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Development of a Three-Dimensional Simulation Tool to Investigate the Effects of Ankle Foot Orthosis Joint Misalignments

Stefania Fatone, PhD, and Kerice Tucker, BS

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Accurate alignment of anatomical and mechanical joint axes is one of the major biomechanical principles pertaining to articulated orthoses, yet knowledge of the potential effects of axis misalignment is limited. Congruency between anatomical and mechanical joint axes is considered important as misalignment results in undesirable forces (both shear and compressive) and moments, generated as the joints move through their ranges of motion. Such undesired forces and moments may compromise the integrity of the skin; lead to binding, which results in increased resistance to joint motion and the energy required to function with the device; and increase compressive forces at the articular surfaces and/or tension in the ligaments that constrain the ankle joint.

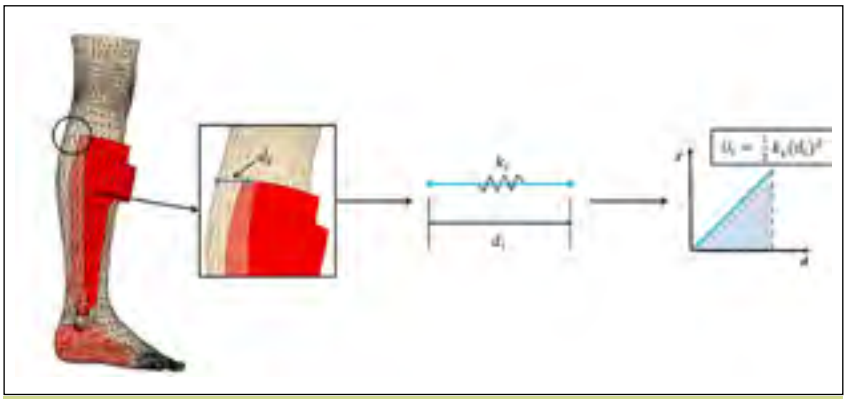

Figure 1: Linear spring model of AFO and leg.

Joint axis misalignment consists of two components: linear (anterior-posterior and proximal-distal) and angular (transverse and coronal plane) misalignments. While the consequences of linear misalignments (i.e., 2-dimensional misalignments) at the ankle joint of an ankle foot orthosis (AFO) were modeled in a previous RERC-funded project (Fatone and Hansen, 2007), there has been more limited consideration for combined angular and linear misalignments at the ankle (i.e., 3-dimensional misalignments).

Since there is natural torsion of the tibia, rotational alignment of the ankle joints and the consequences of ankle axis misalignment in three-dimensions (3D) needs to be considered. Therefore, our objectives for this project were to develop a 3D model to explore the effects of ankle axis misalignment that can be 1) systematically used to analyze the various combinations of ankle axis misalignments possible in an AFO and their effect on motion of the device relative to the limb and compressive displacements at the orthosis-user interface (which relate to pressure on the limb); and 2) compiled into a web-based executable program to be used as an educational, interactive tool by orthotic students.

Using a computer representation (i.e., digital model) of the lower leg of an able-bodied person, a set of commonly used AFO trim lines were identified. Within the AFO trim lines selected, shell copies were created (with the same internal digitized point locations as the leg and the foot). Software was written to relocate the AFO's virtual mechanical axis in 3D space (i.e., to

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create various misalignments). A graphical user interface (GUI) model was developed wherein the displacements can be shown in either of two modes: (1) As physical movements of the shells with respect to the leg and (2) as color coded displacements on the leg model (e.g. warm colors indicating displacements that would compress the leg, and cool colors indicating displacements that would create gapping between the leg and orthosis).

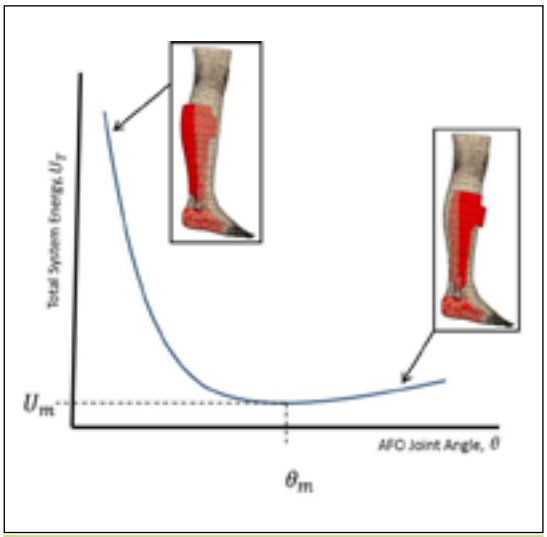

Figure 2: Total system energy related to each AFO joint angle for a given AFO design and joint misaligments.

