improving respiratory functions, restoring bowel and bladder functions, restoring male sexual function and for treating and preventing secondary complications such as pressure ulcers, deep-venous thrombosis, contractures, spasticity, deconditioning due to lack of exercise, bone demineralization, and muscle atrophy.

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DESIGN OF A MUSCULOSKELETAL MODEL OF THE HUMAN THUMB

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The primary goals of surgical restoration of grasping are often to restore the thumb's ability to move and produce forces (i.e., thumb function). However, the anatomic and kinematic complexity of the thumb precludes knowing the quantitative improvements of thumb function a particular surgical modification will produce. The objective of this study is to design a musculoskeletal model of the human thumb that is capable of predicting functional consequences of any reconstructive surgery. Preliminary results of such a design are presented here.

The model includes the kinematics of the joints and a network of thumb muscles and tendons. Despite the published discrepancies over the number of degrees of freedom and the geometry of the rotational axes at each joint, most agree that there are two distinct motions about intersecting perpendicular axes at each of the two most proximal joints (carpo-metacarpal and metacarpo-phalangeal joints) and one at the last joint (interphalangeal joint). As a first approximation, the model contains these kinematic degrees of freedom. The model predicts the muscle coordination patterns that produce maximal thumb-tip forces based on the complex mechanical interactions among the kinematic, anatomic and physiologic elements of the thumb and numerical optimization techniques.

Experimental coordination patterns and maximal forces are used to validate model predictions. Preliminary results indicate that a purely mechanical model can predict the salient features of muscle coordination for the thumb in several functional postures--particularly, key (thumb pad in contact with the medial side of the index finger's mid-phalanx)--producing maximal thumb-tip forces in several directions—particularly, palmar (force emanating from mid-distal phalanx of thumb used in key pinch). When producing palmar force, most muscles are activated at medium to high levels (extensor pollicis brevis and abductor pollicis longus, at low to silent levels).

Initial findings show that the coordination of thumb musculature can be explained by the principles of mechanics alone. When the model has been validated fully (i.e., for the other functional postures and directions), it may be used in a variety of ways; two of which include: elucidating control strategies in the thumb and acting as an *"in-vitro"* test-bed for designing new and modifying existing reconstructive surgical techniques for improving grasping ability for those with peripheral nerve injuries and the spinal-chord injured, like the veteran population with quadriplegia.

S-161

A MEASURE OF FUNCTIONAL PERFORMANCE FOR SIT-TO-STAND AND STANDING PIVOT TRANSFER MANEUVERS

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Objectives: Existing clinical assessment techniques for rehabilitation outcomes (i.e. the FIM.) are not specific or sensitive enough to detect changes in the effort exerted and assistance required for persons with spinal cord injuries to stand or transfer. In particular, conventional evaluations of motor function do not capture the increased capabilities provided by various rehabilitative interventions or assistive technologies, such as functional electrical stimulation (FES). This study was undertaken to develop, validate and apply a new clinical tool to measure the ability to stand and transfer with electrical stimulation.

Methods: The Functional Performance Measure, originally created at the Center for Inclusive Design & Environmental Access at the State University of New York, Buffalo, was adapted for this purpose. It consists of two rating scales for determining the effort and assistance required for each phase of the sit-to-stand and standing pivot transfer activities. Through an analysis of videotaped movements, each maneuver was decomposed into its elementary components. The standing pivot transfer was divided into eight phases: 1) system activation, 2) rising, 3) stabilization, 4) pivoting , 5) restabilization, 6) system deactivation, 7) lowering, and 8) sitting stabilization. During each phase of the maneuver, effort and assistance was rated on a scale from 0 (no effort or assistance required) to 6 (effort or assistance thwarted). Rigorous scoring conventions were constructed by reviewing videotapes of standing and standing transfer maneuvers performed by various neuroprosthesis users in our laboratory with and without FES. The scoring criteria and definitions were presented to a panel of rehabilitation professionals for critique and comment before generating the first version of the instrument. The tool was then applied to a series of 31 videotaped sit-to-stand and standing pivot transfer maneuvers by several independent reviewers, and their preliminary ratings were compared to resolve inconsistencies and eliminate ambiguities in the standardized scoring conventions.

Results: Agreement between applications of the assessment by independent observers has established the final form of the tool. It is currently being applied at discharge and at follow-up intervals to document functional utility of performing standing pivot transfers with and without FNS. Preliminary data indicate that FES reduces the effort and assistance required to complete standing and transfer activities, especially in the rising, pivot and lowering stages of the maneuver.

Conclusions: A new tool to assess the effort and assistance required for standing and transfers has been constructed and validated for FES- assisted maneuvers. It is currently being applied to document the clinical utility of implanted standing neuroprostheses. This new evaluation may be applicable to the generalized assessment of rehabilitation outcomes related to upright mobility. Future work will focus on applying similar techniques to quantify performance in stand-to-reach activities.

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PROVAR ASSISTIVE ROBOT SYSTEM ARCHITECTURE

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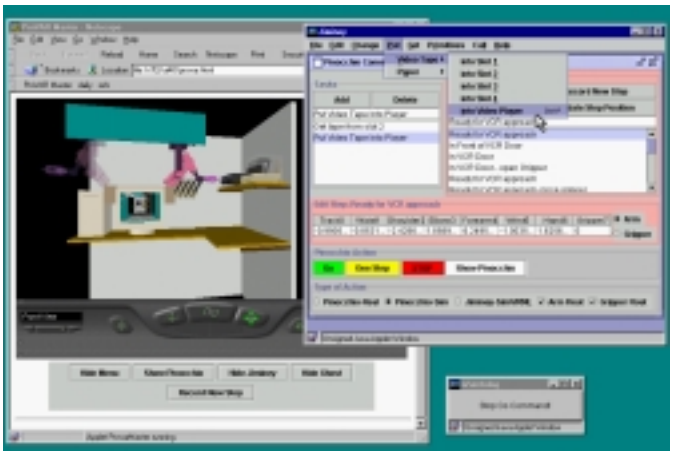
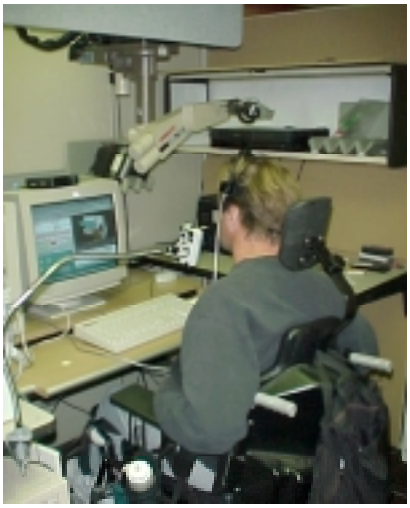
Objectives: The ProVAR (Professional Vocational Assistant Robot) system is an assistive robot that enables individuals with a physical disability such as high-level tetraplegia to manipulate physical objects in a semi-structured office workstation environment. ProVAR allows its users to create and execute Activities of Daily Living (ADLs) and vocational support tasks that are complex yet robust. The goal of the project is to augment the user's autonomy and independence while simultaneously reducing the resources needed in terms of human attendant care in a vocational setting.

Methods: The robot arm, mounted overhead on a transverse, motorized track, can execute tasks created through commands given by the user, who manipulates a 3-D graphic representation of the workstation. The user previews the task on-screen in a live dynamic simulation of the robot calculated by the robot arm's controller before final execution of the task by the arm. The ProVAR interface *combines* a task creation and manipulation window with the 3-D world model. The representation of the user's work area contains a "live" robot model showing the position of the real robot and a "virtual" robot model that the user can move to set new goal positions. The user interacts with the ProVAR system through various adaptive access devices selected according to each user's specific physical capabilities and preferences. The ADL and vocational manipulation tasks that ProVAR can perform (medication, drinks, paper handling, disks, videotapes, etc.) allow the user to be without an attendant for a large portion of a working day, increasing overall independence and permitting a measure of personal privacy.



Results: User testing has aided in refining the interface and confirming the success of the design strategy. The test subjects were able to execute pre-programmed tasks and create new ones after two training sessions. Using the interface and creating new tasks were reported to be "very easy, very straight-forward." The test subjects gave enthusiastic responses when they were able to watch the robot arm perform a task in real life that they had created and tested on-screen in simulation.



Conclusions: The novel interface and controller designs are expected to lead to technology transfer of the ProVAR concept and an eventual assistive robot product. Additional user trials in a vocational setting are pending.

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A CLINICAL INTERFACE FOR CONTROL AND EVALUATION OF FNS SYSTEMS

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Objectives: A lower extremity FNS portable system for standing, exercise, and transfer was developed for individuals with spinal cord injury. A PC based clinical interface was developed to configure the system and collect information from the system for clinical evaluation purposes. These tools will facilitate the exchange of information in multi-center trials.

Methods: A neuroprothesis, composed of an implanted stimulator-telemeter device, multiple implanted stimulating electrodes, and an external power and control unit has been developed. The user has the ability to put the system into standing, exercise, and diagnostic modes using input from buttons on the external control unit (ECU) as well as from a tethered fingerswitch. A Windows based clinical interface was designed to provide a high level interface to the ECU. The following functions are provided by this interface:
Muscle profiling
Logging of usage compliance data
Automatic generation of stimulation parameters
User information data storage
On-line help
Storing this information in electronic form will enable the immediate exchange of information between cooperative centers through E-mail.

Results: At present five individuals have received the neuroporthesis. All five individuals have acheived the necessary proficiency to use the system for standing and use their systems on a regular basis at home. Clinical personnel utilized the PC based clinical interface to evaluate the user's response to the stimulation and configure the ECU for stand-alone operation. This tool was also used to evaluate muscle response in surgery. Usage data was stored in the ECU and retrieved using the clinical interface when users returned for check-ups. This data allowed the clinical personnel to monitor progress and determine future exercise sessions.

Conclusions: The ECU design gives the user a simple interface to run a variety of stimulation functions. The clinical interface provides a useful way of collecting data for record keeping and program evaluation. This interface will enable the distribution of information throughout cooperative centers in multi-center trials.

Funding Acknowledgement: Funding for this project is provided by the Department of Veterans Affairs and the U.S. Food and Drug Administration.

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GDNF RESCUES TTX-RESISTANT Na^+ CURRENTS IN NOCICEPTIVE DRG NEURONS AFTER AXOTOMY

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Dorsal root ganglion (DRG) neurons become hyperexcitable following axonal injury, in part due to changes in Na^+ currents, and this contributes to neuropathic pain. We previously demonstrated that C-type rat DRG neurons express Na^+ currents with dramatically different kinetics following axotomy (sciatic n. ligation). Uninjured C-type neurons predominantly express slowly-inactivating TTX-resistant (TTX-R) and slowly-repriming TTX-sensitive (TTX-S) Na^+ currents. Following axotomy, TTX-R current density is greatly reduced and rapidly repriming TTX-S currents predominate. These changes may substantially alter excitability and could contribute to some chronic pain syndromes associated with injury to the axons of DRG neurons.

