

### SUMMARY OF SCIENTIFIC/TECHNICAL PAPERS IN THIS ISSUE

#### **Design and Pilot Testing of the DVA/Seattle Footwear System for Diabetic Patients with Foot Insensitivity.**

Gayle E. Reiber, MPH, PhD; Douglas G. Smith, MD; David A. Boone, CP; Michael del Aguila, MS; Robert E. Borchers, MS; David Mathews, CP; Aaron W. Joseph, MS; Ernest M. Burgess, MD, PhD (*p. 1*)

**Purpose of the Work.** Clinical epidemiology studies suggest the majority of lower limb amputations were preceded by a minor traumatic event, often footwear-related, and lower limb ulcers. To reduce foot trauma and ulcers, the diabetic patient with foot insensitivity has unique footwear needs. To address these needs for patients not requiring custom shoes, the DVA/Seattle Footwear System was developed and pilot tested in a 6-month cross-over trial to determine the feasibility of producing, and the safety of wearing, depth-inlay study shoes and two types of insoles. **Subjects/Procedures.** Twenty-four ambulatory male veterans, ages 45–84, who had some foot insensitivity but no prior history of foot ulcers or amputation were enrolled. During the first 4 weeks, patients were assigned to the study shoes and one type of insole; during the next 4 weeks, they wore the other type of insole in the study shoes; and during the final 4 months, they chose which pair of insoles to wear with the study shoes. **Results.** Over 150 person-months of footwear observation revealed no breaks in the cutaneous barrier with the use of study shoes and insoles. Patient compliance with the footwear was 88%. Patients were highly satisfied with the appearance and stability of both types of insoles. There was no strong comfort-based patient preference for either insole at the study conclusion. **Relevance to Veteran Population.** Over half of VA amputations occur in veterans with diabetes. A minor traumatic event, often footwear related, usually precedes these ulcers and amputations. The development and testing of insoles and depth-inlay shoes suggests future directions and opportunities for prevention of limb loss.

*Gayle E. Reiber, MPH, PhD*

#### **Stair Ambulation in Persons with Transtibial Amputation: An Analysis of the Seattle LightFoot™.**

Christopher M. Powers, PhD; Lara A. Boyd, MPT, Leslie Torburn, MS, PT; Jacquelin Perry, MD (*p. 9*)

**Purpose of the Work.** The purpose of this study was to document gait patterns in a group of individuals with transtibial (TT) amputations during stair ambulation and to identify the functional limitations associated with this task. **Subjects.** Ten males who were independent community ambulators and had unilateral TT amputations were fitted with the Seattle LightFoot prosthetic component. Additionally, 14 control subjects without amputations also participated in this study. **Procedures.** Electromyographic activity of the vastus lateralis, rectus femoris, gluteus maximus, semimembranosus, biceps femoris long head, and biceps femoris short head was assessed using indwelling wire electrodes during ascending and descending stairs. Lower limb motion and stride characteristics also were collected. **Relevance to Veteran Population.** During stair ambulation, the lack of normal ankle dorsiflexion reduced the ability of those persons with TT amputations to progress over the prosthetic foot. This necessitated changes in gait patterns, resulted in a slower walking velocity, and increased muscular activity. The requirements of stair ambulation challenge designers of prosthetic feet to provide the mobility needed for optimum progression while preserving stability for level surface gait. Additionally, stair ambulation should be recognized by rehabilitation professionals as a separate, highly complex task for those with TT amputations.

*Lara A. Boyd, MPT*

#### **Interface Pressures and Shear Stresses at Thirteen Socket Sites on Two Persons with Transtibial Amputation.**

Joan E. Sanders, PhD; Dickson Lam; Alan J. Dralle, CP; Ramona Okumura, CP (*p. 19*)

**Purpose of the Work.** The goal of this study was to better understand the patterns of pressures and shear stresses at the residual limb–prosthetic socket interface when a person with a transtibial amputation walks with a prosthesis. **Subjects and Procedures.** Using custom-designed instru-

mentation, interface pressures and shear stresses were measured on two subjects walking with patellar-tendon-bearing prostheses. **Results.** The data showed that the stresses tended to be concentrated at the front end of the residual limb over the bone. Shear stresses at some sites in the upper half of the socket were directed upward toward the socket brim, a finding possibly explained by soft tissue displacement in the residual limb. **Relevance to Veteran Population.** The results from this study are potentially useful for enhancing prosthetic design and fitting to reduce the risk of tissue injury from interface stresses.