The model is based on a number of assumptions: 1)The ideal AFO joint angle is the angle that minimizes the total potential energy of the system; 2) the AFO is rigid; 3) the AFO foot shell remains fixed relative to foot; 4) ankle rotations take place about a single axis through lateral and medial malleoli; 5) the AFO ankle joint is a single axis that rotates freely; 6) there is no slippage between the AFO and leg; and 7) the AFO does not alter the leg's kinematics.

A linear spring model was used to represent the leg and AFO (Figure 1). Each vertex of the leg mesh is assumed to be a linear spring with a rest length of zero. Each vertex spring within the leg mesh has an associated relative stiffness (k_i) that, for a specific AFO joint angle, is used to calculate the potential energy (U_i) for that point's displacement (d_i). Only those displacements that are compressive are considered. Any AFO position that compresses the tissue causes these vertex springs in the compressed region to stretch, resulting in an increase in the spring's potential energy. Summing the potential energy over all vertices in the compressed regions results in the total system energy related to that AFO position. Calculating the total energy related to each AFO position results in a curve (Figure 2).

The stiffness values are relative, so vertices over bony prominences will have higher values compared to those over soft muscle bellies. These stiffness values aren't related to real world values. The relative stiffness of a vertex is based on the region in which the vertex resides.

The optimal AFO joint angle (θ_m) is the angle that minimizes total system energy (U_T). The program can calculate and display all compressive displacement and pressure magnitudes.

The completed program, "AFO3D", has been compiled into an executable file that can be uploaded to the Web for dissemination. The program consists of two main windows: a Command Window where the simulation is setup and run, and a Plot Window where the results of the simulation are displayed (Figure 3).

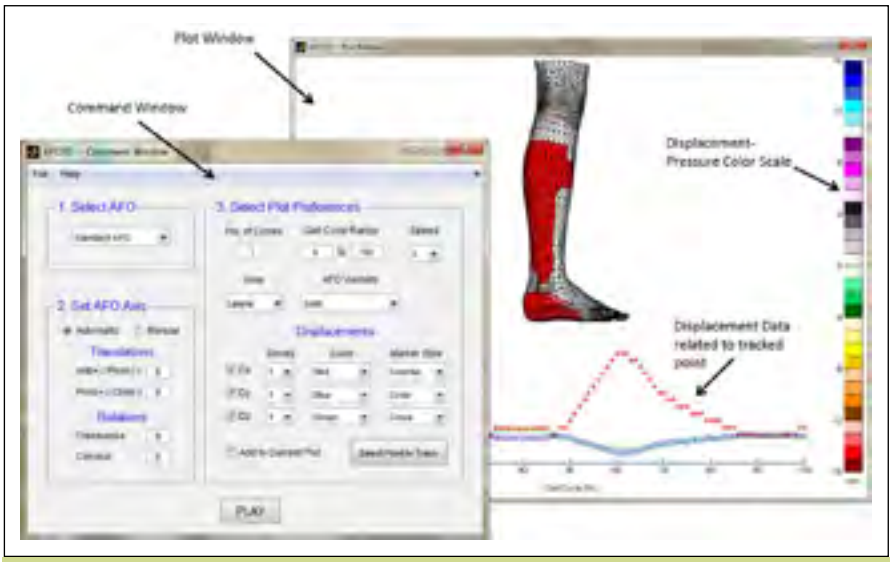

Figure 3: The two windows of the completed program "AFO3D".

Instructors and students in the Orthotics Certificate Program at NUPOC are currently evaluating the tool to provide feedback to improve utility for education purposes.

References

Fatone S and Hansen AH. (2007) Effect of Ankle Joint Misalignment on Calf Band Movement in Ankle-Foot Orthoses. *Prosthetics Orthotics International*, 31(1):76-87 17365887.

Durbin Introduces Legislation to Support Prosthetic and Orthotic (P&O) Research and Education

R. J. Garrick, PhD

U.S. Senator Dick Durbin announcing legislation in support of P&O research and education.