Recently we demonstrated that glial derived growth factor (GDNF) can modulate Na^+ channel expression in cultured DRG neurons. To examine the role of GDNF in modulating DRG Na^+ currents in vivo, GDNF was delivered directly to the transected sciatic n. stump using an osmotic pump. Ten days following axotomy the TTX-R Na^+ current density was larger in axotomized C-type neurons treated with GDNF (16±2 nA, n=54) than in axotomized C-type neurons treated with Ringer solution (6±2 nA, n=50), but not as large as in uninjured C-type neurons (28±4, n=27). The TTX-S currents in GDNF –treated neurons reprimed slower than in axotomized neurons, but not as slow as in uninjured neurons. This indicates that GDNF can partially reverse the effects of axotomy on the excitable properties of DRG neurons. Manipulation of GDNF levels should be explored as a new strategy for treatment of chronic pain. [Supported by Rehabilitation Research and Development Service and Medical Research Service, Department of Veterans Affairs]

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COMPUTER ASSISTED TRAINING FOR UNILATERAL NEGLECT

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Objectives: Patients with strokes involving the right hemisphere (R-CVA) who also have unilateral neglect of left space (UNL), sustain more accidents than all other rehabilitation patients. We have developed a computer assisted technique to train these patients to compensate for UNL-related problems during simulated high accident risk activities (i.e. wheelchair propulsion). This research has been funded by Merit Review: Rehab R&D. grants awarded to Dr. Webster. Patients are trained to compensate for UNL on a computer simulated obstacle course which does not require the exertion of propelling a real chair. We have conducted several research projects to determine 1) if this technique simulates real obstacle course performance, 2) if training produces decreases in neglect-related accidents during wheelchair propulsion, and 3) if it can be used by therapists in rehabilitation settings.

Methods: In Study1, 19 subjects with UNL were trained to compensate for neglect on the computer assisted training device. We trained these subjects to sit at true vertical, systematically scan into left space, to inhibit scanning to right space, and to scan while performing computer simulations of risky activities including propelling a wheelchair through a cluttered path. Computer simulation was used so that training began as soon as the subject was admitted to the rehabilitation . Each subject had approximately 15 sessions of training Pre and post measures included performance on a wheelchair obstacle course (WOC), incident reports in the hospital, and ratings by Occupational Therapist and Physical Therapists concerning accident risks. Scores from the WOC and incident reports were compared with those from a group of UNL patients who did not receive this training.

Study 2 compared the effectiveness of the computer programs presented on a LCD projector and a computer monitor (CRT). Thirty subjects were be randomly assigned to an LCD projector trained group and a computer monitor trained group.

Results and conclusions: In Study 1, we found that trained patients did significantly better on the WOC and fell less frequently in the hospital than untrained subjects. In Study 2, we found that CRT subjects and LCD subjects did equally well on outcome measures. We have also collected 1 year follow-up on 18 of these patients. The training results of Study 2 indicated that 66% of the subjects showed positive training effects and improved performance on the outcome measures. The subjects who did not improve were more severely impaired on screening measures. One year follow-up has thus far revealed that subjects maintained gains from training. In addition, we compared results from our computer simulated obstacle and the real obstacle course. Correlations between the measures were highly significant. ($r(44)=.63$, $p<.001$). These results suggest that computer simulated wheelchair propulsion was similar to real wheelchair propulsion, and that training on these tasks did improve compensation for UNL-related problems contributing to fall risk. We also have successfully made the techniques more accessible to rehabilitation therapists by demonstrating that therapy can be effective using a computer monitor. In limited trials with Occupational Therapists, we found that they could successfully use the programs.

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ALTERED VENOUS VASCULAR COMPLIANCE IN HEALTHY VETERANS WITH SPINAL CORD INJURY

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Alterations in peripheral blood flow associated with spinal cord injury (SCI) are the result of both sympathetic denervation and the loss of an active muscle pump. Determining the contributions of autonomic denervation and the absence of orthostatsis to alterations in peripheral circulation may have important clinical implications in persons with SCI. The study objective was to describe venous vascular function in subjects with SCI and in able-bodied controls, both sedentary (S) and active (A). Forty-eight subjects were studied, 24 individuals with SCI, 12 S and 12 A. Venous vascular function was assessed by strain-gauge venous occlusion plethysmography. A pressure cuff distal to the calf was inflated to a suprasystolic pressure and a thigh cuff to a pressure slightly below diastole. While the leg was supported horizontally, a strain-gauge placed around the calf detected change in limb circumference caused by occluded venous outflow while arterial inflow continued unimpeded until venous stabilization occurred. Results are expressed as mean±SD.

Maximal venous distention (VDm) was significantly reduced in the SCI group compared with both S and A groups, and also in the S relative to the A group (0.31±0.13 vs. 1.61±0.76 vs. 2.1±0.55 %Δ, respectively; $p<0.05$). Total venous outflow (VOt) was also significantly lower in the SCI group than in the S and A groups and in the S versus the A group (2.95±1.3 vs. 39.0±18.8 vs. 66.7±45.2 %Δ*sec, respectively; $p<0.05$). Finally, venous emptying rate, expressed as an index of VDm (VEi), was significantly higher in the SCI group compared with the S and A groups (39.3±13 vs. 21.2±8.9 and 21.2±4.9 %, respectively; $p<0.05$).

The results indicate a reduced maximal venous capacity resulting in attenuated VOt in both the SCI and S groups compared with the A group, whereas augmented VOt in the A group is primarily the result of enhanced elastic recoil of vessel wall smooth muscle. The differences between the S and A groups suggest level of activity (orthostasis) as an important modulator of a healthy vascular system. The loss of vascular compliance in the SCI group is depicted by higher VEi, representing the inability of the vessel wall to react to small changes in pressure, and thus contributing to altered peripheral blood flow. These findings suggest that regular orthostatic challenge may improve vascular compliance and peripheral circulation in individuals with SCI.
We acknowledge support from the Vidda Foundation and Eastern Paralyzed Veterans Association.

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SUPPORTED TREADMILL AMBULATION TRAINING (STAT): EQUIPMENT SPECIFICATIONS

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Supported Treadmill Ambulation Training (STAT) is a mode of therapy for gait retraining for patients with spinal cord injuries or other upper motor neuron dysfunction. The STAT program involves supporting a portion of the patient's weight while gait training on a treadmill. STAT has been successful in improving the gait of many research subjects, but has not been widely applied in clinical practice. The goal of this study is to acquire practical, clinically useful information regarding this therapeutic intervention in order to remove barriers to its use. This manuscript enumerates equipment specifications for the treadmill, body weight support (BWS) system, and harness. The ergonomics of the workspace are also considered since the therpist(s) will need access to the patient's legs during therapy. The specific recommendations were determined through interviews with clinicians, consultation with anthropometric tables, and application of engineering principles. The guidelines listed are intended to facilitate safe and effective application of the therapy at minimum hardware cost.

Required Features	Recommended Features
Minimum walking surface: 140cm x 60 cm	Ramp for wheelchair access
Maximum walking surface width: 75 cm	Speed increments of 1.5 km/hr
Minimum speed: .3 km/hr	Cantilever handrails
Power to move 140 kg @ .3 km/hr	
Handrails	
Safety stop apparatus	
Spring support system	Hooke's Law spring system
Unloading of 40% of body weight	
Accessible controls to adjust support	
Fall prevention system	
Reliable reporting of unloading	
Two point suspension (50 cm apart)	
Allow 5 cm of vertical displacement	
Promote upright posture	None
Two points for attachment to BWS	
Easy to don and doff	
Maintains comfort during unloading	
Adequate seating space (25 cm width)	Lift system to raise walking surface
Back support	
Adequate access to patient's legs	

Acknowledgments: Supported by the Center on Healthy Aging with Disabilities, VA Medical Center, Houston, TX and by Texas Woman's University, Houston, TX.

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IDENTIFICATION OF LOWER LIMB MOTOR CONTROL STRATEGIES

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Objectives: Restoration of walking to individuals with neurological impairments is challenging because of the complex interplay between neural control and musculoskeletal biomechanics. But, rehabilitation strategies to retrain muscle recruitment or strengthen muscles, for example, are based on qualitative simple, phenomenological cause-effect models of unimpaired walking. Our immediate goal is to develop scientific, experimentally based, computer-implemented models of lower limb motor tasks to identify basic principles of neural control and musculoskeletal biomechanics. Future goals are to use the models and perform experiments to elucidate the motor control deficits in veterans and other individuals with hemiparesis after stroke, to design rehabilitation strategies based on these modeling and experimental studies, and to evaluate the efficacy of these strategies.

Methods: Pedaling,rather than walking, is used to identify neural-control strategies for locomotion. Both pedaling and walking *propulsion* are dominated by sagittal-plane mechanics involving flexion-extension alternation of the legs at similar cyclic rates. Pedaling is ideal for experimental study because, in contrast to walking, balance and level of body weight support can be easily controlled. Moreover, bilateral lower limb coordination mechanisms difficult to study in walking can be found in pedaling using a split-axle pedaling ergometer with computer-controlled servomotors connected to each crank. Computer simulations are generated from pedaling models and experimental data to understand intra- and inter-limb muscle coordination, such as the role of each muscle in accelerating the body segments. Four pedaling experiments on 60 neurologically healthy subjects, along with computer simulations, have been completed and neuromotor control strategies identified.

Results: Basically, two-legged backward or forward pedaling is achieved by coordinating muscles to cyclically execute six biomechanical functions, organized antagonistically (flexor-extensor, anterior/posterior, plantarflexor/dorsiflexor). In one-legged pedaling tasks, the coordination of these functions is different, even when the loading is identical to the loading experienced during two-legged pedaling. The two-legged coordination pattern is restored when the contralateral leg generates rhythmic force and is moved antiphase to the ipsilateral leg. Our results suggest that excitatory and/or inhibitory interlimb influences operate between a biomechanical function and it's antagonistic function in the contralateral leg.

Conclusions: The neural control strategy to execute pedaling, a complex lower limb motor task, depends on the sensorimotor state of the contralateral limb. Bilateral coordination of muscles is believed to result in robust control, e.g., to assure alternation of the limbs. Also, the control of each muscle is quite simple and depends on its ability to contribute to the execution of the biomechanical functions. These conclusions form the basis for an approach toward understanding changes in sensorimotor state that occur post-stroke. Computer simulations of unimpaired walking are now being used to assess how applicable these control strategies are to walking.

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OTHER

Abstract
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CHANGE IN FUNCTIONAL NEUROANATOMY AFTER SUCCESSFUL TREATMENT OF PHONOLOGICAL ALEXIA

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Objective: Regional cerebral blood flow (CBF) was measured in a patient, GK, with phonological alexia before and after successful therapy (Auditory Discrimination in Depth; ADD) given more than 1 year post stroke.

