



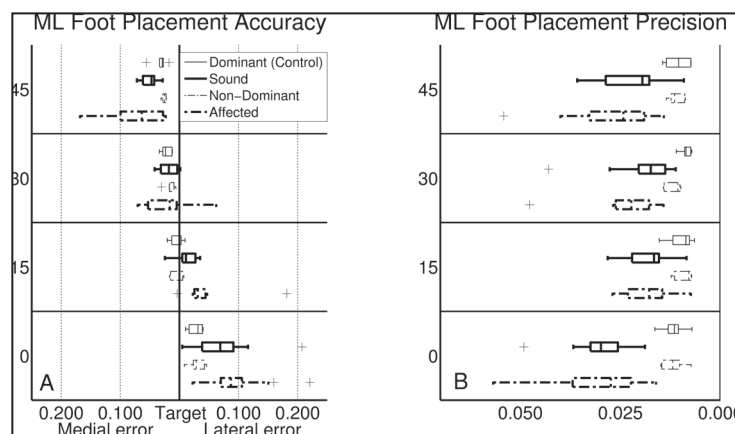
## Balance and Confidence during Post-Stroke Gait

Angelika N. Zissimopoulos, PhD

*This work was funded in part by the National Institute on Disability and Rehabilitation Research (NIDRR) Grant H133E08009 of the US Department of Education, the Orthotic and Prosthetic Education and Research Foundation Grant OPERF-2010-FA-1/2, and the Nicholson Fellowship. The opinions in this article are those of the grantee and do not reflect those of the US Department of Education or OPERF. Grantees appreciate the use of the Jesse Brown Veterans Affairs Medical Center Motion Analysis Research Laboratory.*

Stroke, the leading cause of serious, long-term disability in the United States<sup>1</sup>, occurs when an artery supplying the brain with key nutrients and oxygen becomes blocked or ruptures. Damage typically occurs on one side of the brain and results in neuromuscular impairments on the contralateral (i.e., opposite) side of the body, referred to as the affected or hemiplegic side<sup>2</sup>.

Abnormal gait biomechanics are common post-stroke and persist long after the initial neurological insult. Specifically, swing phase of the affected limb is often characterized by an equinovarus posturing of the foot and ankle complex (i.e., toe down (equinus) and tilted inward (varus)) and reduced knee flexion. These deficits increase effective leg length (LL) so that mid-swing toe clearance is inadequate on the affected



**Figure 1:** Boxplot of the reduced ML foot placement accuracy (A) and precision (B) for post-stroke subjects (n = 13) compared to control subjects (n = 6). Bold vertical lines within the box represent the median percent of foot strikes for each condition. The 25th and 75th percentiles of the data are graphically represented by the upper and lower edges of the box. Whiskers extend to data not considered outliers while crosses represent outliers.

side. Compensatory mechanisms, employed during swing phase to prevent tripping, yield abnormal swing phase biomechanics<sup>3</sup>.

The locomotor system prepares for a forthcoming mediolateral (ML) foot placement during the swing phase of the gait cycle<sup>4</sup>. ML foot placement is an important feature of locomotion because it redirects the lateral component of the body center of mass (BCoM) trajectory with each step. The ML component of

BCoM trajectory then remains within the base of support (BoS), loosely defined by the lateral borders of the feet<sup>5</sup>, averting a sideways fall. Therefore, the ability to prepare for and achieve an accurate ML foot placement is important for safe and efficient ambulation<sup>6-8</sup>. Abnormal swing phase biomechanics may result in reduced ML

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foot placement accuracy and precision with negative implications for balance during walking.

While swing phase compensations may improve mid-swing toe clearance, their use may negatively affect end point control of the foot and ultimately the accuracy of ML foot placement in persons post-stroke. The central goal of our research was to investigate ML foot placement accuracy and precision and their associations with abnormal swing phase biomechanics in individuals with chronic post-stroke hemiplegia. Additionally, we investigated whether correction of equinovarus using an ankle-foot orthosis (AFO) was associated with improved ML foot placement ability.