On March 11, 2013, **U.S. Senator Dick Durbin** (D-IL) discussed two bills he introduced to improve prosthetics and orthotics (P&O) care, enhance research in best practices, and support university degree programs that train clinical prosthetists and orthotists. The bills build on the work of Northwestern University Prosthetics-Orthotics Center (NUPOC) and the Rehabilitation Institute of Chicago (RIC), two national leaders in the field of P&O. Senator Durbin said, "*Chicago is at the front of the pack when it comes to prosthetic and orthotic training and research. I will introduce two bills to help spread that good work to the rest of the country. The men and women who suffer serious injuries in the line of duty have already sacrificed enough. They should expect nothing less than the highest standard of care throughout their lives*."

Steven A. Gard, PhD (right) greets U.S. Senator Dick Durbin.

Steven A. Gard, PhD, speaking (center), flanked by Todd Kuiken, MD, PhD (left), U.S. Senator Dick Durbin (right) and Joanne Smith, MD (far right).

Senator Durbin introduced two bills: the *Wounded Warrior Workforce Enhancement Act of 2013,* a competitive grant program to help colleges and universities develop master's degree programs focusing on prosthetics and orthotics (P&O); and the *Wounded Warrior Research Enhancement Act of 2013,* establishing the first centralized collection of outcome-based research and empirical data for P&O fittings. The bill also requires the VA to establish a Center of Excellence in Prosthetic and Orthotic Education to provide evidence-based research on the knowledge, skills, and training clinical professionals need to care for veterans. Chicago would be a leading contender for that Center of Excellence.

The two bills, if passed by Congress, will improve prosthetics and orthotics (P&O) care, enhance research in evidence based outcomes, and support universities that establish degree programs to train P&O specialists. **Steven A. Gard**, PhD, Executive Director of the Northwestern University Prosthetics-Orthotics Center (NUPOC) and a Research Health Scientist with the Jesse Brown VA Medical Center, Department of Veterans Affairs, stated that from June 2013 NUPOC will offer a Master's degree in Prosthetics and Orthotics (MPO).

Dr. Gard thanked Senator Durbin for sponsoring the legislation, "*We deeply appreciate your dedicated support for veterans, their healthcare, and the medical research that improves their daily lives. The Wounded Warrior Research Enhancement Act will provide the necessary funding to increase our understanding and develop better technologies to serve individuals who use prostheses and orthoses*." NUPOC is the oldest and largest P&O program in the USA, graduating more prosthetist-orthotists than any other school. Dr. Gard concluded, "*Through education, science, engineering and related disciplines, NUPOC is dedicated to developing and providing limb replacements (prostheses), structural and movement aids (orthoses), and P&O professionals to help humans affirm their lives with wholeness. NUPOC strongly supports the goals of Senator Durbin's legislation and hopes that Congress will act quickly to enact these important bills*."

Dilatancy Casting for Prosthetics and Orthotics: A Translational Technology

R. J. Garrick, PhD

Development of a Low-Cost Dilatancy-based System for Orthotic Fabrication (FO, AFO, KO, KAFO, TLSO) is supported by the National Institute on Disability and Rehabilitation Research (NIDRR) Field Initiated Grant Number H133G110266 of the US Department of Education. Opinions expressed in this presentation do not reflect those of the US Department of Education.

Yeongchi Wu, MD, is Principal Investigator of a 3-year NIDRR-funded research project, Development of a Low-Cost Dilatancy-based System for Orthotic Fabrication at the Northwestern University Prosthetics-Orthotics Center (NUPOC). The project goals are 1) to create a dilatancy (vacuum-based) system to capture the accurate impression of a body part and fabricate biomechanically individualized custom orthoses that will enable low-cost and rapid fabrication of orthoses; 2) evaluate the orthotic fabrication system on human subjects; 3) prepare technical manuals for knowledge translation; and 4) conduct training workshops for orthotists. Wu's research team includes **Steven A. Gard**, PhD, **John Michael**, MEd, CPO, **Chris Robinson**, MBA, CPO, **Larissa Conner**, CO, and **Hector Casanova**, CP. The team is conducting clinical evaluations of the new orthotic fabrication system on volunteer research subjects.

Yeongchi Wu, MD, demonstrating the concept of dilatancy casting at NUPOC.