Methods: The patient underwent SPECT studies prior to the initiation of the treatment protocol and again after the successful treatment protocol was completed. During the initial study, the patient performed a linguistic task (reading nonwords) after infusion of a CBF tracer which was imaged with SPECT. The SPECT study was subsequently repeated twice after treatment to assess changes associated with remediation of alexia. During one of the subsequent scans the patient was infused during the same linguistic task performed on the initial scan and during a third scan the patient was infused while performing a nonlinguistic comparison task.

Conclusion: Before ADD, the right hemisphere was inactive during nonword reading relative to the nonlinguistic task. After treatment, nonword reading increased CBF in right perisylvian cortex, homologous to dominant hemisphere areas involved in language processing. Results indicate that rehabilitating alexia may entail recruitment of nondominant networks.

Funding Acknowledgement: : This work was supported in part by a grant to Dr. Nadeau by the University of Florida Foundation.

Relevance: This work adds to the growing body of evidence that the opposing hemisphere may be recruited to support recovery as the result of treatment.

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PRELIMINARY EVIDENCE OF CORTICAL REORGANIZATION OF LEXICAL PROCESSING IN APHASIA: A SINGLE SUBJECT, WHOLE BRAIN fMRI STUDY

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Objective: The physiological mechanisms underlying recovery of language after left hemisphere damage are not well understood. Some studies have suggested that regions in the right hemisphere may support this recovery (Weiller *et al.*, 1995). Using fMRI, we examined the pattern of activation in a word generation task to explore this hypothesis.

Methods: *Subject:* A 49 year old, right handed man was examined 6 months after a large left MCA territory infarction. At this time he demonstrated a moderate nonfluent aphasia with good comprehension. *Task:* During 17.5s periods, the subject heard a category name (e.g. tree) and silently generated as many exemplars as he could (e.g. maple). The subject completed 6.4 rest and word generation cycles. *Image Acquisition:* Images were obtained using a 1.5 Tesla GE Signa with a 2-spiral gradient echo scan with 22 contiguous sagittal 6.0 mm thick slices; 180 mm FOV; TR/TE/FA = 1740ms/40ms/70deg; temporal resolution = 3.48 s. *Image Analysis:* Functional images were overlaid onto high-resolution anatomic images obtained with a 3D-SPGR sequence (TR/TE/FA = 27ms/7ms/45deg); FOV = 240 mm; 256 x 192 x 124 matrix; voxel size = 0.94 x 0.94 x 1.3 mm. Significantly active voxels (r>.50) were visualized using the AFNI package (Cox, 1996).

Conclusion: The mean volume of activation in the right hemisphere was larger than that which occurred in the left hemisphere. These asymmetries may be related to reduced activation of the left hemisphere because of injury or evidence that the right hemisphere may be important in the recovery of language.

Funding Acknowledgement: This research was supported by a VA Medical Research Service, the National Institute on Deafness and other Communicative Disorders of the NIH, and the Research Service, No Florida/So Georgia Veterans Health System.

Relevance: While preliminary, the ability to depict task related activation for single subjects, provides a tool for future exploration of the specific pathways which are engaged during the recovery of function after neurological injury. Additionally specific modifications of the experimental paradigm were developed which permitted the testing of an aphasic subject in the loud and distracting environment of the MR scanner. These emerging developments create the possibility of monitoring either the natural course of recovery or the specific effects of treatment for veterans who experience language dysfunction after neurological injury. Therefore the *in vivo* differential effects of either pharmacological or behavior treatment can be assessed, which will compliment existing experimental paradigms with the RR&D Brain Rehabilitation Center.

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DOPAMINE AGONIST THERAPY WORSENS MOTOR-INTENTIONAL NEGLECT

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Objective: In animals, removing ascending dopamine input produces a syndrome analogous to unilateral neglect in humans. Studies report bromocriptine can improve neglect in animals and humans. As dopamine deficit reduces intention to act, we suspected that bromocriptine would improve deficient hemispatial attention. Therefore the objective of this study was to determine the effect of bromocriptine, a dopamine agonist, on line bisection in a patient with neglect primarily due to failure of the attention-intention system.

Methods: DB, 58, with a right ICA stroke involving MCA territory and subcortical structures including the striatum, bisected lines under two conditions of video monitoring: visual right and left space congruent with body right/left (direct condition) and visual right/left dissociated from body right/left (indirect condition). Bromocriptine was started, increased to 20 mg/day over a two-week period, and he was retested. Bromocriptine was tapered to off for a third session two weeks following.

Results: DB exhibited a “pure” intentional bias to the right in all three sessions. Performance was worse on bromocriptine and improved when bromocriptine was stopped ($p<.01$). However, strength, tactile extinction to double simultaneous stimulation and emotional prosody either did not change or improved.

Conclusions: Bromocriptine may worsen neglect when putamenal receptors are damaged because dopamine agonists activate the normal hemisphere and increase the intentional bias.

Funding Acknowledgement: Portions of this project were funded by a grant to Heilman from the Medical Research Service, Department of Veterans Affairs.

Relevance: Group studies of bromocriptine or other dopamine agonists in neglect, with placebo controls and characterization of the anatomy and neglect syndrome of each patient, are needed in order to clarify the role of dopaminergic drugs in treatment of this disorder.

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COGNITIVE RETRAINING IN SCHIZOPHRENIA: PRELIMINARY FINDINGS

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Objectives: Results on the first 6 subjects with schizophrenia who completed 40 or more cognitive retraining session are presented including their individual training performances and pre-post neuropsychological testing results. Neuropsychological testing results are compared with a match sample of 6 subjects from our work rehabilitation program.

Methods: Subjects were invited to participate in a randomized study of the rehabilitative effects of work therapy combined with cognitive retraining compared with work therapy alone. Subjects in the cognitive retraining condition participated in multiple training sessions each week using 5 computer based attention and memory tasks of progressively increasing difficulty. A weekly social information processing group was also a part of their training. All subjects were placed in a work therapy program similar to Incentive Therapy which provides entry level work activity in a variety of placements for up to 20 hours per week. Subjects were paid $3.40 per hour for productive activity including participation in cognitive training. Comprehensive neuropsychological testing was performed pre-post the six months of active intervention. Subjects presented in this report were the first to reach follow-up who also had 40 or more sessions of cognitive training. A comparison group comprised on subjects in the Work Only condition was matched for IQ and hours of work activity.

Results: Subjects varied in their response to training. While all 6 subjects improved in at least two of the 5 computer based training tasks, most subjects improved on attention, dichotic listening and digit recall tasks while only 1 out of 6 improved on a serial word position recall task. Paired *t*-test showed significant improvement on relevant neuropsychological testing including the WAIS-III Digit Span ($p<.001$), Wisconsin Card Sorting Task Perseverative Error ($p < .025$), and the Thought Disorder Score on the Gorhams Proverb Task ($p < .025$). ANCOVA revealed significant differences ($p < .01$) between the cognitive training condition and those in the Work Only condition on all three tasks.

Conclusions: Preliminary results support the hypothesis that cognitive retraining in schizophrenia can lead to improved performance on training tasks and improved performance on related but different neuropsychological testing tasks. Subjects in the control condition did not improve on pre-post neuropsychological testing despite their participation in work therapy. It appears that cognitive retraining conferred specific neuropsychological benefits that could not be obtained from non-specific features of rehabilitation activity.

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COGNITIVE THERAPY MATERIALS ADAPTED FOR DEPRESSED, VISUALLY IMPAIRED/BLIND PERSONS

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Objectives: The primary objective of this project was to make prototype patient cognitive therapy materials, that were not visually impaired friendly, suitable for people with vision problems.

Methods: Cognitive therapy includes a large educational, skills training component that involves forms for monitoring activities and feeling between sessions. Methodologies using tape recorders, a combination of braille and tape recorders, large print, and computer diskette make monitoring and other practice forms accessible to persons with visual impairments.

Results: Protype patient cognitive therapy materials have been developed for people with vision problems.

Conclusions: It is possible to adapt cognitive therapy materials to be appropriate for visually impaired persons. These adaptations allow persons with vision impairments to participate fully in cognitive therapy for depression.

Funding Acknowledgement: This project was a developmental activity funded by the Atlanta VA Rehabilitation Research and Development Center (# 998).

Clinical Relevance And Future Research: Prior research has suggested that treatment of depression may decrease disability associated with impaired vision over and beyond the disability created by the visual impairment alone. Depression impacts not only on the psychological adjustment to loss of vision, but, also, on the person's likelihood to choose to participate in rehabilitation and to remain motivated long enough to effectively participate in the learning process necessary to make rehabilitation strategies and tools a useful and comfortable part of their lives. The current project allows persons with visual impairments to participate, fully, in cognitive therapy as a treatment for depression. Future, possible research includes development of a brief therapy program, and pilot and clinical trials for evaluating the effectiveness of these materials with depressed, visually impaired persons, and to evaluate the impact of such treatment on rehabilitation outcomes.

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QUALITY OF LIFE BENEFITS OF WORK REHABILATATION IN SCHIZOPHRNEIA: A LONGITUDINAL ANALSYSIS

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Objective: The two main objectives of this study were: (1) to determine if randomization into a paid work rehabilitation program produced greater quality of life benefits than unpaid work rehabilitation and (2) to determine if hours of participation in a work rehabilitation program were related to quality of life benefits.

Method: One hundred fourteen (114) participants with schizophrenia or schizoaffective disorder were randomized into either the Pay or No Pay condition of a work rehabilitation program to determine the impact of work activity and pay on rehabilitation outcomes. Quality of Life assessments were conducted monthly for a six month period, including one assessment before active program participation.

Results: Randomization to the Pay condition improved ratings on the Heinrich's Quality of Life Scale (QLS). The improvements are found both in overall QLS and more specifically in the domain of Intrapsychic Foundations (motivation, sense of purpose, anhedonia, and empathy.) Amount of participation was related to improvement on the QLS total and Intrapsychic Foundations domain. Improvement in the Interpersonal Foundations scale was positively correlated with weeks of participation for the most consistent participants.

Conclusions: Compensated participation in vocational programs improve quality of life, particularly in the areas of motivation, enjoyment of life and overall sense of purpose.

Clinical relevance: This report indicates that compensated vocational programming is strongly related to improvements in quality of life for people with severe mental illness.

Funding Acknowledgement: This research is funded by The Department of Veteran's Affairs, Rehabilitation Research and Development Office.

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PARTIAL BODY WEIGHT SUPPORT USING AIR PRESSURE: SAFETY AND UNLOADING

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Introduction: Many different forms of gait training with body weight support (canes, therapeutic pools, and overhead harness systems) have been used to restore ambulation in different patient populations. A novel system has been designed to provide supported walking using air pressure. The system consists of a treadmill enclosed in a flexible bag. A subject is positioned on the treadmill and the bag is sealed at waist level, enclosing the lower body in an airtight chamber. . Air pressure in the chamber is increased below the waist relative to above the waist. The differential pressure creates a buoyant force.

Objective: The overall objective is to determine the physiological effects of walking in the system and to characterize the relationship between intra-chamber pressure, body size and reduction of ground reaction forces.