Individuals with chronic post-stroke hemiplegia who routinely used a non-rigid ankle-foot orthosis (AFO) were recruited for this study. To assess ML foot placement ability, individuals were instructed to walk with 4 different targeted step widths (0%, 15%, 30%, and 45% of the leg length to account for stature) that were delineated with tape on the laboratory floor. Researchers tested 13 chronic post-stroke individuals with and without an AFO and 6 able-bodied controls. The accuracy and precision of ML foot placement was quantified for each targeted step width condition.

We found that ML foot placement accuracy and precision were impaired bilaterally in post-stroke individuals compared to controls (Figure 1). The post-stroke population achieved a smaller range of step widths during level ground walking. Furthermore, AFO use did not significantly reduce compensatory swing phase movements or improve ML foot placement ability for any step width condition. The narrowest step width condition (i.e., 0% LL) revealed a unique finding: preferred walking speed, hip ab/adduction range of motion, and sound limb hip abduction strength were strongly associated with accuracy of affected limb ML foot placement. Future work is needed to continue to explore this finding with respect to the complex role of the hip during post-stroke locomotion.

Ultimately, balance during gait is multidimensional. This study focused on biomechanical contributions to balance, namely ML foot placement. However, in addition to motor mechanisms, balance requires the coordination of proprioceptive, cerebellar, vestibular, and cognitive mechanisms. AFO mediated improvements in confidence (a cognitive mechanism) have been reported post-stroke<sup>9, 10</sup>. However, the *perception* of ability, which is one aspect of AFO prescription, may be as important as actual ability in determining function and mobility<sup>11</sup>. While reports of improved balance confidence have been largely anecdotal, we conducted an investigation of the effects

of AFO use on self-efficacy using the Activities-Specific Balance Confidence (ABC) scale on the same cohort of subjects<sup>12</sup>. The ABC scale is a valid and reliable measure of self-efficacy in the post-stroke population. There was significant improvement in balance confidence with AFO use ( $p = 0.009$ ). Therefore, an AFO may influence the user's mobility through improved balance confidence, not just through biomechanical changes.

Despite decades of gait research that has focused on the post-stroke population<sup>2</sup>, the mechanisms underlying locomotor functioning post-stroke are not fully understood. This incomplete understanding ultimately limits the efficacy of locomotor-related rehabilitative efforts. For example, about 30% of people over the age of 65 who survive an ischemic stroke are unable to walk without assistance at six months post-stroke<sup>13</sup>. Our research recognizes that locomotor deficits post-stroke are a manifestation of impaired motor control, compensatory mechanisms, system biomechanics, and psychological factors. Within this multidimensional context, our work contributed new knowledge related to balance capabilities in post-stroke individuals by investigating ML foot placement ability and balance confidence.

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## NUPOC Welcomes First MPO Class

R. J. Garrick, PhD

NUPOC has launched the **Master's in Prosthetics & Orthotics (MPO)** with a full cohort of MPO students who attended the NUPOC Orientation on June 6 through 8, 2013. Students met their classmates and discussed educational expectations and standards with faculty.

The Orientation included a tour of NUPOC, completion of important administrative tasks such as issuance of Net ID, NU WildCards and laptop computers that will be their core educational delivery medium during the distance learning courses. Students attended Tech Boot Camp and seminars with Student Services. The group enjoyed time at Navy Pier, where they embarked on a mid-day cruise on Lake Michigan.

NUPOC Director **John Michael**, CPO, MEd, reported excellent response, with 48 highly qualified students who were accepted into the NUPOC MPO. The inaugural MPO class consists of 28 men and 20 women



The inaugural MPO class takes time to meet their colleagues at the Northwestern University Prosthetics-Orthotics Center (NUPOC).

who hail from 25 of the 50 states in the USA. Mr. Michael characterized the inaugural MPO class, *"This cohort is nearly all millennials from top tier universities. Their undergraduate majors include biomedical engineering, kinesiology, and other sciences that have clinical exposure. These statistics are similar to other programs in the*

*Feinberg School of Medicine."*

Assistant Professor **Robert Lipschutz**, BSME, CP, who teaches biomechanics at NUPOC, reported that the MPO students are highly interactive and responsive, *"I received more than 350 response threads within a single week. They are a keen and highly committed group."* Currently, the MPO cohort are participating in online courses from the convenience of their homes before they return to NUPOC in January 2014 to conduct their on-site practicum in P&O.