Dilatancy is the concept that granules maintain a rigid shape under vacuum, as seen in a stiff and inelastic block of vacuum-packed coffee beans. The contents remain inflexible within the package as long as the vacuum is not released. Dr. Wu explained, "*Dilatancy technology offers a better, economical, speedy and ecological alternative to the costly, decades-old plaster-based approach*." At NUPOC, Dr. Wu recently demonstrated the speed and accuracy with which dilatancy can yield an accurate prosthetic socket in about one hour. It is inexpensive and entails little waste.

A lifelong advocate for economic, functional, and culturally appropriate technology, Wu developed dilatancy technology for prosthetic sockets with support from NIDRR (1998-2003), 2003-2008) and the collaboration of NUPOC when he was Director of Research at the Center for International Rehabilitation (CIR). Wu's research in dilatancy technology characterizes translational science in its scientific methodology to achieve cross-disciplinary, practical applications that can improve human health, mobility and quality of life. Dilatancy is a successful technique in fabricating prostheses for humans; and it has be translated to veterinary use, as documented in the film, *The Eyes of Thailand*.

If it is true that an elephant never forgets, then two Thai elephants, each suffering an amputated leg from land mine explosions, would likely remember Dr. Wu for helping to restore their ability to walk. *The Eyes of Thailand* (FilmWorks Entertainment, 2013) chronicles a multi-disciplinary effort to help elephants Mosha and Motala walk again. Thanks to dilatancy casting, the prosthetics fabrication technology that Dr. Wu developed while leading a research team at CIR, elephants Mosha and Motala can walk again.

Dr. Wu introduced dilatancy technology to Bangkok, Thailand during a World Health Organization sponsored knowledge translation workshop in 2007. Lakeside VAMC-trained Thai physiatrist Therdchai Jivacate, MD, founder of the Prostheses Foundation (Chiang Mai, Thailand) that provides free prosthetic limbs to amputees, embraced Wu's dilatancy casting technology. To date, the Foundation has fabricated more than 7,000 human limbs…and also prosthetic legs for two elephants!

Dr. Wu concluded, "*Dilatancy is a cross-culturally accessible and appropriate technology that does not rely on plaster-based or CAD/CAM-based fabrication of prostheses and orthoses. I believe that dilatancy technology can improve rehabilitative care for many people who live with physical disabilities throughout the world*." Dilatancy casting for prosthetics and orthotics is a translational technology with application to veterinary science as well as human P&O. Further development of dilatancy technology offers speedy, accurate, economical and ecologically sustainable fabrication of prostheses and orthoses for humans and other species.

> For more information about Yeongchi Wu's dilatancy research, see:
www.nupoc.northwestern.edu/nupoc-research/orthotics/Dilatancy_Ox_Fabrication.html

> For more information about *The Eyes of Thailand*, see: http://eyesofthailand.com/

Larissa Conner: Emerging Clinician and Researcher

R. J. Garrick, PhD

Larissa Conner, CO, is working with **Yeongchi Wu**, MD, as a research assistant on exciting new developments in dilatancy (vacuum casting) orthotics. Ms. Conner knows NUPOC in multiple contexts. She is a graduate of the NUPOC Othotics (2010) and Prosthetics (2012) certificate courses; and participated in the 2012 **NUPOC International Service (NUPOC-IS)** trip to Zacapa, Guatemala (see *Capabilities* 21(1):7, 2013) where she contributed her prosthetics and orthotics skills at the Range of Motion (ROMP) clinic. She divides her week between NUPOC research duties and volunteering at the Edward Hines, Jr. VA Hospital and Jesse Brown VA Medical Center prosthetics departments.

Larissa Conner, CO

Before studying at NUPOC, Ms. Conner completed a BS in Engineering Physics (Taylor University, 2005), completed the Mastectomy Fitter course and was certified as an Orthotics Fitter. As an undergraduate, she worked as an intern at the Center for International Rehabilitation (CIR) where Dr. Wu developed the sand casting technique for prosthetic sockets.

Ms. Conner recalled, "*At CIR, I became familiar with the dilatancy concept of socket casting and developed a passion for P&O. I distinctly remember the day Dr. Wu showed the interns his sand casting system. I realized how this could change lives.*" Her internship sparked the impetus to pursue a career in P&O. Currently, she assists Dr. Wu in testing the Dilatancy-based System for Orthotic Fabrication. She conducts literature reviews; helps collect, extract and enter data; interprets results; and prepares material for presentation and publication.