Methods: Ten subjects with stable cardiac, vascular and/or respiratory disorders were tested to examine the physiological response to walking with differential pressure compared to walking without differential pressure. An additional ten subjects reflecting a wide spectrum of body weight, height and waist girth were tested to determine the relationship between system pressure, anthropometric characteristics and ground reaction force reduction.

Results: All subjects were able to complete the entire testing session without adverse effects. When comparing time and subject matched vital signs while walking with no air pressure to walking with maximal air pressure support, no significant differences were seen in heart rate, mean arterial pressure, respiratory rate, oxygen saturation or limb circumference. All subjects comfortably tolerated the intra-chamber pressures needed to support up to 75% of body weight (0.68 - 1.07 psi). Height was shown to be the most significant predictor of the pressure needed to determine body weight support. Ground reaction forces decreased with increasing intra-chamber pressure.

Conclusions: Walking with air pressure support was subjectively comfortable and appears to be safe for subjects tested with medically stable cardiac, vascular and respiratory disorders. Intra-chamber pressures of less than 1.1 psi provided up to 75% body weight support with concomitant reduction in ground reaction force.

Funding Acknowledgement: VA Merit Review (A2070-RA)

Clinical Relevance, Future Research: Aging veterans and the rest of the aging population are at an increased risk for mobility impairments. Developing more effective rehabilitation techniques for treating gait dysfunction may reduce hospitalization and improve functional outcomes. Currently, subjects with hemiplegia are being studied to determine the potential to improve functional walking ability and gait mechanics using this system.

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EXCURSION AND STROKE FREQUENCY DIFFERENCES BETWEEN MANUAL WHEELCHAIR PROPULSION AND POWER ASSISTED MANUAL WHEELCHAIR PROPULSION

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Objectives: The objective of this study was to collect and compare kinematic data from wheelchair users while performing wheelchair propulsion in their own manual wheelchair and in a power assisted manual wheelchair (Yamaha JWII wheel).

Research Plan: Subjects were recruited from a large subject pool and tested in a random order repeated measures design.

Methods: Nine manual wheelchair users were tested for excursion of the right, third metacarpophalangeal (MP) joint in the sagittal plane during wheelchair propulsion on a dynamometer at a resistance of 300 Ohms and a speed of 2 mph. Kinematic data was collected during the last 30 seconds of a three minute trial using an Optotrak 3-D motion sensor system (Northern Digital). Kinematic data was analyzed utilizing a custom made MatLab (The Mathworks Inc.) program. The same custom program also allowed for analysis of stroke frequency.

Findings: Paired samples t-tests revealed significant decreases in the amount of excursion of the right, third MP joint in both the x-direction ($p<0.05$) and y-direction ($p<0.05$) while propelling the power assisted wheelchair. However, no significant differences were found for stoke frequency between propulsion of the subjects' own wheelchair and the power assisted wheelchair.

Clinical Relevance: Although right, third MP joint data was analyzed, inference to the kinetic chain of the wrist, elbow, and shoulder may be made. The decreased range of motion (ROM) evidenced in this study suggests that the use of the power assist wheel may decrease repetitive strain injuries caused by excessive ROM at the wrist, elbow, and shoulder during wheelchair propulsion.

Funding Acknowledgement: Funding for this study was provided by: Yamaha Motor Corporation, USA and the Department of Veterans Affairs, Pittsburgh Healthcare System.

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USE OF NONSYMBOLIC GESTURES OF THE LEFT HAND TO ENHANCE WORD FINDING OF NONFLUENT APHASIA

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Objective: Using functional magnetic resonance imaging (fMRI), we have recently shown in individual subjects that left medial frontal cortex is consistently involved in word generation (Crosson et al., 1999). The medial frontal areas that are involved are proximate to areas involved in both simple (supplementary motor area[SMA]) and complex (pre-SMA and adjacent Brodmann's area 32) motor activities (see Picard & Strick, 1996). Based on the literature on akinetic mutism, it is apparent that these medial frontal areas are involved in language initiation. In a single subject with nonfluent aphasia, we have demonstrated with fMRI that language production mechanisms shifted from damaged left-hemisphere cortex to homologous right-hemisphere areas, while initiation mechanisms remained in undamaged left medial frontal cortex. We have wondered if this mismatch between the hemispheres of language production and language initiation mechanisms could impede word finding. A number of past studies have shown that naming can be improved in patients with motor programming problems when American Indian Sign Language (AmerInd) gestures are learned with the left hand and then performed simultaneously with oral picture naming. Neither learning AmerInd alone nor practicing oral naming alone improved naming performance (Hoodin & Thompson, 1983; Kearns et al., 1982; Pashek, 1998). It has bee presumed that the symbolic nature of AmerInd is crucial to improving naming performance. However, it is also possible that performing complex movements with the left hand "primes" initiation mechanisms in the right medial frontal cortex without respect to the symbolic nature of the movement. This priming may make it possible for those right-hemisphere mechanisms to become dominant in attempts at language initiation. In other words, the success of the treatment may depend upon engaging right-hemisphere initiation mechanisms in the service of initiating word finding and word production processes.

Methods: We have developed a treatment that relies upon performance of a complex, nonsymbolic movement with the left hand simultaneously with attempts to name pictures. Using within subject experimental designs, this treatment has been administered to one patient with primarily motor programming deficits, to another patient with a moderate to severe Broca's aphasia, and to a third patient with a mild to moderate Broca's aphasia.

Conclusions: When compared to their established stable baseline performances, all patients have shown significant improvement in response to the treatment protocol
Funding Acknowledgement: This work was funded by a grant from the Brooks Health Foundation to Drs. Crosson and Rothi.

Relevance: The next step in our treatment research is to ascertain that the complex movement is indeed the active component of treatment.

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A METHOD FOR CHARACTERIZING A WHEELCHAIR DYNAMOMETER

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Objective: Dynamometers are used in numerous studies to simulate wheelchair propulsion and to record real-time kinetic and kinematic data. Most studies, however, do not provide a full characterization of the dynamometer. Therefore, there is a need to dynamically determine the inertia (J), viscous friction coefficient (B) and coulomb friction (T_L) of the roller/motor system, as well as the torque constant (K_i), the back-emf constant (K_b) and the armature resistance (R_a) of the motor. The purpose of this study was to describe and validate a dynamic method for characterizing a wheelchair dynamometer.

Methods: Our dynamometer consists of two independent rollers connected to two motors through gears and a timing belt. A dc-motor model was chosen to represent the roller/motor assembly [Kuo, BJ, Automatic Control Systems, 1991]. The system inputs are the power supply voltage (E_a) and T_L. The system outputs are the motor speed (Ω_m) and the torque about the motor arm (T_e). The equations used to model the dynamometer assume step inputs for E_a and T_L. 10 trials with a step voltage input of 10V, 15V, and 20V, respectively, were completed for a total of 60 trials (30 on each side). A step voltage input was selected, as opposed to a polynomial or sinusoidal input, since it can be easily applied without computer control of the power supply. Therefore, this methodology can be applied in clinical as well as research settings. Initial estimates of the parameters were determined using linear regressions of the transient and steady-state responses independently. Finally, a modified Gauss-Newton Nonlinear Regression was performed [Gallant, AR, Nonlinear Statistical Models, 1987] which allowed for the inclusion of the entire trial (not just the steady-state or transient response) in the regression and the calculation of a 95% confidence interval for each parameter.

Results: The results of the calculated parameter are listed in the following table. J, B, and T_L are reflected at the motor arm.

	B (kg-m^2/s)	J (kg-m^2)	K_b (V-s/rad)	K_i (N-m/A)	R_a (Ohm)	T_L (N-m)
Left	0.00161	0.0966	0.2773	0.2773	0.703	0.213
Right	0.00254	0.0947	0.2680	0.2680	0.727	0.237

The nonlinear regression coefficient of determination, r^2, is greater than 0.9997 for both the left and right sides. The 95% confidence interval, using a t-test, does not affect any of the parameters until the third significant digit.

Conclusion: The methodology described allows researchers and clinicians to quantifiably describe the characteristics of the dynamometer. This is important for comparison of kinematic and kinetic results and to allow for repeatability of previous studies. These parameters could have been calculated theoretically using the geometry of the roller system, or independently through other motor tests (e.g. stall torque test, no load test, load test). However, the dynamic method presented here is more appropriate since it is similar to actual wheelchair propulsion. Finally, this method is very accurate as is seen with the coefficient of determination and the 95% confidence interval.

Acknowledgement: Partial funding was provided by the U.S. Department of Veterans Administration Affairs (Project B689-RA), the National Institutes of Health (NIH K08 HD01122-01) and the Paralyzed Veterans of America.

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VIDEOCOUNSELING FOR PATIENTS WITH SEIZURE DISORDERS: FIRST WAVE RESULTS WITH RURAL TEENS

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Objectives: The primary objectives of our project are to: (a) evaluate the differential impact of home-based videosystem, speakerphone, and office-based family counseling on the educational and social functioning of rural at-risk adolescents with seizure disorders, and (b) assess the effects of these three counseling modalities on the therapeutic relationship between family member and counselor, adherence to intervention, and overall treatment costs.

Methods: 39 adolescents with epilepsy and their parents were randomly assigned to either (a) 6 sessions of home-based, videosystem's family counseling, (b) 6 sessions of office-based family counseling, or (c) a waiting list control group. In addition, families in the home videoconferencing condition who did not have access to digital service were offered speakerphone counseling. The differential effects of these counseling interventions on outcome were assessed one week after the 6-session counseling program, and 6 months following treatment.

Results: Twenty-two families completed the six-session counseling program. Twelve families dropped out before the first assessment session and 5 families dropped out after the initial assessment session. Dropout was differentially associated with office counseling that required long distance travel. Adolescent and parents reported significant improvement in identified family problems across all three modalities from pre- to one-week posttreatment and from pretreatment to the 6-month follow-up. Furthermore, parents and teachers reported significant reductions in problem behaviors at home and at school from pre- to the one-week posttreatment to the six-month follow-up. Adolescent and parents reported moderately high and equivalent therapeutic alliance across all three modalities. Contrary to prediction, no substantial differences were found across conditions on completion of therapy homework assignments and number of missed appointments. speakerphone, and office-based counseling for rural families. Last, the per family costs for videosystem, speakerphone and office counseling were $2,400, $700, and $2,100, respectively.

Conclusion: Although our findings are only preliminary, mode of service delivery did not appear to influence treatment outcomes. The findings on adherence to intervention and cost-effectiveness should be interpreted cautiously as a result of differential dropout in the office condition and current martketplace trends.

Funding Source: National Institute on Disability and Rehabilitation Research

Future Directions: We plan to expand the scope of telehealth interventions and disabled populations in future research endeavors, in particular, cognitive rehabilitation for veterans with neurological disabilities (i.e., stroke and dementia).

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SURVEY AND ANALYSIS OF INTELLECTUAL PROPERTY

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Objectives: To understand the depth and breadth of the Intellectual Property (IP) developments in the diverse Functional Electrical Stimulation research program in Cleveland in order to establish a plan for identifying individual disclosures, protectable matters, and properties with clinical and/or economic value.

