NORTHWESTERN UNIVERSITY

Capabilities

Communicating the Science of Prosthetics and Orthotics

Volume 20, Number 1, Winter 2012

Portable Equipment and Clinical Collaboration Enable Collection of Off-Site RGO Gait Data

Brett Johnson, PhD

This research is supported by the National Institute on Disability and Rehabilitation Research (NIDRR) of the U.S. Department of Education under grant number H133E080009. The opinions expressed are those of the grantee and do not necessarily reflect those of the Department of Education and do not constitute endorsement by the Federal Government.

One of the biggest challenges in rehabilitation research is collecting data from human subjects. Small, diverse, clinical populations make the recruitment of large, homogenous sample populations for rehabilitation research projects difficult. I wrestled with this challenge while studying the effects of increased hip joint stiffness on Reciprocating Gait Orthoses (RGOs) during my graduate work at the Northwestern University Prosthetics-Orthotics Center (NUPOC).

Data are collected on-site for much of the research conducted at NUPOC. Our facilities offer many sophisticated instruments that measure human movement, including a marker-based motion capture system that quantifies joint angles in three dimensions and force plates that measure ground reaction forces and their center of pressure. The equipment used for these types of measurements cannot be transported to use off-site.

Physical distance from NUPOC can be a significant barrier that prevents potential research subjects from participating in our studies. I encountered a number of potential research subjects who, for a variety of reasons, were unable or unwilling to travel to NUPOC to participate in my research. Therefore, I had to find a way to take the research to them. I needed instruments that were portable. Since portable instruments cannot measure the wide variety of variables that can be measured in-house at NUPOC, I had to identify the main variables I wanted to measure and then identify the instruments I would need to measure those variables.

Leanne LaChance, CO (left), with researcher and author William (BJ) Johnson, PhD (right), at Wright & Fillippis in Michigan.

RGO-assisted gait requires the use of walking aides such as crutches to accomplish reciprocal ambulation and has been documented to be an inefficient way to walk in terms of metabolic energy. Previous research on the effects of hip joint stiffness on RGO-assisted gait, while limited, suggested that increased hip joint stiffness may decrease the forces exerted by the arms during walking. For my research, I hypothesized that reducing loads on the arms could potentially reduce the high energy expenditure of RGO-assisted gait. However, increasing hip joint stiffness would also make hip joint flexion more difficult; and as a result, RGO users would likely reduce their hip motion. Such a reduction in hip motion would likely decrease walking speed, which would potentially increase the energy required to walk. I wanted to determine if there was an optimal hip joint stiffness where the benefits of reduced arm loading on energy expenditure would outweigh the detrimental effects of decreased walking speed. To answer this question, I needed to measure four variables: 1) the magnitude of the forces exerted through RGO users' arms, 2) the range of hip motion, 3) the walking

Continued on page 2

Continued from page 1

speed, and 4) the oxygen cost (i.e., energy expenditure).

Portable equipment that could measure some of these variables was available through NUPOC. We already possessed a Cosmed K4b^2 portable spirometer that could measure oxygen cost. Additionally, the Cosmed included a timer and marker mechanism that could be used to calculate walking speed. To measure hip motion and the forces exerted through the arms, I had to design and build my own portable equipment. To measure hip motion, I designed a simple, single-axis goniometer that could be easily attached and removed from a subject's RGO. With the assistance of my NUPOC colleagues, **Edward Grahn**, Engineer, and **Dilip Thaker**, Instrument Maker, I also instrumented a set of crutches with miniature load cells to measure the forces exerted through RGO users' arms. The goniometer and load cells required electrical power, and the signals from the load cells required amplification. To address these needs, my NUPOC colleague, **Craig Heckathorne**, MSc, Research Engineer, helped me design an amplifier and power supply that ran on 9-volt batteries, thus ensuring that the equipment could operate in areas that did not have power outlets.

Figure 1: Subject wearing portable instrumentation for measuring gait.

I also needed equipment that would allow me to change the stiffness of a RGO's hip joints. I wanted a device that could attach to a pre-existing RGO without damaging the orthosis. In this way, I could perform my experiments using the subjects' own RGO, and did not need to fabricate a test orthosis. Again, with the assistance of Edward Grahn, I designed a set of adjustable clamps that could be attached to different kinds of RGOs. These clamps were then used to attach springs across a RGO's hip joints, allowing me to control the stiffness of the joint by changing the springs.