Ms. Conner said, "*It is really an honor for me to work with Dr. Wu. I have learned so much from him. I think it is important to train people in other countries so they can help their citizens. P&O is established in the USA, but developing countries lack many resources and services. When I was a NUPOC-IS volunteer in Guatemala, I recognized the importance of providing accessible P&O care. I can help make a difference by improving my clinical skills, working in research and development, and transferring new P&O technologies*."

Originally from North Dakota, Ms. Conner has moved frequently throughout the Midwest and east coast to complete her training. Her busy schedule leaves little time for other activities, but she is training for a half-marathon this year. She learned how to knit from a college friend and enjoys it as a creative hobby, crafting unique sweaters, cowls, hats and blankets as gifts for her friends and family.

Ms. Conner concluded, "*I care about being a good clinician. I can see the global need for new technology in P&O and I want to help develop and transfer those technologies.*"

Fatone Co-Chairs Symposium at ISPO 2013

On February 5, 2013 **Stefania Fatone**, PhD, chaired an ISPO 2013 symposium with colleagues Andrew Hansen, PhD (Minneapolis VA Health Care System) and Elaine Owen, MSc, MBE (Child Development Centre, Bangor, Wales, UK) in Hyderabad, India. The symposium addressed clinical practice issues in orthotic and prosthetic treatment of the lower limb. Speakers focused on designs for ankle-foot orthosis-footwear combinations and lower limb prostheses that have direct relevance to current clinical practice and future research for both child and adult patients. Dr. Hansen spoke on "*Effective Rocker Shapes for Walking and Standing-Implications in P&O*". Ms. Owen spoke on "*The Importance of Segment Kinematics to Designing and Aligning AFO Footwear Combinations, for Stable Standing, First Steps and Walking*." Dr. Fatone spoke on "*Rocking with Orthotics*".

The PowerPoint slides for these presentations may be accessed on the NUPOC website: http://www.nupoc.northwestern.edu/news-publications/news/index.html#ISPO_2013_Handouts.

NUPOC Researchers Present at ISPO 2013

R. J. Garrick, PhD

NUPOC researchers **Steven A. Gard**, PhD, **Stefania Fatone**, PhD, BPO(Hons), **Yeongchi Wu**, MD, NUPOC doctoral graduate **Sara Koehler**, PhD, and doctoral candidate **Kiki Zissimopoulos**, MS, attended the 14th World Congress of the International Society of Prosthetics and Orthotics (ISPO) in Hyderabad, India, on February 4-7, 2013. NUPOC gave podium presentations, free papers, symposia and poster presentations about an extensive array of Prosthetics and Orthotics foci, including clinical outcome measures and new fabrication technology.

NUPOC researchers at ISPO site (from left) Yeongchi Wu, MD, Stefania Fatone, PhD, Kiki Zissimopoulos, MS, and Steven A. Gard, PhD.

NUPOC presented 15 research reports at the 14th World Congress of the International Society of Prosthetics and Orthotics in Hyderabad, India, February 4-7, 2013. Underline indicates the presenter.

Boutwell EV and **Gard SA.** *Investigation of In Vivo Prosthesis/Residual Limb Stiffness Using a Novel Impact Test Apparatus*. Free Paper.

From left, NUPOC Bioengineering graduates Sara Koehler, PhD, and Charles Wang, MS, and doctoral candidate Kiki Zissimopoulos, MS in the exhibit hall at ISPO 2013. Mr. Wang is an Ossur representative currently stationed in Shanghai.

Fatone S, Caldwell R, Komolafe O, Tucker K. *Subischial Sockets with Vacuum Assisted Suspension for Persons with Transfemoral Amputation*. Instructional Course.

Fatone S, Wood S, Caldwell R, Komolafe O, Chen W, Sun C, Hansen A. *Socket/Liner Interface Volume and Vacuum Pressure Decay in Persons with Transfemoral Amputations.* Free Paper.

Fatone S, Stine R, Rodriguez A, Gard S. *Spinal Motion during Walking in Persons with Unilateral Transfemoral Amputation with and without Low Back Pain*. Free Paper.

Fatone S, Wood S, Caldwell R, Komolafe O, Chen W, Sun C, Hansen A. (Presenter S Koehler) *Characterization of Mechanical and Electrical Vacuum Pumps for Use in Vacuum-Assisted Suspension*. Poster Presentation.