Methods: An interview survey questionnaire was developed to guide a series of one-on-one interviews with research program participants. Investigators, staff, and students from all of the institutional partners comprising the Cleveland FES Center were included in the subject population. Copies of the questionnaire were distributed in advance of scheduled interview times to enable data gathering in response to individual items. An independent research assistant was recruited to lead or conduct all interviews, with all personal interviews audio recorded. Individual reports were developed from each personal interview. Where identified, individuals were listed for follow-up to complete disclosures or to assist in the evaluation of identified properties.

Results: The interview phase of the survey was conducted through the Fall of 1999. The results have been identified as both primary and secondary effects. The primary data includes a clearer definition of the areas of IP development within the program and have been used to assist in directing technology transfer resources. The second effect has been seen primarily in the development of a greater awareness of the value of IP to the program and in the value in transferring innovative concepts from research into wide spread clinical use. Several IP properties that were placed in the public domain were also identified.

Conclusions: The survey/interview technique has proven an effective means of developing a definition of the Intellectual Property component of a diverse research program. The utilization of a written survey instrument kept the interviews targeted while insuring that sufficient information was gathered from each individual to assess their contributions, concepts and ideas, and the potential ownership issues involved for each property. The personal interview technique also proved useful as an educational tool and to increase the awareness of technology transfer opportunities.

Funding Acknowledgement: This work was funded by the Department of Veterans Affairs, Rehabilitation Research and Development Service through the RR&D Center at Cleveland Ohio.

Emphasize clinical relevance, implications for the Veteran population and for future research: Funding for research programs is an increasingly competitive venture. As the demands for effective end-use clinical results and end-user impact are rising, it is critical for research programs to develop efficient mechanisms to identify and transfer their developments into wide-spread clinical use. An active technology transfer program, augmented by periodic surveys such as this one, provide the opportunity to insure that Rehabilitation Research makes the transition “from bench to bedside”.

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WRIST FLEXOR MUSCLE ACTIVITY DURING WHEELCHAIR PROPULSION

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Objective: Propelling a manual wheelchair may play a significant role in the development of wrist pain and injury. In one study, 74% of a group of 31 individuals with paraplegia complained of clinical symptoms related to carpal tunnel syndrome (CTS) in at least one hand (Davidoff, 1991). CTS may result from the repetitive application of high forces, extremes of wrist range of motion and/or concurrent wrist flexor activity experienced while pushing a wheelchair. The purpose of this study was to use surface electromyography (sEMG) to describe the activity of wrist flexor muscles: flexor carpi radialis (FCR), finger flexors (FF), and the flexor carpi ulnaris (FCU) during wheelchair propulsion.

Methods: Nine unimpaired subjects (mean age 29 $\pm$ 7.4 years) provided informed consent prior to participation in this study. Surface biopolar electrodes were positioned on the right wrist flexor muscles as described by Basmajian *et al*. (Basmajian, 1980). Subjects propelled at a constant 0.9 m/s (2 mph) while seated in a Quickie GP wheelchair that was secured to a wheelchair roller system. Dynamic EMG (Noraxon, Inc.) data were collected for 20 seconds at the end of a one minute propulsion period. EMG data were normalized to EMG peak signals obtained during a maximum contraction test (%MAX). During this test, the subjects first grasped onto the pushrim, then flexed, and then deviated the wrist in both the radial and ulnar directions while maintaining flexion.

Results: All variables were determined for the first five strokes and averaged . A repeated-measures ANOVA test resulted in a significant difference between the mean propulsive peak ($p=0.018$) and average ($p=0.008$) activity level of the wrist flexor muscles as well as the duration ($p=0.003$) of activity measured as a percentage of the push phase. A Bonferroni post-hoc analysis showed that at the 0.05 α-level, the FCR peak mean activity and duration (29.1%MAX and 45.5%MAX, respectively) was significantly different than the other two muscle groups. Also, mean FF activity (peak and average values: 62.3%MAX and 36.6%MAX, respectively) and duration (67%MAX) was greater during the push phase.

Conclusions: The extensive and long lasting activity of the FF suggests that wheelchair propulsion requires one to maintain wrist flexion and grasp on the pushrim long enough to deliver the force necessary to propel forward. The FF pass through the carpal tunnel and thickening of the flexor tendon sheaths is thought to contribute to CTS. Although the wrist has been shown to pass through extremes of radial and ulnar deviation during propulsion, the demand on the FCR and FCU muscles to produce the propulsive force does not appear to be great. Understanding wrist flexor activity may help identify who is at risk for developing CTS. The basic premise that wrist pain and injury can be reduced provides hope to veterans that long-term wheelchair use may not need to lead to further debilitation. Future studies will involve investigating wrist muscle activity in veterans with and without signs of CTS.

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A BIOACTIVE SCAFFOLD FOR BONE REPAIR

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Objectives: Revision total hip arthroplasties are complicated by massive bone loss of the proximal femur. Allograft is typically used to reconstruct the site. For long term fixation and function of the new prosthesis, it is desirable that the allograft becomes fully replaced by bone tissue and aids in the regeneration of bone to that site. Allograft typically displays delayed incorporation and poor remodeling. This problem is particularly significant in the Veterans' population, because many veterans have concomitant medical illnesses which have compromised their overall health with a negative impact on bone healing. A tissue engineering approach would be to combine osteogenic activity with a resorbable scaffold such that bone formation can be stimulated while providing structure and stability to the limb during scaffold incorporation and remodeling. We have developed a porous, surface modified bioactive scaffold. We investigated the rate of incorporation of the scaffold and two tissue engineered constructs, osteoprogenitor cells seeded onto scaffolds or cells expanded in culture to form bone tissue on the scaffold, in a long bone defect in the rat.

Methods: Porous, surface modified bioactive ceramic (specimens called pSMC), processed from 45S5 granules (45% SiO_2, 24.5% Na_2O, 24.5% CaO and 6% P_2O_5, in weight %), had a macroporosity and pore size range of 21% and 200-300□m, respectively. The ceramic was surface treated in a 2-step process to promote cellular attachment, growth and formation of a mineralized matrix. Rat bone marrow stromal cells were isolated from 4-5 week old Fisher 344 rats. After 8 days in culture, cells were seeded onto pSMC and allowed to attach for 2 hours prior to implantation (specimens called primary) or were expanded in culture for 14 days to form bone-like tissue on pSMC prior to implantation (specimens called hybrid). A unicortical window defect, 1.1mm width x 4.5mm length, was created bilaterally in the anterolateral femoral cortex of 96 adult, male syngeneic Fisher 344 rats (350-400g). Defects were treated randomly with pSMC, primary, hybrid, or left untreated (sham). The rate of incorporation was examined histomorphometrically and mechanically at 2, 4 and 12 weeks.

Results: Both the hybrid and primary constructs had comparable percent bone in the defect and were both significantly higher than pSMC alone at 2 weeks. The percent bone in the defect increased significantly over time for all treatment groups. By 12 weeks, there was a 40% increase in bone and a 40% reduction of the scaffold in the defect for all treatment groups. The ultimate torque and stiffness of long bones treated with the hybrid and primary constructs were comparable to intact bone by 4 weeks. Lone bones treated with pSMC alone demonstrated a return in normal torsional properties by 12 weeks.

Conclusions: Porous, surface modified bioactive ceramic is a promising scaffold for tissue engineered bone repair. Bone formation and scaffold resorption act in concert for maintenance and improvement of the mechanical properties of the long bones over time. Both tissue engineered constructs stimulated bone formation and mechanical repair of the long bones at comparable rates. Based on these findings, we are now addressing the efficacy of the tissue engineered scaffolds in a dog model closely mimicking hip revision surgery.

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PORTABLE AMBULATORY AND ACTIVITY MONITORING IN HEMIPARETIC STROKE PATIENTS

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Objectives: Stroke is a leading cause of disability in our aging veteran population, and residual hemiparesis the most common neurologic deficit persistently impairing functional mobility. Recovery of mobility following stroke is conventionally measured using standardized subject or observer rated instruments assessing ADL function. These methodologies do not quantify physical activity in the home/community setting, and often lack sensitivity in the mild-moderately impaired patient. In this preliminary study, we investigated the accuracy of a portable, beeper sized microprocessor-based step ambulatory monitor (SAM) and the reliability of belt-worn accelerometer recordings, as indirect measures of total home/community based physical activity levels in chronic hemiparetic stroke patients.

Methods: Subjects included six community dwelling stroke patients with chronic hemiparetic gait deficits (>6 months) requiring unilateral assistive device (N=6, cane or quad cane) and ankle-foot orthoses (N=3). Accuracy of SAM device determined step counts versus visually counted steps (two observers) was directly determined in all patients with the SAM attached by elastic stocking on the non-paretic ankle while patients ambulated using their usual assistive device/orthoses during a three minute timed floor walk at self-selected pace. Test-retest of home/community based total activity by one-dimensional accelerometer recordings using Caltrac was evaluated across three separate 48-hour weekday recording epochs conducted within a three week period in five patients. All patients had long since completed conventional physical therapy, and were considered neurologically plateaued in mobility recovery at the time of testing.

Results: SAM determined step counts were 99 % accurate (N=6, $r = 0.99$, $p<0.001$) compared to visually determined step counts in all patients tested. Accelerometer derived home/community-based activity measures for these older hemiparetic stroke patients (age, 67 ± 3, mean ± SD) revealed only 397 ± 210 Kilocalories/day energy expenditure. Analysis from triplicate 48 hour recordings revealed a high test-retest value ($r = 0.81$) for accelerometer based activity recordings in these patients.

Conclusions: The SAM device accurately measures ambulatory activity and cadence, and portable unidirectional accelerometers reliably estimate the total daily energy expenditure from physical activity in hemiparetic stroke patients with mild-moderate gait deficits. Stroke patients are sedentary.

Implications: These preliminary findings suggest that personal status monitoring devices offer the potential for reliable and valid measurement of home/community based ambulatory function and energy expenditure of physical activity following stroke. Further evaluation is warranted to investigate their utility as rehabilitation outcomes instruments, and as adjuncts providing vital information for determining whether patients are in compliance with NIH and Surgeon General recommendations promoting daily physical activity to optimize cardiovascular health and fitness.

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SUBJECTIVE FATIGUE: A MISSING PIECE IN THE REHABILITATION PROCESS

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Although fatigue is very common among patients undergoing rehabilitation, research in the rehabilitation field has thus far been limited to examining central and peripheral fatigue. Rehabilitation professionals have not examined the subjective experience of fatigue. Fatigue is known to disrupt usual life activities and decrease patients' quality of life. While it is important for health care professionals to assess quality of life issues, such as fatigue, it is imperative that we do so in a parsimonious manner so as to avoid overburdening patients.

Purpose: The objective of this study was to test a new measure of fatigue, the Bruner Fatigue Scale, and compare it to the more established Piper Fatigue Scale. The Bruner scale offers the advantage of having approximately half the number of items as the Piper scale. The study sample consists of patients receiving radiotherapy for prostate cancer, but the measures would be applicable to a variety of patients experiencing varying levels of fatigue.