## Zissimopoulos Accepts Position at Purdue University

R. J. Garrick PhD

**Angelika N. Zissimopoulos**, PhD, has accepted a position as an Instructional Developer in the Center for Instructional Excellence (CIE) at Purdue University (Lafayette, IN). At CIE, Dr. Zissimopoulos will work within the program Instruction Matters Purdue Academic Course Transformation (IMPACT), part of the nexus that includes the Purdue Libraries, Discovery Learning Research Center, Information and Technology, Office of the Provost and the Purdue Extended Campus.



Kiki Zissimopoulos, PhD

Dr. Zissimopoulos will support the teaching and learning mission of Purdue University by

providing professional and consulting services to graduate students, teaching assistants, faculty, instructional staff, and professional staff. She will help University personnel to develop training programs designed to promote best practices in teaching and learning. Dr. Zissimopoulos said, *"I look forward to working collaboratively with faculty, instructors and students on projects that include curriculum development, instructional design, the integration of technology tools in teaching and learning, and the evaluation of instructional outcomes."*



## Michael Dillon, PhD, BPO(Hons), Visits NUPOC

R. J. Garrick, PhD

NUPOC welcomed Michael Dillon, PhD, BPO(Hons), Senior Lecturer at the National Centre for Prosthetics and Orthotics, La Trobe University, Melbourne, Australia on July 1-3, 2013. Dr. Dillon has developed significant experience as a teacher of clinical and research subjects and has been instrumental in the design of the evidence based practice and research curriculum within the new Master's course. During his visit to NUPOC, Dr. Dillon presented formal and informal presentations, mock classes, discussions, and the weekly Grand Rounds in the Department of Physical Medicine and Rehabilitation.

La Trobe University is Australia's largest provider of health sciences education and its only prosthetics and orthotics (P&O) program. Transitioning to the baccalaureate degree in the early 1990s established a strong, academic P&O education. In 2006, the Faculty of Health Sciences launched a faculty-wide curriculum reform designed to: 1) increase the number of graduates by 30% to meet the projected demand for health sciences professionals; 2) educate health professionals to the Master's level; 3) reduce face-to-face instruction by 25%; and 4) shift to an enquiry-based learning model. Broad scale curriculum reform offered opportunities to redefine the skills and attributes required of future P&O clinicians and how P&O educators could facilitate their learning.

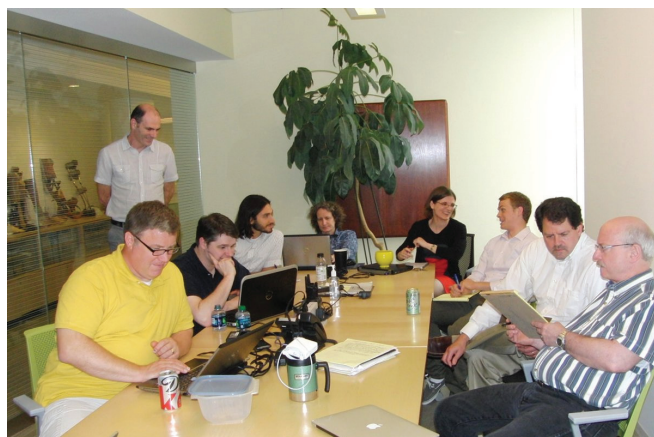
Dr. Dillon highlighted discrete aspects of the curriculum design process and discussed what La Trobe educators learned from working with expert educational design-



Michael Dillon, PhD, BPO(Hons)

ers. He addressed the challenges of ongoing refinements to the MPO program following graduation of the second Master's cohort. His presentation opened a dialogue that engaged NUPOC educators, clinicians and researchers who shared their experiences and discussed ideas. During a mock class conducted for NUPOC personnel, Dr. Dillon demonstrated examples of how educators can weave research into clinical teaching. The mock class prompted insightful exchanges with NUPOC education faculty. Dr. Dillon presented a follow-up discussion of 1) assessing student performance; 2) evaluation techniques and assessment tools specific to P&O; and 3) use of task trainers for practicums.