Owen E, Hansen A, **Fatone S.** (Chair: Fatone) *From Stable Standing to "Rock'n'Roll" Walking.* Symposium.

Gard SA, Su PF, **Lipschutz R**, Hansen AH. *Effect of Prosthetic Ankle Units on Roll-Over Shape Characteristics during Walking in Persons with Bilateral Transtibial Amputations*. Free Paper.

Gottipati P, Major MJ, Gard SA. (Presenter Y Wu.) *Dynamic Stability of Individuals with Transfemoral Amputations Walking with Varying Prosthetic Knee Alignment*. Poster Presentation.

Heinemann A, Ehrlich-Jones L, Connelly L, **Fatone S.** *Improving the Quality of Prosthetic and Orthotic Services with Process and Outcome Information*. Free Paper.

Koehler S, Lipschutz R, Stine R, Gard S. *Does a Mechanically-Demanding Task Exaggerate the Effect of Prosthetic Alignment for Persons with Transfemoral Amputation?* Free Paper.

Komolafe O, Caldwell R, Tucker K, Hansen A, Chen W, Sun C, Fatone S. *Stress Analysis of Different Rigid Frame Designs within a Flexible Transfemoral Prosthetic Socket*. Free Paper.

Major MJ, Stine R, Gard SA. (Presenter Y Wu.) *Lateral Trunk Flexion during Bilateral Transtibial Amputee Gait*. Poster Presentation.

Waldera K, **Heckathorne C,** Parker M, **Fatone S.** *Assessing the Prosthetics Needs of Farmers and Ranchers in the USA: Interview Results*. Free Paper.

Wu Y, Robinson C, Casanova H, **Michael J, Gard S**. *Development of a Low-Cost Dilatancy-Based Casting System for Fabrication of Ankle-Foot Orthoses: A Preliminary Report*. Free Paper.

Zissimopoulos A, **Gard SA, Stine R, Fatone S.** *Mediolateral Foot Placement during Post-Stroke Ambulation with and without an Ankle-Foot Orthosis*. Free Paper.

ISPO 2013 Presents the Yeongchi Wu International Educational Award

R. J. Garrick, PhD

On February 7, 2013, ISPO awarded the 2013 **Yeongchi Wu International Educational Award** to Mr. Sushant Veer (India, Department of Mechanical Engineering, IIT-Chennai) for his article "*Design of a Standing Wheelchair*." Annually, ISPO representatives select individual award recipients for developing a new or innovative P&O technique or product. This award recognizes contributions to the field of Prosthetics and Orthotics by innovators in lower income countries. **Yeongchi Wu**, MD, a NIDRR-funded researcher at NUPOC, is a recognized innovator and strong proponent of affordable, appropriate and ecologically sustainable P&O technologies for use in developing economies.

Read more about the Yeongchi Wu Prize: www.ispoint.org/news/indian-sushant-veer-winner-yeongchi-wu-prize-hyderabad-india.

2013 Dale Yasukawa Scholarship Annual Competition Opens

R. J. Garrick, PhD

The Dale Yasukawa Scholarship is open to all full-time candidates enrolled in the Northwestern University Prosthetics-Orthotics Center (NUPOC) P&O Certificate program. This $1,000 scholarship defrays registration fees, enabling NUPOC students to attend local meetings of the American Academy of Orthotists and Prosthetists. It also assists in purchasing texts, supplies and equipment necessary for study at NUPOC. Submit applications to the Orthotics & Prosthetics Activities Foundation (OPAF) office by May 1, 2013.

Dale Yasukawa completed his prosthetics training in the NUPOC Certificate course, treated patients of all ages, and completed service as immediate past president of the Midwest Chapter of the American Academy of Orthotists and Prosthetists prior to his death in 2001.

For more information, visit: www.opafonline.org/programs/scholarship/.

NUPOC NEWS

Fatone Presents Monthly Veterans Research Forum

Stefania Fatone, PhD, BPO(Hons), was invited to speak at the Jesse Brown VA Medical Center Monthly Veterans Research Forum (Chicago) on March 7, 2013. Dr. Fatone introduced the veterans to "*A New Socket for Persons with above Knee Amputation*" based on her research funded by the USA Department of Defense to develop a flexible subischial socket with vacuum assisted suspension for highly active persons with transfemoral amputation. The presentation generated intense interest among veterans about how the socket works, how it is fabricated and the most suitable candidates for its use.