Methods: Forty-six patients receiving radiotherapy for localized prostate cancer at the Houston VAMC completed the Piper Fatigue Scale and the Bruner Fatigue Scale prior to radiotherapy, during the middle of radiotherapy, upon completing a 7-8 week course of radiotherapy, and at a follow-up appointment 4-5 weeks after radiotherapy ended.

Results: The Bruner Fatigue Scale demonstrated adequate internal consistency across all four times of testing (Cronbach's coefficient alphas ranged from .82-.91). The Bruner Fatigue Scale was highly correlated with the Piper Fatigue Scale across all four times of testing (Pearson *r*'s ranged from .75-.85). Correlations between the Bruner Fatigue Scale and the Beck Depression Inventory, BDI, (*r*'s ranged from .65-.74 across the four assessments) were similar to correlations between the Piper Fatigue Scale and the BDI (*r*'s ranged from .61-.70). Finally, using repeated measures analysis of variance, a significant within-subjects effect was found with both the Bruner Fatigue Scale ($\underline{F} = 2.83$, $p < .05$) and the Piper Fatigue Scale ($\underline{F} = 6.78$, $p < .01$). Both measures detected a significant quadratic pattern in fatigue over time, indicating that fatigue increased significantly during radiation therapy and then dropped off by the 4-5 week follow-up appointment.

Conclusion: Preliminary evidence supports the utility of a new measure of fatigue, the Bruner Fatigue Scale, for use among patients with prostate cancer. The Bruner scale was highly correlated with the more established Piper Fatigue Scale and performed similarly in terms of its correlation with other measures and its ability to detect changes in fatigue during the course of radiotherapy.

Discussion: Given the relevance to quality of life, it is important for rehabilitation professionals to assess subjective aspects of fatigue among their patient populations. The two measures presented here both appear suitable for rehabilitation populations; the Bruner measure offers the additional advantage of brevity. Many veterans have physical impairments with concomitant fatigue. Assessment of veterans' subjective fatigue and incorporation of fatigue into rehabilitation treatment and treatment planning is important for improving veterans' quality of life.

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HEALTH-RELATED QUALITY OF LIFE FOR PEOPLE WITH COPD IN CALIFORNIA AND SCOTLAND

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Background: Health-related quality of life (HQOL) is multidimensional and subjective. HQOL differs between people with chronic obstructive pulmonary disease (COPD) and those with healthy lungs and may also be influenced by culture/environment. An earlier study by the authors validated a general HQOL model of 5 factors (Romney & Evans, 1996) for people with COPD in southern California. Subscales of the Short-Form-36 Health Survey (SF-36), a generic HQOL instrument, and the Chronic Respiratory Disease Questionnaire (CRQ), a disease-specific HQOL instrument were used. Biomedical predictors did determine psychosocial functioning. Symptoms (dyspnea or fatigue) were the strongest predictors of friendships and well-being. Pulmonary impairment (FEV_1% pred) alone predicted employment.

Objective: The study purpose was to examine if culture/environment impacts HQOL in people with chronic lung disease. The hypothesis was that differences in HQOL measures exist between patients with COPD in west of Scotland (rainfall/yr=38 inches, sunshine/yr = 1470 hrs) compared to southern California (rainfall/yr=10 inches, sunshine/yr = 3015 hrs).

Sample, Setting, Years: The convenience sample consisted of 27 southern California (X(sd)=67.2(9.9))years old, FEV1%pred = 35.7(14.7) subjects and 19 Glasgow, Scotland (63.4(9.3)) years old, FEV1%pred = 44.9 (22.3) subjects with COPD enrolled in an outpatient pulmonary rehabilitation program.

Methodolgy/Findings: Using independent-samples t-tests, fatigue, emotional function, and mastery CRQ subscales and the general health (GH) SF-36 subscale, were significantly different. The Glasgow sample reported more fatigue (t=-2.25, p=.03), lower emotional function (t=-2.32, p=.03), lower mastery (t=-2.20, p=0.03) and poorer evaluation of general health (t=2.99, p= 0.005). The t-tests also showed the five factors in the general HQOL model (symptoms, physiological impairment, friendships, well-being, physical role functioning) from the earlier study were not significantly different between the two groups. As a follow-up to tests for differences, regression analyses were used to assess the contribution of group toward prediction. The results were: (1) fatigue (F=5.063, R^2=.10, p=.029); (2) emotional function (F = 5.389, R^2 =.11, p=.025); (3) mastery (F=4.855, R^2=.10, p=.033; (4) general health (F=7.835, R^2=.15, p=.008).

Conclusions: These findings suggest culture/environment may influence measured HQOL in people with COPD. This speculation was supported with simple linear regressions. The geographical location predicted 10 -15% of the variance in each of the dependent variables that were significantly different between the two groups. The general HQOL factors were not significantly different between the two groups.

Implications: Further work should test a HQOL structural equation model that may be applicable to veterans with COPD.

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EVALUATING AN EXERCISE SYSTEM FOR WHEELCHAIR USERS

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Objectives: The purpose of this study was to investigate a system which allowed individuals in wheelchairs to control a computer video game with the forward and rearward propulsion of their wheelchair, and to examine whether subjects playing a video game, with the GAME^{WHEELS} system, can reach their predicted exercise training zone.

Methods: Nine individuals who used wheelchairs for their main source of mobility volunteered and gave written consent to test the system. The subjects' mean age was 34 $\pm$ 10.4 years old and 14 $\pm$ 10.7 years post SCI. Injury levels ranged from T 2-3 to L 2, in addition one had MS and one had CP. The individuals were tested for a twenty minute exercise period (2 minutes of warm-up, 16 minutes of exercise, 2 minutes of cool-down). The only verbal cues given to the individual were: 'warm-up is over exercise time' and 'cool-down time'. The individuals were instructed to exercise and try to reach their projected training zone, which was 60% of their predicted heart rate max. Oxygen consumption and heart rate (HR) were collected at 20 second intervals using a SensorMedic metabolic cart and a Polar heart rate monitor. A questionnaire was filled out after completing the trial. Following the trial, criteria of whether the individuals' reached their training zones was determined by 50% of their predicted VO_2 max along with 60% of their predicted heart rate max.

Results: All nine subjects were able to elevate their heart rate and oxygen consumption into their training zones. The mean HR and VO_2 values, over the 16 minutes of exercise, indicated all subjects were within their training zone for that time period. Seven of the nine subjects reported that the GAME^{WHEELS} system helped them to exercise and they enjoyed exercising with the system. All nine subjects reported that they thought the system would help other wheelchair users exercise longer or on a regular basis.

Conclusions: The system was effective at eliciting an exercise response. The individuals were motivated to exercise into their training zone, above the 50% and 60% of the predicted VO_2 and HR, respectively. This research could lead to the development of a system that might be used to help Veterans exercise and maintain a healthy lifestyle. Improving their health might help decrease health care costs.

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IPSILATERAL M1 IS NOT INVOLVED IN LONG-TERM RECOVERY OF DISTAL ARM MOVEMENTS AFTER A CONTRALATERAL M1 LESION

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In humans, considerable recovery of motor function can follow lesions of the primary motor cortex (M1) or its projections to the spinal cord. One possible mechanism for such recovery is involvement of M1 in the intact hemisphere, contralateral to the lesion and ipsilateral to the affected limb. We examined this possibility in a primate model of M1 damage. We used the ^{14}C-2-deoxyglucose (2DG) technique to map the functional activity in the cerebral cortex of monkeys who had recovered the ability to perform wrist movements after removal of M1. Two macaques were trained to perform step-tracking movements of the right wrist. The trained movements required 8 different combinations of flexion-extension and radial-ulnar deviation and 10-20° changes in joint angle. Then, the arm area of M1 in the left hemisphere was removed by subpial aspiration. Immediately after the surgery, both monkeys were hemiparetic. After 3.5-5 months of retraining the animals were again able to perform the task, although changes in movement kinematics and EMG were present (Hoffman & Strick, 1995). After a further 2-3 years of training, even these motor deficits were reduced. We then used conventional 2DG procedures to map the activity of the left and right hemispheres during performance of the task. In the right hemisphere, ipsilateral to the working wrist, 2DG uptake in the arm area of M1 was *not* greater than background (measured in the leg area of M1). In fact, the pattern of activation in ipsilateral M1 of the lesioned monkeys was indistinguishable from that of ipsilateral M1 of normal monkeys performing visually-guided arm movements. These results indicate that ipsilateral M1 is not responsible for the performance of distal arm movements that recover from an M1 lesion, at least in the long-term. Instead, preliminary observations suggest that recovery of motor function depends on the involvement of premotor areas in the hemisphere contralateral to the recovered limb. Studies in progress should indicate which of the premotor areas are essential. This information could be critical to attempts to rehabilitate stroke patients.

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CI THERAPY: A PLACEBO-CONTROLLED TRIAL OF CLINICAL EFFICACY FOR PATIENTS WITH CHRONIC STROKE

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Objectives: The purpose of the study was to determine in a placebo-controlled trial whether CI Therapy is an efficacious method for increasing the amount of use of the more-affected upper extremity in patients with chronic stroke.

Methods: The subjects were from the upper quartile of stroke survivors with residual motor deficit who were more than one-year post-stroke. The experimental group was given restraint of the less-affected hand in a protective safety mitt for a target of 90% of waking hours for two consecutive weeks and for the 10 weekdays during that period were given training (by shaping) of the more-affected upper extremity for 7 hr/day (including 1 hr. of rest). The placebo group was given a “general fitness” intervention involving walking, other lower extremity strength exercises and relaxation training. A pre-treatment expectancy questionnaire indicated it had as much face credibility for patients as the experimental treatment.

Results: The CI Therapy group showed a very large treatment effect both on a laboratory motor function test and in the actual amount of use of the more-affected extremity in the home environment over the treatment period and for one year afterward. The placebo-control group exhibited no change or a small decline over same period. At the one-year time point the placebo group was crossed over to CI Therapy and then showed a very strong treatment effect.

Conclusion: CI Therapy is a new neurorehabilitation technique that produces large improvements in motor ability in patients with chronic stroke. Since CVA is becoming increasingly prevalent in the aging population of WWII and Korean War veterans, CI Therapy has strong and increasing relevance to the VA mission.

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FATIGUE LIFE ANALYSIS OF MANUAL WHEELCHAIRS

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Objectives: The purpose of this study was to determine the most common fatigue failure points for manual wheelchairs. It was also determined whether there was a significant difference in the number of cycles until failure between the different types of failures.

Methods: Over the past 5 years, the Human Engineering Research Labs have tested a total of 49 manual wheelchairs to failure using the 2-drum and curb drop tests as described in the ANSI/RESNA Wheelchair Standards. The results were grouped according to the specific failure area. Statistical analysis (ANOVA) was performed on the data to determine any differences in overall cycles until failure.