This portable equipment enabled me to collect data outside of NUPOC. For this study, I focused my subject recruitment efforts on orthotists who were located in the Midwest and requested their assistance in recruiting RGO users who ambulated with crutches. Orthotists such as **Leanne LaChance**, CO, from Wright & Fillipis, Inc. in Michigan, and **George Keller**, CO, of Keller Orthotics, Inc. in Chicago, IL, were instrumental in my efforts to recruit subjects for this study.

My first data collection trip took me and my NUPOC colleague, **Stefania Fatone**, PhD, BPO(Hons), to Ms. LaChance's clinic in Madison Heights, MI. This trip provided me opportunities to collect data for my experiment and to test the capabilities of the custom-designed portable equipment. Upon arrival, we set up our equipment and then met with the subjects and their parents to obtain their informed consent. After we fitted each subject with the measuring instruments (Figure 1), we asked them walk 40 m along an indoor route for four different trials. Subjects used a different hip joint stiffness for each trial. For the baseline trial, subjects walked using their RGO's regular hip joint stiffness, and for the three remaining trials, the hip joint stiffness was increased by varying degrees. Electronic signals from the goniometer and crutches were transmitted to a laptop computer by a 10 m cable that was carried behind the subject by one of the researchers. So that we could later calculate walking speed, we marked 10 m intervals along the 40 m route and used our portable spirometer to mark the duration of time that each subject needed to traverse these intervals.

The results of these off-site data collection sessions using custom-designed and fabricated portable

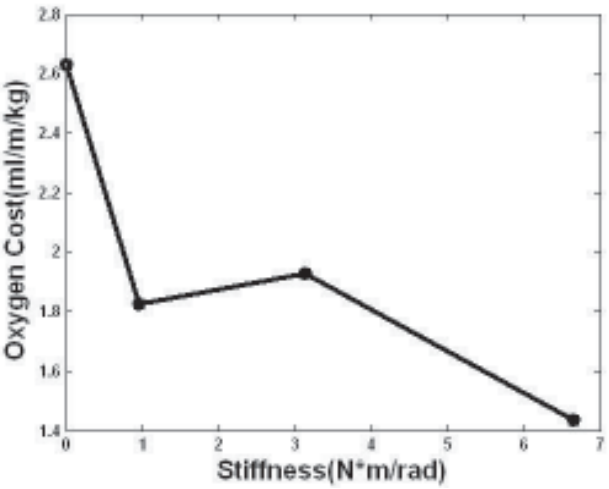

Figure 2: Graph shows calculated oxygen cost (i.e., energy expenditure) for a single subject plotted against hip joint stiffness.

Continued on page 3

Continued from page 2

equipment suggest that increasing a RGO's hip joint stiffness may help RGO users walk more efficiently. One of the two subjects measured to date experienced a 45% decrease in oxygen cost while walking with a stiffer hip joint, thus providing some preliminary support for my hypothesis (Figure 2). Contrary to my expectations, this decrease in oxygen cost was accompanied by an *increase* in walking speed. Originally, I hypothesized that subjects' walking speed would decrease as hip joint stiffness increased and hip range of motion decreased; however, this subject walked faster for each of the increased stiffness conditions, even though the hip range of motion decreased. This increase in walking speed may be the result of an increase in cadence (i.e., steps/minute).

This subject had not ambulated with crutches in several years, and she struggled visibly to take steps when walking in the baseline condition. However, after we attached springs to the subject's RGO, she appeared to take steps with less effort and at a higher frequency. A possible explanation for this behavior is that stiffer hips make it easier to walk by preventing RGO users from taking relatively large steps. We have observed that RGO users sometimes struggle after taking a large step. Large steps increase the distance over which the trunk needs to be elevated using the arms and crutches in order to position itself over the stance hip. Increased hip joint stiffness limits the RGO users' step length by constraining their hip motion. This analysis is based on data from one subject. Obviously, more research is needed to confirm these findings.

Although portable research experiments cannot measure as many variables as a motion analysis laboratory, we can conduct studies that are designed to measure a focused set of variables. Portable research equipment helps us address the challenges of subject recruitment by broadening the geographic area over which we recruit subjects, so that we have a larger population from which to recruit. Regardless of whether research is conducted in-house at NUPOC or out in the community, we rely on collaborations with clinicians to help identify and recruit subjects. With the invaluable assistance of clinicians we can conduct research aimed at improving the quality of life of persons who use prostheses and orthoses.