As a capstone presentation during his time at NUPOC, Dr. Dillon presented the PM&R Grand Rounds on July 3, 2013. His address, *"Do We Pay Heed to the Purported Benefits of Partial Foot Amputation at the Expense of Minimizing Complications?"*, prompted active discussion. PM&R physicians and other professional rehabilitation personnel responded positively with questions and comments based on clinical practice and outcomes.



Michael Dillon, PhD (standing) conducts a training session with NUPOC researchers and educators.



Michael Dillon, PhD (center) presented PM&R Grand Rounds at RIC. He stands with PM&R Professor Elliot Roth, MD (left) and Stefania Fatone, PhD (right).

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NUPOC education and research personnel enjoyed discussing the transition to the Master's curriculum and exploring opportunities for further research. Dr. Dillon said, *"I don't think that, as educators or researchers, we engage in these sorts of thoughtful discussions often enough. I found it helpful to realize that many of the challenges we face are universal and to learn from NUPOC faculty how these challenges are being addressed. I hope my visit leads to further discussion."* NUPOC looks forward to future collaborative interactions with Dr. Dillon in areas of P&O research and education.

## NUPOC Presents Research at AAOP Midwest Chapter Meeting

R. J. Garrick, PhD

NUPOC researchers gave five presentations at the Midwest Chapter of the American Academy of Orthotists & Prosthetists (AAOP) annual Meeting and Scientific Session at Lake Geneva, WI, on May 30 through June 1, 2013.

**Stefania Fatone**, PhD, BPO(Hons), noted that the meeting featured interesting presentations on new products and fabrications issues, "NUPOC presentations were well attended and well received. Both my presentations generated a lot of questions." Terry Supan, CPO, who attended the meeting, remarked, "I heard all of the NUPOC talks this weekend in Wisconsin and was very impressed by the quality of the work being done, its relativity to the profession and the quality of the presenters and presentations."

The following works, with speakers' names underlined, were presented at the Midwest Chapter AAOP Meeting:

**Tucker K, Fatone S**. (2013) Development of a Three-Dimensional Simulation Tool to Investigate the Effects of



Christopher Robinson, CPO, MBA, MS, discusses aspects of dilatancy technology at AAOP Midwest Chapter meeting.

Ankle Foot Orthotic Joint Misalignments.

**Fatone S, Stine R**, Tillges R. (2013) Effect of Socket Characteristics on Coronal Plane Stability during Gait in Persons with Unilateral Transfemoral Amputation.

**Komolafe O, Caldwell R, Fatone S**. (2013) An Analytic Approach to Assessing

Transfemoral Socket Flexibility.

**Major M, Stine R, Gard S**. (2013) The Effects of Walking Speed and Prosthetic Ankle Adapters on Upper Extremity Dynamics and Stability-related Parameters in Bilateral Transtibial Amputee Gait.

**Wu Y, Robinson C, Casanova H, Michael J, Conner L, Gard S**. Demonstration of Dilatancy Casting for Transtibial Socket and Foot Orthosis: A Reverse Innovation of Appropriate Prosthetic/Orthotic Technologies.

See more information about the AAOP Midwest Chapter, including the Gunter Gehl Scholarship, at: [www.mwcaaop.org/meetings--events.html](http://www.mwcaaop.org/meetings--events.html).

## Dilatancy Project Team Presents Workshops

R. J. Garrick, PhD

**Yeongchi Wu**, MD, and his dilatancy project research team presented two 2-hour workshops on June 1, 2013 at the AAOP Midwest Chapter meeting: *Demonstration of Dilatancy Casting for Transtibial Socket and Foot Orthosis: A Reverse Innovation of Appropriate Prosthetic/Orthotic Technologies*.