Results: Of the 49 wheelchairs tested; 43% experienced frame failures at the seat/backrest joint, 33% of the wheelchairs experienced some sort of caster failure, 14% failed at the front of the frame, and 10% of the wheelchairs failed at the cross brace. Table 1 lists the average number of cycles until failure for each class.

Area of Failure	Average # of Cycles Until Failure
Seat/Backrest Failure	230,186 ± 79,368
Caster Failure	614,972 ± 295,123
Front Failure	808,986 ± 122,756
Cross Brace Failure	258,918 ± 177,909

There were significant differences in the number of cycles until failure between the different groups ($p < .05$). Specifically, failures that occurred at the front of the frame transpired after a significantly higher number of total cycles than failures occurring at the cross brace. Also, failures that occurred at the casters did so after a significantly higher number of total cycles than failures occurring at the seat/backrest interface.

Conclusions: The results of this study help identify the major areas of failure for manual wheelchairs. The failures occur at parts of the wheelchairs that experience the largest repetitive stresses, like the seat/backrest interface and casters. Stress cracks are often visible before catastrophic failure. This information can help educate wheelchair users about how to inspect their wheelchairs and possibly prevent serious injury or inconvenience from failures. Companies and developers may also find the information useful in determining how to design better and longer lasting manual wheelchairs.

Acknowledgements: This study was supported in part by the US Department of Veteran Affairs, the Paralyzed Veterans of America, and the Eastern Paralyzed Veterans of America.

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TREATMENT OF A CASE OF PHONOLOGICAL ALEXIA WITH AGRAPHIA USING THE AUDITORY DISCRIMINATION IN DEPTH (ADD) PROGRAM.

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Objectives: Phonological alexia and agraphia are acquired disorders characterized by an impaired ability to convert graphemes to phonemes (alexia) or phonemes to graphemes (agraphia). These disorders result in phonological errors typified by adding, omitting, shifting, or repeating phonemes in words during reading or graphemes when spelling. In developmental dyslexia, similar phonological errors are believed to result from deficient phonological awareness, an oral language skill that manifests itself in the ability to notice, think about, or manipulate the individual sounds in words. The Auditory Discrimination in Depth (ADD) program has been reported to train phonological awareness in developmental dyslexia and dysgraphia. The purpose of this study was to learn if we could treat a patient, GK, with acquired phonological alexia and mixed agraphia using the ADD program.

Methods: We used a multiple-probe single subject experimental design to evaluate the ADD program's effectiveness with GK who displayed a mild phonological alexia and mixed agraphia (as well as a mild conduction aphasia) following a left hemisphere infarction 15 months prior to treatment onset.

Results: After completion of 101.1 hours of ADD treatment, large gains (to near normal levels of performance) in phonological awareness, reading and spelling of nonwords, and reading and spelling of real words were demonstrated. Monitoring of unrelated behaviors during the treatment interval supported the suggestion that changes in performance on tasks of reading and spelling of nonwords and real words noted above were the result of the intervention. A follow-up reassessment, 2 months posttreatment, found that GK had maintained treatment gains in phonological awareness and reading, and attained additional improvement in real word reading.

Conclusions: In this case of acquired phonological alexia and conduction aphasia, improved phonological awareness as the result of ADD treatment was associated with dramatic improvements in reading and spelling.

Funding Acknowledgement: This work was supported in part by grants to Drs. Rothi, Heilman, and Crosson from the National Institutes of Health and by a grant to Dr. Heilman from the Medical Research Service of the Department of Veterans Affairs.

Relevance: This study supports the use of the ADD program in cases of phonological alexia.

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INTRAMUSCULAR FUNCTIONAL NEUROMUSCULAR STIMULATION (FNS-IM) TREATMENT OF IMPAIRED GAIT IN CHRONIC STROKE PATIENTS

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Background: Stroke is the third leading cause of disability for adults in the United States. There are 500,000 individuals each year who suffer a new stroke and 1,000,000 individuals in the United States are suffering with residual disabilities from strokes. To date, rehabilitation techniques have not proven sufficient to restore normal, safe, gait for many individuals with stroke. FNS-IM is an experimental rehabilitation technique that directly stimulates muscles under computer control to produce functional activity. FNS-IM has been used for 10 years for rehabilitating spinal cord injured patients, but FNS-IM has not been used extensively for gait rehabilitation of stroke patients.

Methods: We studied 8 gait-impaired patients 1 year after stroke onset, which is beyond the time when patients spontaneously recover function. Patients were treated sequentially with conventional rehabilitation (CR) followed by FNS-IM, with each technique applied until a patient achieved a maximum benefit. Patients reached a plateau for lower extremity motor function within 3 months of CR treatment. FNS-IM was applied to 8 paretic lower extremity muscles. With FNS-IM, patients reached a stable plateau within 6- 8 months. FNS electrodes were removed at the end of FNS-IM gait training. Patients were examined at 6 months after electrode removal. Outcome measures (done with FNS off) included kinematics of voluntary gait, Fugl-Meyer index and the motor subscore of the FIM (FIM-M).

Results: Patients tolerated the FNS-IM treatment well. We designed stimulation paradigms that minimized discomfort associated with electrical stimulation of a leg with preserved sensation. Monolimb stimulation, using the FNS protocols we developed, did not increase cardiac output above that of volitional activity. With CR each patient improved in some aspects of gait kinematics. In contrast, each patient improved with FNS-IM in gait kinematics beyond that attained with CR. Improvements in gait kinematics achieved with FNS-IM compared with CR include: knee flexion at toe-off increased from 15±5 to 39±4, peak-swing phase knee flexion improved from 22±7 to 49±10, ankle dorsiflexion at heel strike increased from 2±2 to 19±4, peak swing phase ankle dorsiflexion increased from 2±3 to 20±5, knee extension at heel strike decreased from 22±4 to 2±1 and knee wobble in stance phase decreased from 11±4 to 1±1 (all were $p<0.001$). The Fugl-Meyer score improved by 8.1±6.4 during conventional rehabilitation and 25.2±5.1 ($p<0.001$) during FNS-IM treatment. FIM-M improved by 5.3 ±3 during conventional therapy to 53.1 ±6.1. With FNS-IM, FIM-M further improved to 64.9 ±6.8 ($p<0.01$). Functional gains persisted after removing the FNS-IM electrodes including advancement from wheelchair use to walking from car to restaurants, malls or medical appointments (i.e., walking independently 1 block).

Conclusions: 1) FNS-IM can be used in stroke patients without discomfort or excessive increases in cardiac output. 2) FNS is a useful stroke rehabilitation technique that can restore voluntary gait function beyond that attained by spontaneous recovery and conventional rehabilitation. 3) The improved gait persists after completion of FNS-IM treatment. 4) FNS-IM is a promising rehabilitation tool for veterans with gait disorders due to stroke.

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O-192

CARDIOVASCULAR FITNESS AFTER STROKE: ROLE OF MUSCLE MASS AND GAIT DEFICIT SEVERITY

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Objectives: Functional disability following hemiparetic stroke may be compounded by physical deconditioning and muscular wasting, factors related to disuse and advancing age. However, the role of body composition, severity and chronicity of gait deficits as determinants of exercise fitness following stroke is unknown. The purpose of this study was to determine whether oxygen consumption during peak exercise (VO_2 peak) is associated with body composition, the severity or duration of gait deficits in chronic (> 6 months) hemiparetic stroke patients.

Methods: Twenty-six patients (22 males, 4 females), aged 66 $\pm$ 9 years (mean $\pm$ SD), completed a progressive graded treadmill test until fatigue to measure VO_2 peak (1.3 $\pm$ 0.4 L/min). Timed 30' walks were used to determine self-selected floor walking velocity (0.63 $\pm$ 0.31) m/s), an index of gait deficit severity. Percent body fat (30.4 $\pm$ 10.6%), total lean mass (52.0 $\pm$ 9.3 kg), lean mass of the paretic and non-affected legs (17.2 $\pm$ 3.7 kg), and lean mass of the paretic and non-affected thighs (13.2 $\pm$ 2.7 kg) were determined by dual-energy x-ray absorptiometry (DEXA).

Results: Total lean mass (r=0.60), lean mass of both legs (r=0.58), paretic leg lean mass (r=0.55), lean mass of both thighs (r=0.64), and self-selected floor walking velocity (r=0.53, all $p<0.01$) correlated with VO_2 peak. In contrast, percent body fat and latency since index stroke were unrelated to VO_2 peak. In a stepwise regression analysis, lean mass of both thighs (r=0.64, $p<0.001$) and self-selected walking velocity (cumulative r=0.78, $p<0.001$) were independent predictors of VO_2 peak and explained 61% of the variance.

Conclusions: These results suggest that hemiparetic stroke patients are profoundly deconditioned, regardless of latency since stroke, and that lower lean thigh mass and greater gait deficit severity predict even poorer peak exercise capacity.

Clinical Implications: These results support a rationale for further studies investigating the functional benefits of therapeutic exercise to reverse deconditioning and disuse atrophy in the chronically disabled stroke population.

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A METHODOLOGY FOR EXAMINING THE EFFICACY OF TELEREHABILITAION

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Objectives: This study concerns itself with a new application of rapidly evolving technologies in telecommunications and applies it to a specialist area within the field of Rehabilitation. This telecommunications technology has become known as TeleRehab. TeleRehab has the potential of increasing the availability of these specialist services to Veterans and others who are not receiving them because of geographical and/or transportation issues, and of reducing the cost of delivering these services at an appropriate level. The study will establish a scientific basis for the reliable use and limits of, telecommunication based remote prescription of Assistive Technology (AT), and also to establish methodologies which may be reproduced for further evaluation activities in this or related fields. The expected benefit of this work is that the use of TeleRehab technologies has a high likelihood of positively affecting outcomes of Veterans using wheelchairs who are remote from comprehensive rehabilitation resources or who have limited access to specialists in wheelchair prescription. It is anticipated that this work will serve as a basis from which service delivery models can be developed to better serve this population. Additionally this work will form the basis of other proposed studies in the areas of remote data acquisition and service, including - measurement of tremor; measurement of pressure ulcers (size and healing); and acquisition of dimensional information for ergonomic fitting of wheelchairs.

Methods: This study is designed to test the reliability of the clinical decision process. We will identify a group of experienced clinicians and using our protocols and "instruments" compare the results of their face to face evaluations across a varied group of individuals with mobility needs in order to refine the process and determine 2 clinicians who are most "correct". The sample size for the final study that is necessary to achieve a 10% margin of error in estimating the population proportion will be calculated based on the inter-rater agreement rate observed in the pilot study. If inter-rater agreement rates of 0.8 to 0.9 are reached, the sample size needed for the final study would range from 35-61. Our previous experience in this field indicates that by designing the assessment protocols carefully and the recording of prescription decisions in a layered manner we will be able to achieve these levels of inter-rater reliability.

Results and Conclusions: At the time of writing this is a newly funded project-preliminary results will be presented at the conference.