Fatone Participates in OSR Panel

Stefania Fatone, PhD, BPO(Hons), was an invited speaker at the First Mondays Faculty Development Series panel discussion "*Working with the Northwestern Office of Sponsored Research (OSR)*" on April 1, 2013. This panel, chaired by David E. Lynch, Executive Director, Office of Sponsored Research (Chicago), informed first year faculty and postdoctoral fellows about requirements for grant submission; described OSR units with regard to pre- and post-award activities; and presented essential information about how to work with OSR during preparation and submission of grant proposals.

NUPOC in the News

The February 2013 release of *FSM Researcher*, issued by the Feinberg School of Medicine Research Office, features NUPOC researchers in the article, "*Understanding Disability and Its Mechanisms*" (pp. 1-2). Read about research projects conducted in Physical Medicine and Rehabilitation by Elliot Roth, MD; Thomas Schnitzer, MD, PhD; **Stefania Fatone**, PhD, BPO(Hons); and **Matthew Major**, PhD: http://www.feinberg.northwestern.edu/research/docs/newsletters/February2013.pdf.

Also, the March 13, 2013 edition of *My Northwestern Medicine* includes a link directly to the NUPOC website article about Senator Durbin's legislative announcement and its potential impact for NUPOC research and education programs. Go directly to the NUPOC website: http://www.nupoc.northwestern.edu/news-publications/news/index.html

Zissimopoulos Contributes to NU-Science in Society

Kiki Zissimopoulos, MS, a NUPOC doctoral candidate in biomedical engineering, presented three one-hour training sessions to Northwestern University students who volunteer as Science Mentors at the Science Club, an after-school science mentorship program at McCormick Boys & Girls Club. The Science Club and the mentorship program are part of Science in Society at Northwestern University. On September 15, 2012 Ms. Zissimopoulos presented "*Designing a Learner Centered Course*". On January 12, 2013, she presented "*Teaching Methods: How Will I Help My Students Meet the Learning Objectives?*" On April 6, 2013, she presented a session on "*Teaching and Learning Assessments*". The objective for all training sessions is to provide Science Club mentors with pedagogical training for teaching in a small group environment. NUPOC is committed to education, training and the dissemination of accessible science information.

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Meet International Scholar: Elisah Pietersma

R. J. Garrick, PhD

NUPOC welcomes International Scholar, **Elisah Pietersma**, BS, a Biomedical Engineering (BME) master's student at Delft Technical University (Netherlands). During her 10-weeks at NUPOC Ms. Pietersma is working collaboratively with Research Engineer **Craig Heckathorne**, MS, to design a durable, comfortable prosthetic socket for farmers and ranchers with transradial amputation. "*At NUPOC, I have reviewed different socket designs, fabrication techniques, and methods to make a quantified design. Sensitivity of sensors between the residual limb and the socket interface hindered measurement of pressures. These quantification issues cannot be resolved during my time at NUPOC, so I will use my industrial design background to design a socket.*" Ms. Pietersma will return to Delft to complete her graduate work under the mentorship of Dick Plettenburg, PhD. She expects to graduate in 2014 with a master's degree in BME and a specialization in Biomechatronics.

Elisah Pietersma

A native of north Friesland, she learned about structure, mechanics and building while working with her father, a specialist in design architecture and construction. Since childhood she enjoyed drawing and built electronic and motorized items. In high school she pursued technical studies, biology, Latin, and Greek. In university she specialized in Industrial Design, drawing both by hand and on computer. After completing her Bachelor's degree, Ms. Pietersma re-directed her skills toward creative, functional and aesthetic engineering solutions in BME. "*I really want to do something to help people, to create things that are useful for the world*." About her future, Ms. Pietersma said, "*I like research, but I may prefer to work in a corporate or commercial capacity.*" Ms. Pietersma intends to use her engineering skills to solve real-life problems and improve human lives.

For leisure, she enjoys running and takes annual ski trips to Switzerland. She has visited the major cities of Europe and reflected, "*Chicago is so different than any European city. The people are very polite here and I've enjoyed visiting local museums. I was delighted to see the Picasso exhibit*."

Welcome to NUPOC, Elisah!