Dr. Wu presented a lecture-demonstration of the dilatancy transtibial system that generated intense interest among the audience. Dilatancy project team members **Chris Robinson**, CPO, presented historical background information about dilatancy for P&O, international knowledge transfer, and the pre-clinical evaluation of orthotic fabrication; and **Larissa Conner**, CO, presented technical information and a demonstration of the dilatancy-based foot orthotic

system.

Dr. Wu noted that P&O dilatancy fabrication offers a *"better, cheaper and/or faster, green technology [that] has improved the productivity and quality of P&O services in developing countries facing challenges...of manpower shortages and dated manufacturing techniques."* Ten individuals who completed the workshop at AAOP also signed up to attend additional on-site training in dilatancy fabrication at NUPOC.

Dr. Wu and the dilatancy project research team also presented a similar lecture-demonstration to the Pediatric O&P Department headed by Bryan Malas, MHPE, CO, CPed, Director Orthotics/Prosthetics, at the Lurie Children's Hospital on May 29 and June 26; and began training sessions on July 16, 2013.



Larissa Conner, CO (left) and Yeongchi Wu, MD (right) are presenting a series of workshops to introduce the potential of dilatancy technology.



## National Student Leadership Conference Learns about Biotech at NUPOC

R. J. Garrick, PhD

On August 5, 2013, NUPOC presented *Biotechnology: High Tech, Low Tech, the Right Tech!* for 40 students from the National Student Leadership Conference (NSLC) Biotechnology Group who learned about human biomechanics and gait with respect to prosthetics and orthotics (P&O), participated in research demonstrations and used several analog and digital biometric devices.

**Oluseeni Komolafe**, PhD, established the conceptual basis for the activities with his presentation, *Understanding the Biomechanics of Human Gait and Its Application to Prosthetic and Orthotic Devices*.

**Desmond Masterton**, CO, MS, CPed, presented *Foot Impressions: Using the Harris Mat to Image Analog Plantar Pressure Distribution*. NSLC students applied information about human biometrics by capturing static plantar pressure foot impressions using Harris Mats. NUPOC personnel, **Erin Boutwell**, MS, **Pranitha Gottipati**, PhD,



NSLC students worked in teams to examine their plantar pressure distribution impressions.



NSLC students learned about gait and human motion analysis from demonstrator Sam Kwak (center) and Rebecca Stine (not shown), who explained the system and kinds of human motion data that can be collected.

**Oluseeni Komolafe**, PhD, **Brian Robillard**, BS, and **Sam Kwak** helped the students obtain accurate plantar impressions and Mr. Masterton helped them interpret their plantar pressure data. Each student received a goniometer provided by Scheck and Siress, and learned how to measure range of motion of the knee.

Ms. Boutwell discussed the PEDAR system, an in-shoe, dynamic plantar pressure distribution measuring system,

and compared it to the analog information students obtained using Harris Mats. NUPOC Research Extern Sam Kwak demonstrated human biomechanics and gait while **Rebecca Stine**, MS, discussed features of the force plates and the Motion Capture System located in the Jesse Brown VA Medical Center Motion Analysis Research Laboratory.

**Yeongchi Wu**, MD, and **Christopher Robinson**, CPO, MBA, MS, ATC, FAAOP, team-presented the final module, *Dilatancy Casting: An Innovative & Translational Biotechnology*. Dr. Wu emphasized the need for better, cheaper, faster and greener technology in prosthetics and orthotics. Dilatancy technology, which is applying vacuum to granules to capture 3-dimensional shape, ensures an environmentally sustainable technology with little waste and appropriate application in resource-limited settings. Noting that millions of people in the developing world need affordable P&O devices and services, Dr. Wu discussed the use of dilatancy technology for human prosthetics and orthotics and also its proven translational application in restoring mobility for two Thai elephants with amputated limbs. Following a demonstration of the speed and accuracy with which dilatancy technology can generate negative and positive molds, students tested the casting materials.

NSLC students came from as far away as California, Texas, and Florida. Other attendees included Executive Director Rick Duffy (NSLC), Site Director David Lowitz (NSLC), teaching assistants; Senior Associate Director for Major Gifts Cynthia Horvath Garbutt, JD (FSM Office of Development and Alumni Relations) and Director of Donor Relations Kathryn Swary (FSM Global Health Initiative).