*Joan E. Sanders, PhD*

#### **Noninvasive Quantification of Muscle Oxygen in Subjects with and without Claudication.**

Bok Y. Lee, MD; Lee E. Ostrander, PhD;  
Milon Karmakar, MD; Lubov Frenkel;  
Burton Herz, MD (p. 45)

**Purpose of the Work.** The study describes measurement of oxygen deficiency within the limb tissues when patients with claudication experience the disabling pain of claudication during exercise and walking. **Subjects/Procedures.** The present study reports on data from the limbs of 11 claudicant subjects and 12 subjects without claudication. The results consist of photon reflectance measurements at red and infrared wavelengths taken before, during and after exercise. Other vascular test results were also recorded. **Results.** Reflectance data show responses that are generally consistent with the expected physiological changes in mild exercise for both claudicant and nonclaudicant subjects. **Relevance to Veteran Population.** The findings of this study may lead to noninvasive testing procedures for measuring the ischemic and exercise-induced changes in muscle oxygenation and for assisting in conservative management of treatment programs such as cessation of smoking, alternative exercise regimens, weight loss, and alternative pharmacological agents.

*Bok Y. Lee, MD*

#### **Analysis of a Vertical Compliance Prosthetic Foot.**

Laura A. Miller, MS and Dudley S. Childress, PhD (p. 53)

**Purpose of the Work.** Until now, new vertical compliance feet (e.g., Re-Flex VSP™) have not been studied. The purpose of this work was to conduct laboratory studies of the mechanical characteristics and biomechanical effects of vertical compliance feet. **Subjects/Procedures.** We investigated gait parameters of two subjects with transtibial amputation who used vertical compliance feet for walking, jogging in place, and curb descent. Mechanical testing was

conducted on the prosthetic feet. **Results.** Mechanical properties of the vertical compliance feet correspond well to those reported in the literature for the physiological limb. The biomechanical effects of added vertical compliance were most significant during fast walking and jogging. Subjects preferred the feet with the vertical compliance mechanism for all activities. **Relevance to Veteran Population.** The subjective preference, along with the fact that the mechanical properties of the system matched physiological measurements, indicate that the role of compliance in prosthetics has a reasonable foundation. Veterans with amputation, particularly those with bilateral limb loss, may find these feet useful for normal walking and standing. Veterans with unilateral amputation who run, jog, or walk quickly may also find them useful.

*Laura A. Miller, MS*

#### **Wheelchair Rider Injuries: Causes and Consequences for Wheelchair Design and Selection.**

Ronald P. Gaal, BSME, PE; Nancy Rebholtz, BSME; Ralf D. Hotchkiss, ScD; Peter F. Pfaelzer, PhD, PE (p. 59)

**Purpose of the Work.** Our goal was to deepen understanding of the causes of adverse incidents and injuries sustained by active wheelchair riders, with the overall aim of improving safety via wheelchair design, selection, and configuration. **Subjects/Procedures.** One hundred and nine active wheelchair riders were interviewed, reporting from memory on a total of 253 incidents that occurred during a 5-year period. Participants described the situation and action of each incident, the wheelchair involved, and personal data. **Results.** Of particular interest are the associations of the direction of tips and falls with wheelchair type (manual or powered) and with riding surface (level, sloped, etc.), and the high incidence of tips and falls among manual chairs with small, solid casters. **Relevance to Veteran Population.** Aspects of wheelchair tipping stability are important engineering issues affecting wheelchair safety. Our interpretation of the results highlights the mechanics of wheelchair stability and potential design improvements. *Ronald P. Gaal, BSME, PE*