NUPOC and the author appreciate Leanne LaChance, CO (Wright and Fillipis); George Keller, CO (Keller Orthotics, Inc.); Luciano Dias, MD (the Rehabilitation Institute of Chicago); and Gerald Harris, PhD, Joe Krzak, PhD, and Adam Graf (Shriners Hospital for Children, Chicago) for their assistance in subject recruitment.

William Brett Johnson, PhD, Successfully Defends Dissertation

R. J. Garrick, PhD

William Brett (BJ) Johnson, PhD, successfully defended his doctoral dissertation, *Modeling the Effects of Hip Joint Stiffness on RGO-Assisted Gait*, submitted in the field of Biomedical Engineering in the Robert R. McCormick School of Engineering and Technical Science at Northwestern University. Dr. Johnson conducted his defense at NUPOC before a panel headed by his advisors **Steven A. Gard**, PhD, **Stefania Fatone**, PhD, BPO(Hons), and others.

Dr. Johnson investigated methods of improving Reciprocating Gait Orthosis (RGO) assisted gait. He designed and built a Lower Limb Paralysis Simulator (LLPS) that permits able-bodied subjects to model RGO-assisted gait. His project simultaneously evaluated the LLPS's efficacy in modeling RGO-assisted gait and investigated how changes in hip joint stiffness may improve efficiency in RGO-assisted gait. Dr. Johnson's results showed that LLPS users demonstrated distinguishing features of RGO-assisted gait. Decreased hip joint stiffness in the coronal plane increased walking speed. The study identified optimal hip joint stiffness in the sagittal plane that maximized LLPS users' walking speed, while minimizing their energy expenditure.

BJ Johnson, PhD

Congratulations, BJ!

Shenan Hoppe-Ludwig, CO, Joins NUPOC

R. J. Garrick, PhD

NUPOC is delighted to welcome **Shenan Hoppe-Ludwig**, CO, as the newest professional who will instruct and assist the Blended Learning Program. Ms. Hoppe-Ludwig completed the NUPOC Certificates in Prosthetics (2011) and Orthotics (2008), and her residency (2010) at MD Orthotic & Prosthetic Labs in Brookfield. Subsequently, she achieved her ABC Certification and Illinois License in Orthotics.

NUPOC welcomes Shenan Hoppe-Ludwig, CO!

Ms. Hoppe-Ludwig has multidisciplinary skills that enhance her instructional and practice skills in Orthotics. Her professional experience prior to working in P&O includes work as a Physical Medicine Technician and EMG Technician. Experienced in inpatient, outpatient, and wound clinics, Ms. Hoppe-Ludwig just returned from the December 2011 NUPOC International Service (NUPOC-IS) P&O outreach trip to Zacapa, Guatemala, where she contributed her clinical skills to improving mobility in an underserved population.

When time allows, she enjoys gardening, cooking, and spending time outdoors. She is an avid supporter of the arts and enjoys classic film. An enthusiastic and congenial team worker, Ms. Hoppe-Ludwig is generous with her time and energy.

Welcome to NUPOC, Shenan!

Learn more about NUPOC-IS at:
www.nupoc.northwestern.edu/education/NUPOCInternationalService/nupoc_is_overview

NUPOC NEWS

Grant Submissions continued from page 7

Gard, SA and **Heckathorne, CW**. "Force Feedback to Improve Performance of Transradial Prosthesis Users." Submitted to the National Institutes of Health (NIH) for the October 2011 due date.

Gard, SA and **Zissimopoulos, K**. "Frontal Plane Dynamic Stability in a Chronic Post-Stroke Population." Submitted to the National Institutes of Health (NIH) for the October 2011 due date.

Gard, SA. "Effect of Prosthetic Foot and Ankle Stiffness on Standing and Walking." Submitted to the Department of Veterans Affairs for the December 2011 due date.

Gard, SA and **Boutwell, E**. "Effect of Prosthetic Compliance on Shock Absorption and Proprioception." Submitted to the Department of Veterans Affairs for the December 2011 due date.

Gard, SA and **Casanova, H**. "Evaluation of a Vacuum-Based Impression and Alignment Device (V-BIAD)." Submitted to the Department of Veterans Affairs for the December 2011 due date.

Gard, SA and **Heckathorne, CW**. "Force Feedback to Improve Performance of Transradial Prosthesis Users." Submitted to the Department of Veterans Affairs for the December 2011 due date.

Gard, SA and **Zissimopoulos, K**. "Frontal Plane Dynamic Stability in a Chronic Post-Stroke Population." Submitted to the Department of Veterans Affairs for the December 2011 due date.