**R. J. Garrick**, PhD, designed and developed the educational module, *Biotechnology: High Tech, Low Tech, the Right Tech!*

**NUPOC APPRECIATES SCHECK AND SIRESS FOR THEIR  
GENEROUS SUPPORT OF THIS EDUCATIONAL PROGRAM.**

*Capabilities* (ISSN 1055-7156) is published quarterly by the Northwestern University Rehabilitation Engineering Research Center for Prosthetics and Orthotics.

**Director:** Steven A. Gard, PhD  
**Editor:** R. J. Garrick, PhD

This work is funded by the National Institute on Disability and Rehabilitation Research (NIDRR) of the Department of Education under grant number H133E080009. The opinions expressed in this publication are those of the grantee and do not necessarily reflect those of the Department of Education.

Subscription is free to all individuals and institutions interested in prosthetics and orthotics. Issues are archived on the NUPOC website, [www.nupoc.northwestern.edu](http://www.nupoc.northwestern.edu). Send subscription requests and address changes to: *Capabilities*, Northwestern University RERC, 680 North Lake Shore Drive, Suite 1100, Chicago, IL 60611.

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## NUPOC Presentations at 3<sup>rd</sup> MRS Training Day



Mr. Robillard discusses his work on the rapid prototyping of prosthetic sockets.

NUPOC researchers presented posters at the 3<sup>rd</sup> Annual Musculoskeletal Research Sciences Training Day sponsored by Physical Therapy and Human Movement Sciences at the Feinberg School of Medicine on August 27, 2013.

**Erin Boutwell, MS**, presented "*Effect of Stiffness on Impact Forces during Walking and Sudden Limb Loading*", co-author **SA Gard**.

**Pranitha Gottipati, PhD**, presented "*Dynamic Stability of Individuals with Transfemoral Amputations Walking with Varying Prosthetic Knee Alignments*", co-authors **MJ Major** and **SA Gard**. **Matthew Major, PhD**, presented "*Lateral Trunk Flexion during Bilateral Transtibial Amputee Gait*", co-authors **SA Gard** and **RL Stine**. **Brian Robillard, BS**, presented "*Fabricating Prosthetic Sockets with Rapid Prototyping Technology*", co-authors **O Komolafe**, **R Caldwell** and **S Fatone**.

See more information about Ms. Boutwell's research and other work presented at the 2013 MRS Training Day at this link: [www.feinberg.northwestern.edu/news/2013/08/MRS\\_Training\\_Day.html](http://www.feinberg.northwestern.edu/news/2013/08/MRS_Training_Day.html).

## NUPOC News

### Publications

**Gottipati P, Fatone S**, Koski T, Sugrue, P, Ganju A. "Crouch Gait in Persons with Positive Sagittal Spine Alignment Resolves with Surgery." Accepted for publication in *Gait & Posture*.

Heinemann A, Connelly L, Ehrlich-Jones L, **Fatone S**. "Outcome Instruments for Prosthetics Clinical Applications." Invited Paper submitted to *Physical Medicine and Rehabilitation Clinics of North America*.

**Johnson WB, Fatone S, Gard SA**. "Modeling the Effects of Sagittal-Plane Hip Joint Stiffness on Reciprocating Gait Orthosis Assisted Gait." Accepted for publication in *Journal of Rehabilitation Research and Development*.

**Major M, Fatone S**, Roth E. "Validity and Reliability of the Berg Balance Scale for Individuals with Lower Limb Amputation." Accepted for publication in *Archives of Physical Medicine and Rehabilitation*.

Prenton S, Kenney L, Cooper G, **Major MJ**. "A Sock for Foot-Drop: A Preliminary Study on Two Chronic Stroke Patients." Accepted for publication in *Prosthetics and Orthotics International*.