Funding Acknowledgement: VA Rehabilitation Research & Development Service

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EFFECTS OF AEROBIC TREADMILL TRAINING ON GAIT VELOCITY, CADENCE, AND GAIT SYMMETRY IN CHRONIC HEMIPARETIC STROKE: A PRELIMINARY REPORT

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Objectives: Following ischemic stroke, limited or no improvement in functional mobility is currently thought to be possible beyond the sub-acute recovery period. Contrary to this belief, we studied "neurologically-plateaued" stroke patients with chronic hemiparesis to assess whether a "task-oriented" treadmill-training regimen would improve walking speed, cadence, and gait cycle symmetry on a modified "Get-up and Go" task.

Methods: Five (5) male patients with a mean age of 60.4 ± 2.7 years (mean ± S.D.) status-post ischemic stroke (> 6 months prior) participated in this non-randomized low intensity treadmill exercise pilot study 3x/week for 3 months. All patients had mild to moderate gait asymmetries due to residual hemiparesis. Patients were videotaped before and after 3 months of treadmill aerobic exercise (AEX) while performing a functional task consisting of arising from a chair, walking 3.1 m without an assistive device as fast as safely possible, and returning to sit. Gait events were timed using a 2-D Peak Motus™ video analysis system. Results: After 3 months AEX training, times for the overall "get-up and return-to-sit" (GURS) task and the "straight-away walk" (SAW) segment decreased from 8.2 ± 1.4 sec to 6.5 ± 0.8 sec. (mean ± SEM) ($p<0.05$), and from 3.7 ± 1 sec to 2.8 ± 0.7 sec. ($p<0.05$), respectively. These data represent improvements of 21% and 24% for the GURS and SAW segments, respectively. Mean velocity increased from 0.9 ± 0.2 to 1.2 ± 0.21 m/sec, a 33% improvement ($p<0.01$). Mean cadence (steps/min) increased from 89 ± 9 to 97 ± 8, a 9% increase ($p<0.05$). Mean stance and swing duration diminished for both paretic (P) and non-paretic (NP) limbs, and the intralimb stance/swing ratio values moved towards normal for both the paretic and non-paretic limbs. However, these latter changes reached significance only for the P limb. Interlimb stance symmetry was unchanged. The more impaired subjects experienced the greatest gains in gait velocity and temporal measures.

Conclusions: Collectively, these findings indicate that treadmill exercise improves functional overground mobility in individuals with chronic, stable hemiparesis.

Clinical Implications: These results also suggest that current dogma regarding the windows of motor recovery following stroke may be too narrow in their scope.

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EFFECTS OF TREADMILL TRAINING ON TRANSLATIONAL BALANCE PERTURBATION RESPONSE IN CHRONIC HEMIPARETIC STROKE PATIENTS

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Objectives: Individuals with chronic hemiparetic gait deficits following ischemic stroke are at high risk for falls. It is generally assumed that limited or no further recovery in functional balance is possible beyond the sub-acute stroke recovery period. In this non-controlled pilot-feasibility study, we investigated the effects of 3 months treadmill aerobic exercise training (AEX) on dynamic responses to destabilizing horizontal balance perturbations (anterior-posterior) in 11 chronic hemiparetic stroke patients.

Methods: Patients stood without support on a computer-controlled platform which delivered standardized perturbations (10 cm - 40 m/s - 150 m/s^2). Footswitches registered on/off ground contact at the feet. Recovery time (RCT) was measured from perturbation onset to the recovery of stable foot contacts. Reaction time (RT) was the time from perturbation onset to initial loss of foot contact, and movement time (MT) was the difference between RCT and RT.

Results: Baseline data identified a subset of patients (n = 6) with markedly slower RCTs vs. a subset (n =5) with faster RCTs (1252.4 vs. 718.9 ms, $p < .001$). A group x time analysis, considering slow vs. fast subgroups, showed significant improvement in the slower group's RCTs post-AEX (-300 ms, $p < .05$). Analysis of RTs and MTs indicated that the global change in RCTs was attributable to improved MTs in the slow group relative to the fast group. The absence of change in the RTs as a function of the training was interpreted as evidence that the patient's initial reactions were governed largely by the mechanical properties of their static standing posture.

Conclusions: These findings indicate that progressive graded treadmill AEX may improve dynamic balance response in selected chronic hemiparetic stroke patients, and that initial slow RCTs may predict responders. Our results suggest that "task-oriented" treadmill training may translate into improved balance function in some chronic gait-impaired stroke patients, which may reduce their risk for falls. These findings also highlight the need for further studies to help clarify the relative contributions of training-induced neural plasticity vs. peripheral myotrophic alterations in improving the MTs of more impaired stroke patients.

Clinical Implications: These data lend additional support to the contention that many patients in the chronic phase of stroke can continue to make gains in functional performance long after their discharge from conventional rehabilitation programs.

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THE POWER REDUCTION EXPERIENCED BY MANUAL WHEELCHAIR OPERATORS WHEN PROPELLING A MANUAL WHEELCHAIR EQUIPPED WITH POWER ASSIST UNITS

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Objective: The purpose of this study was to determine the power requirements to propel an individual's wheelchair and to compare those to usage of a power assisted device. The power assist device was the JW II (Yamaha Motor Corporation).

Methods: A single subject who uses a manual wheelchair was tested on a wheelchair dynamometer in both his or her personal wheelchair and in a chair similar to their personal wheelchair equipped the Yamaha JW II to determine the energy savings. Torque and angular velocity values of the left and right dynamometer rollers were sampled at 240 Hertz for the final 30 seconds of a three minute bout. The subject was tested at five levels of resistance and velocity. For the regular manual wheelchair, operator muscular exertion accounts for all the energy dissipated by the dynamometer. For a power assist chair, the dynamometer dissipated energy, represents the sum of two work sources: the work expended by the operator and the work contributed by the electric motors. To isolate the work contribution of each, voltage signals from the hand rim torque sensors (potentiometers) were also sampled at 240 times per second. This voltage is proportional to operator torque. Integration of this torque- velocity curve represents the work portion contributed by the operator.

Results: Dynamometer data between manual and powered wheelchairs trials was not consistent. The most likely explanation is that the subject did not maintain the same velocity between chairs or between left and right wheels. Preliminary analysis of this subject indicates a significant reduction in human energy expenditure on four of the five trials.

Power Output (watts)

Effort and Velocity	Personal Chair (human powered)			Yamaha Chair (human and electric motor combined)			Yamaha Chair (human input measured at hand rim)		
	Left	Right	Total	Left	Right	Total	Left	Right	Total
Low	.66	3.25	3.91	1.07	2.71	3.78	.47	5.05	5.52
Medium	1.59	6.94	8.53	3.47	4.64	8.11	-.32	6.75	6.43
High	2.55	4.35	6.90	2.99	3.15	6.14	.455	5.35	5.80
Very High	6.29	9.94	16.23	7.27	6.89	14.16	.372	7.62	7.99
Medium	3.00	5.50	8.50	3.10	3.23	6.23	.77	4.51	5.28

Conclusions: Promising technology which may reduce stress and fatigue for individuals who rely on manual wheelchairs. Additional subject trials will increase confidence.

Funding Acknowledgement: This research is being funded by the Yamaha Motor Corp.

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REMEDIATION OF COGNTIVE IMPAIRMENTS IN SCHIZOPHRENIA THROUGH COMPUTER BASED COGNITIVE ENHANCEMENT

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Objective: To demonstrate computer-based attention, verbal memory, and executive function retraining and an audio-based dichotic listening task for remediating cognitive deficits in people with schizophrenia.

Research Plan: Attendees will experience how patients with schizophrenia or schizoaffective disorder receive cognitive retraining by performing five computer-based tasks on a computer display and by performing a dichotic listening task on a audio display.

Methods: Five tasks from the PSSCogReHab software package (Bracy, 1995) have been modified for the purpose having them administered as a series of difficulty-graded attention, verbal memory and executive function tasks. The first two tasks provide training in visual attention where the trainee is required to respond to a series of targets while visually tracking a moving object. The next two tasks provide training in verbal memory where one task requires the trainee to recall a sequence of digits and the other requires the trainee to indicate the numerical position of a word that was presented in a list. The final task is similar to the Tower of Hanoi and provides training in executive skills. The dichotic listening task provides training in auditory attention in which the trainee is required to pay attention to a story heard in the right ear while a poem is being presented in the left ear.

Clinical Relevance: It is the goal of this demonstration to disseminate information regarding computer-based cognitive retraining as part of rehabilitation services provided to schizophrenic patients.

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COMPARISON OF ENERGY CONSUMPTION IN ELECTRIC POWERED WHEELCHAIRS

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Objective: This project provides data for clinicians and power wheelchair users to compare the energy consumption estimates of five different models of electric powered wheelchairs: the Everest and Jennings Lancer 2000, Quickie P200, Invacare Arrow Action Storm, Pride Jazzy, and the Permobil Chairman.

Methods: The theoretical range of each wheelchair was determined by using the criteria from Section 4 of the ANSI-RESNA Standards, Determination of Energy Consumption for Electric Powered Wheelchairs. Each of the wheelchair's theoretical range (km) was determined using a watt hour meter to measure the energy consumption, while driving around on a test track designated by the standards.

Results: There was an overall significant difference ($p < .05$) between the measured theoretical ranges, or the theoretical distance the wheelchair can travel on a full battery.

Wheelchair Model	Average Range (km)	Maximum Speed (m/s)
Permobil Chairman	25.82 ± 0.0211	1.87 ± .0001
Pride Jazzy	28.08 ± 0.0518	1.82 ± .0017
Invacare Action Arrow	28.54 ± 0.0746	2.77 ± .0002
Quickie P200	32.28 ± 0.0859	3.18 ± .0047
Everest & Jennings Lancer 2000	29.73 ± 0.0295	2.32 ± .0022

The confidence intervals are based on an alpha value of .95.

Conclusion: It was found that there was a significant difference in the amount of energy consumed, as well as the theoretical ranges of the different chairs. There is therefore an advantage to purchasing a wheelchair with a better range in that it will run for a greater amount of time without the need to charge. In the future, it would be beneficial to determine if there is a relationship between the maximum speed of the wheelchair and the energy consumption of the wheelchair.

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References: ANSI/RESNA WC Standards Vol. 1-1998

Background of the Paul B. Magnuson Award

THE PAUL B. MAGNUSON AWARD

The Paul B. Magnuson Award is presented annually to a VA Rehabilitation Research and Development Investigator. The award is given to an investigator who exemplifies the entrepreneurship, humanitarianism and dedication to veterans displayed by Dr. Magnuson during his distinguished career as a bone and joint surgeon and as the Chief Medical Director of the VA from 1948-51. The Award was established in 1988, in recognition of the importance of rehabilitation research within the VA health care system. The first honorary award was given to Ernest M. Burgess, M.D., orthopedic surgeon and prosthetic pioneer, who developed the Seattle Foot and who founded amputee care standards as we know them today. The Award confers a one-time cash award of $5,000 plus $50,000 for up to 3 years, to supplement ongoing peer-reviewed research and is presented each February at the VA RR&D Annual Meeting.

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