Gard, SA and **Major, MJ**. "Incidence and Covariates of Falls in Individuals with Upper Limb Amputations." Submitted to the Department of Veterans Affairs for the December 2011 due date.

Fatone, S. (Subaward PI) "An Active Ankle Foot Orthosis (AAFO) as an Assistive and Rehabilitation Device." Pre-proposal submitted to the DOD Peer Reviewed Orthopaedic Research Program Translational Research Partnership Award for the September, 2011 due date. (PI Mohammad Elahinia, PhD, University of Toledo).

NUPOC Tours: The Potential to Change Lives

R. J. Garrick, PhD

Career-minded Crystal Lake South High School (CLSHS) science students visited NUPOC on November 29 to learn about careers in Prosthetics and Orthotics (P&O) and biomedical and rehabilitation engineering.

Career-minded Crystal Lake South High School (CLSHS) science students visit NUPOC.

CLSHS seniors have visited NUPOC for education and research annually since 2007. This year, 45 science students were accompanied by CLSHS science instructors Mr. **Rich Marrano** and Mr. **Brian Akenas**, health and PE instructor Ms. **Beckie Stevenson**, and career advisor Ms. **Michelle Fitzgerald**. Mr. Marrano, who initiated these tours in 2007, noted, *"I've heard that some students enroll in my class especially to attend the educational tour of NUPOC!"*

NUPOC education and research personnel who contributed to the CLSHS educational tour include: **Edward Grahn**, **Stefania Fatone**, PhD, **Craig Heckathorne**, MSc, **Rebecca Stine**, MS, **R. J. Garrick**, PhD, **Chris Robinson**, CPO, MBA, **Oluseeni Komolafe**, PhD, **Erin Boutwell**, MS, **Sara Koehler**, MS, **William (BJ) Johnson**, PhD, and **Kiki Zissimopoulos**, MS.

Tours of NUPOC can plant intellectual seed in fertile ground, especially for science-minded juniors and seniors who are considering future college programs. Each year CLSHS teachers, administrators, and parents accompany the classes to NUPOC. Last year CLSHS Principal **Marsha Pottoff** attended and this year CLHS Career Center Supervisor Michelle Fitzgerald attended. These are influential individuals in the lives of high school seniors who will remember NUPOC as a portal for P&O education and a site that focuses on biomedical engineering for P&O. We hope that post-high school counselors at CLSHS and other high schools will direct some of their students toward careers in P&O and biomedical engineering.

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**. Send subscription requests and address changes to: *Capabilities*, Northwestern University RERC, 680 North Lake Shore Drive, Suite 1100, Chicago, IL 60611.

***Capabilities* On-line!**

Capabilities is free and you may receive this publication by post or read archived issues on-line at:

www.nupoc.northwestern.edu

If you read *Capabilities* on-line or do not wish to continue receiving it by mail, please contact us to remove your name from the list of postal recipients.

E-mail: reiu@northwestern.edu
TEL: 312.503.5700
HELP LINE: 312.503.5709
FAX: 312.503.5760

Northwestern University Prosthetics-Orthotics Center
680 North Lake Shore Drive
Suite 1100
Chicago, IL 60611
USA

NUPOC Educational Outreach: Science Judges

R. J. Garrick, PhD

Part of NUPOC's mission is to advance biomedical engineering education. Critical evaluation of student science projects is one way that NUPOC doctoral candidate **Kiki Zissimopoulos**, MS, and postdoctoral fellows **Matty Major**, PhD, and **Oluseeni Komolafe**, PhD, support science education among youth. These three NUPOC researchers served as science judges at the Lincoln Park H.S. Science Fair held on December 20, 2011. Ms. Zissimopoulos also evaluated science projects for 6th, 7th, and 8th graders at McCutcheon Middle School on December 15, 2011.

Matty Major, PhD, listens to a high school student's presentation.

Ms. Zissimopoulos noted, *"I am interested in science outreach activities and I like to encourage students to pursue math and science. It gives younger students new perspectives when graduate students show interest in their work. Serving as a judge at science fairs is a way that I can give back what I have learned."*

Judging science fair projects represents a valuable outreach activity and educational contribution. These NUPOC researchers interact with young science students and serve as positive role models. NUPOC researchers hone their critical listening skills and contribute informed feedback, thus providing encouragement and support for students who may pursue careers such as biomedical engineering.

Kiki Zissimopoulos, MS (left) critiques a student's project.