### Presentations

**Stefania Fatone, PhD**, co-authored two presentations presented at PM&R Grand Rounds: (1) "Do We Pay Heed to the Purported Benefits of Partial Foot Amputation at the Expense of Minimizing Complications?" presented by Michael Dillon, PhD, on July 3, 2013. (2) "Enhancing Healthcare Services with Process and Outcome Information" presented by Linda Ehrlich-Jones, PhD, on July 31, 2013.

**Masterton D**. "Predictors of Student Success in a Blended Learning Program." Presented at the 10th Annual Sloan Consortium Blended Learning Conference and Workshop, Milwaukee, WI, on July 8-9, 2013.

### Meetings

**Stefania Fatone, PhD**, and **John Michael, CPO**, were invited to attend a meeting hosted by the American Academy of

Orthotists and Prosthetists SSC Planning Conference held in Rosemont, IL, on July 26-27, 2013.

**Steven A. Gard, PhD**, and **Stefania Fatone, PhD**, BPO(Hons.) attended the annual National Institute on Disability and Rehabilitation Research (NIDRR) RERC Project Directors' meeting in Alexandria, VA, August 8-9, 2013.

### Grant Awards

**Gard S** and **Major M**. "Fall Risk and Prosthetic Influence on Gait Biomechanics in Upper Limb Amputees." Received notification of intent to fund by Department of Veterans Affairs, Rehabilitation Research & Development Service.

### Grant Submissions

**Fatone S**. Co-investigator, "Wireless Epidermal Sensing & Control Architecture for Prostheses (WISP)." Defense Health Program SBIR Phase I application, submitted June 2013. PI on the project is Barry Ives at mc10 Inc.

**Fatone S**. Co-Principal Investigator, "Interface Monitoring System to Promote Residual Limb Health." NSF Smart and Connected Health Program application, submitted June 2013.

**Gard S** and Casanova H. "Evaluation of a Vacuum-Based Impression and Alignment Device (V-BIAD)." Submitted to Department of Veterans Affairs, Rehabilitation Research & Development Service, June 2013.

**Gard S**. "Development and Evaluation of the Ground Control Shoe." Submitted to Department of Veterans Affairs, Rehabilitation Research & Development Service, June 2013.

**Fatone S** and **Gard S**. "RERC for Individual Mobility and Manipulation in Prosthetics and Orthotics." Submitted to NIDRR, August 12, 2013.

**Gard S**. "Effect of Prosthesis Stiffness on Impact Force during *In Vivo* Step Loads and Gait." Submitted to the Department of Veterans Affairs.

**Major M**. "Sensory-Motor Mechanisms Underlying Fall Risk in Transtibial Amputees." Submitted to the Department of Veterans Affairs.

## Capabilities

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## RETURN SERVICE REQUESTED

### NUPOC Welcomes Rush Occupational Therapy (OT) Graduate Students

R. J. Garrick, PhD

NUPOC hosted an educational program and site visit for graduate students in the Rush Occupational Therapy Program. **Edward Grahn**, BSME, Associate Director of NUPOC, and **R. J. Garrick**, PhD, welcomed Linda Olson, PhD, OTR/L, Assistant Professor, and 32 graduate OT students who toured the NUPOC education and research facilities.

**Rebecca Stine**, MS, introduced concepts of human motion analysis and **Dilip Thaker**, Instrument Maker, explained his role in making fine-tolerance metal components in support of research conducted at NUPOC. **Stefania Fatone**, PhD,



Rush OT graduate students examine a cable-operated arm prosthesis.



Rush OT graduate students attended an educational program and site visit at NUPOC.

**BPO(Hons)**, provided an overview of research and development projects, training programs, and knowledge dissemination activities conducted at the center. **Chris Robinson**, CPO, MBA, MS, ATC, FAAOP, presented a survey of upper limb orthoses and their appropriate clinical applications. **Craig Heckathorne**, MS, reviewed representative upper limb prostheses, including body-controlled and those controlled by electromyographic (EMG) signals transmitted from muscles in the residual limb. Students enjoyed the opportunity to examine and manipulate a variety of prosthetic arms and terminal devices.

As part of its mission, NURERC provides educational programs and disseminates information about P&O research and education to consumers, professionals, and students in applied health care and other disciplines.