Center of Excellence for Limb Loss Prevention and Prosthetic Engineering

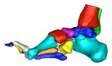
Limb Loss Prevention Research

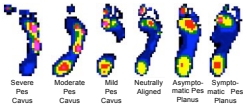
Department of Veteran Affairs Rehabilitation Research and Development (VA RR&D), Seattle, WA

Our aim is to reduce the incidence of lower limb ulceration and amputation in the diabetic veteran population by exploring the mechanics of the foot in general, and the diabetic foot in particular. We are developing and implementing new tools for studying foot structure and function, conducting basic science and clinical research, and exploring new treatment options. Support for this research (2000 to present) includes VA RR&D grants: A2180R, A2362P, A2661C, A3030R, A3217P, A3866R, A3923R, A4056X and A4513R; a VA CSR&D grant; and NIH grant 1R01DK075633-01.

Quantifying Differences in Foot Type

We have employed various techniques to analyze structural and functional differences between foot types, including: plantar pressure measurement; foot bone position via CT; foot bone motion via MRI, retro-reflective motion analysis and ankle circumduction.





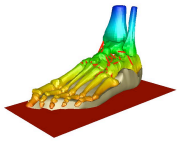


Ankle OA: Athrodesis vs. Arthroplasty

The availability of prosthetic ankle joints has prompted a change from arthrodesis (fusion) to arthroplasty (total joint replacement). This represents a paradigm shift in treatment for end stage ankle arthritis without any substantive supporting evidence. We have begun an observational trial on the activity and full body gait characteristics of patients with ankle arthrodesis or arthroplasty.

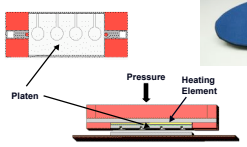
Finite Element Foot Model

We are nearing completion of version 2 of our anatomically accurate finite element foot model. The model includes bones, ligaments, cartilage, tendons, adipose tissue, muscle and skin. Validations were conducted with rigid body bone motion and plantar pressure from cadaveric specimens.



Orthotic Plantar Pressure Reduction

Reducing plantar pressure is often the goal of orthotic prescriptions, but pressure is not typically measured during fabrication. We have developed a novel manufacturing process that provides the clinician with the real-time plantar pressure distribution. The robustness of the new orthoses has been demonstrated and this technique has been used successfully to reduce pressure on healthy subjects.



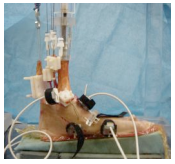


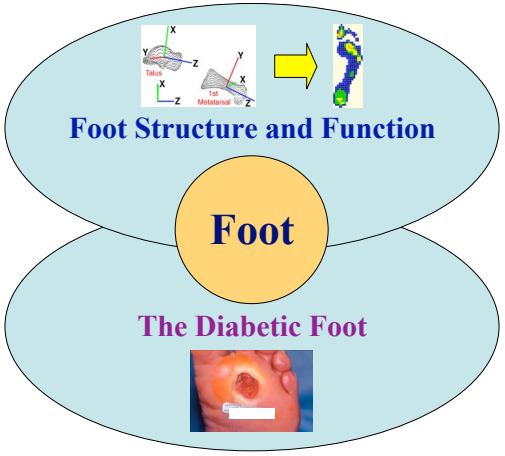
Diabetic Foot Kinematics and Kinetics

It is not known how diabetes and concurrent neuropathy alters the kinematics and kinetics of the multi-segment foot during ambulation, how foot shape may compound this problem, or how plantar shear stress is distributed during turning. Our vision is to use the understanding achieved by this work to develop optimal prevention and treatment strategies for diabetic veterans.

Static Cadaveric Simulations

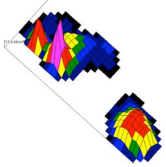
In an effort to generate biofidelic models of foot deformities, we have developed static cadaveric models of pes cavus, pes planus, a clawed hallux and a dorsal bunion.



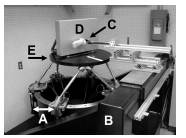
Diabetic Foot Structure and Function

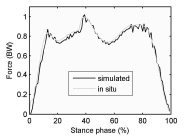
Our research group has participated in three population based research studies that explored the biomechanics of the diabetic foot, demonstrating that: 1) foot type (e.g., pes cavus) is strongly associated with foot deformity (e.g., hammer/claw toes), 2) foot deformity (e.g., hammer/claw toes) is strongly associated with ulceration and 3) prospective high plantar pressure is predictive of ulceration only at certain locations. Expanding upon 3) - Across all plantar tissue locations, sites at which ulcers developed had higher mean pressure, but at a particular site, pressure was unrelated to foot ulcer incidence. However, when the metatarsal heads were considered by themselves, peak pressure was significantly higher for the metatarsal head ulcers. Currently, we are using weight-bearing foot CT scans and plantar pressure to determine differences between ulcer and non-ulcer patients.




Robotic Gait Simulations

Both prosthetic foot design and lower extremity biomechanics research could benefit from an anatomically accurate gait simulator. We have developed a robotic gait simulator (RGS) by leveraging a 6-degree of freedom parallel link mechanism, with the goal of overcoming three significant challenges of gait simulation, including: 1) operating at near physiologically correct velocities, 2) inputting full scale ground reaction forces and 3) simulating motion in all three planes.



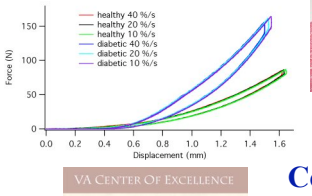


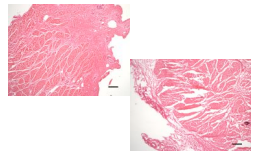
Ankle Equinus

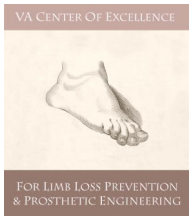
The equinometer is a device used to quantify the stiffness of the ankle plantarflexors. This data will be correlated with plantar pressure data to determine the effect of plantar flexor stiffness on forefoot pressure.

Diabetic Soft Tissue

Amputations often result from ulcers on the plantar soft tissue, a condition predicated on an increase in joint stiffness, plantar pressure and shear stress. These biomechanical changes in the foot complex have yet to be associated with specific tissue cellular/matrix characteristics, wherein therapeutic interventions may prevent ulceration and subsequent amputations. Thus, our group has engaged in an effort to understand the properties of foot soft tissues for healthy (younger and older) and diabetic individuals. Our currently funded NIH proposal aims to test diabetic and non-diabetic plantar soft tissue. To complement this study and fully understand the soft tissue mechanical and cellular/matrix characteristics in healthy and diabetic feet, we also aim to examine the ligaments of the foot.







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