#### **Direct Bladder Stimulation with Suture Electrodes Promotes Voiding in a Spinal Animal Model: A Technical Report.**

James S. Walter, PhD; John S. Wheeler, MD;  
Wuying Cai, MD; Robert D. Wurster, PhD (p. 73)

**Purpose of the Work.** Control of urination is usually lost following spinal cord injury. Electrical stimulation to pro-

mote voiding has been investigated, including stimulation of nerves that go to the bladder (sacral nerves) and direct stimulation of the bladder wall. Sacral nerve stimulation is a currently approved clinical method in Europe and is in clinical investigation in the United States. Direct bladder stimulation has been less successful clinically but offers the opportunity of a less invasive surgery for stimulator implantation. The purpose of this study was to investigate a new suture-type electrode on the bladder wall that might have the advantages of an extended length, which could be placed across the entire nerve bundle on the bladder. **Subjects/Procedures.** Five male cats were instrumented during anesthesia. Suture electrodes were implanted on the bladder wall above the urethra. Bladder filling and stimulation studies were conducted following recovery in tethered animals. To test these electrodes in a spinal cord injury model, a T-1 level complete lesion was performed on the above instrumented animals. **Results.** The animals recovered well from all surgical procedures and the procedures were approved by our institutional Animal Studies Subcommittee. Animals had successful direct bladder stimulation that induced active contractions and voiding both before and after spinal cord injury, but voiding rates were higher more than 2 weeks after SCI and at larger initial bladder volumes. Optimum stimulation parameters consisted of high-frequency pulses, with long pulse durations as well as high stimulating currents. **Relevance to Veteran Population.** Electrical stimulation is becoming an important alternative method for promoting urination following spinal cord injury. These studies show that the suture electrode may be an effective electrode for direct bladder stimulation, and this electrode may be considered for additional investigations to improve direct bladder stimulation methods.

*James S. Walter, PhD*

#### **Instrumented Objects for Quantitative Evaluation of Hand Grasp.**

William D. Memberg, MS and Patrick E. Crago, PhD (*p. 83*)

**Purpose of the Work.** Hand-held devices that are equipped with sensors can be useful in evaluating the

capabilities of persons with diminished hand function. By using these devices in simulated tasks, it becomes easier to analyze different techniques used to improve hand function. **Subjects.** These devices were tested on individuals with quadriplegia who had spinal cord injuries at the C5/C6 level and were using electrical stimulation to restore hand-grasp function. **Results.** A book-shaped object and a pen-shaped object were equipped with force and tilt sensors. These devices, along with contact switches and other information, were used in simulated drinking and eating tasks. The data from these trials were useful in identifying the most difficult portions of the tasks, and can be used to objectively compare future improvements in hand function. **Relevance to Veteran Population.** These instrumented devices will allow researchers to document improvements in hand grasp function.

*William D. Memberg, MS*

#### **Influences of Cane Length on the Stability of Stroke Patients.**

Chun-Liang Lu, MD; Bing Yu, PhD; Jeffrey R. Basford, MD; Marjorie E. Johnson, MS, PT; Kai-Nan An, PhD

(*p. 92*)

**Purpose of the Work.** The purpose of this study was to investigate the influence of cane length on the standing and walking stability of stroke patients. **Subjects/Procedures.** Ten stroke patients were recruited as the subjects for this study. Two methods commonly used to determine cane length when prescribing canes were evaluated. Force plates were used to record the movement of the center of pressure in standing and walking with canes. Maximum sway, total travel distance, and mean travel speed of the center of pressure were determined for each subject. **Results.** The vertical distance from the wrist crease to the ground with an elbow flexion angle of less than 40° can be used as the appropriate cane length for a given patient. **Relevance to Veteran Population.** The results of this study will directly assist in improving the care of stroke patients as well as other patients using canes.

*Kai-Nan An, PhD*