Rodriguez Judges BME Posters

R. J. Garrick, PhD

Azucena Rodriguez, PhD, attended the **Society for Advancement of Chicanos and Native Americans in Science** (SACNAS) conference in San Jose, CA, from October 27 through 30th, 2011. She judged undergraduate poster presentations in mechanical and biomedical engineering. The SACNAS conference featured students' summer research projects in a poster presentation format.

Dr. Rodriguez and other judges wrote their evaluations on feedback forms and provided students opportunities to ask and answer questions. The SACNAS conference also provided opportunities to network and exchange scientific ideas. After the conference, Dr. Rodriguez received an enthusiastic e-mail from a SACNAS participant whose poster she evaluated, *"I could not believe how lucky I was to be speaking with someone who is doing exactly what I see myself doing. I have been so inspired by the work being done at….Northwestern University."*

Azucena Rodriguez, PhD, critiqued SACNAS science posters in San Jose, CA.

Learn more about SACNAS at: www.sacnas.org

Meetings

Craig W. Heckathorne, MSc, attended the Targeted Muscle Reinnervation Workshop: Current Approaches and Future Directions, held in Chicago, IL, October 7-8, 2011.

Kiki Zissimopoulos, MS, attended the American Academy in Orthotists and Prosthetists (AAOP) Certificate Programs for Professional Development held in Chicago, IL, October 28-29, 2011. She participated in the certificate program "The Effect of AFOs on Balance."

Craig W. Heckathorne, MSc, attended the AgrAbility National Training Workshop held in Indianapolis, IN, November 7-10, 2011.

Stefania Fatone, PhD, BPO(Hons) was invited to participate in an NIH Special Emphasis Panel/Scientific Review Group held in Alexandria, VA, on November 18, 2011.

Desmond Masterton, CO, CPed, MS, presented his poster, "Predictors of Student Success in a Blended Learning Program" at The Feinberg Academy of Medical Educators 2nd Annual FSM Education Day on October 27, 2011. Posters were displayed in the Lurie Atrium during the day, with formal presentations in the evening. Additional information can be found on their website at:
http://educationinmedicine.northwestern.edu/academy/about_us/.

Publications

Sanders, J and **Fatone S**. (2011) Residual Limb Volume Change: Systematic Review of Measurement and Management. *Journal of Rehabilitation Research and Development*, 48(8):949-986.

Stefania Fatone, PhD, BPO(Hons) and **Christopher Robinson**, CPO, MBA, were invited to submit an Expert Clinical Viewpoint for publication in the June 2012 issue of *Prosthetics and Orthotics International*. Their paper is titled "You've Heard about Outcome Measures, So How Do You Use Them? Implementing Clinically Relevant Outcome Measures in Orthotic Management of Stroke."

Gard, SA, Su, PF, Lipschutz, RD and Hansen, AH. (2011) The Effect of Prosthetic Ankle Units on Roll-Over Shape Characteristics during Walking in Persons with Bilateral Transtibial Amputations. *Journal of Rehabilitation Research and Development* 48(9):1037-1047.

Boutwell, E, Stine, R, Hansen, A, Tucker, K and **Gard, S**. (2011). Effect of Prosthetic Gel Liner Thickness on Gait and Pressure Distribution within the Transtibial Socket. *Journal of Rehabilitation Research and Development* (Accepted for publication).

Meier, MR, Hansen, AH, Gard, SA and McFadyen, AK. (2011). Unilateral Transfemoral Prosthesis Users' Performance and Movement Efficiency When Using the C-leg, 3R60 and the SNS Prosthetic Knee Joints on an Obstacle Course. *Journal of Rehabilitation Research and Development* (Accepted for publication).

Invited Speakers

Robert Lipschutz, BSME, CP, was a presenter at the Targeted Muscle Reinnervation Workshop: Current Approaches and Future Directions, held in Chicago, IL, October 7-8, 2011.

Honors

Sara Koehler, MS, was awarded 2nd prize for her poster titled "The Effect of Transfemoral Prosthesis Alignment Perturbations on Gait," presented at Northwestern University's annual Biomedical Engineering Research Day, September 14, 2011.

The abstract titled "Spinal Motion during Walking in Persons with Unilateral Transfemoral Amputation with and without Low Back Pain" submitted by **Azucena Rodriguez**, PhD, **Rebecca Stine**, MS and **Stefania Fatone**, PhD, BPO(Hons) was selected as a finalist for the Howard R. Thranhardt Lecture Award to be held at the 38th American Academy of Orthotists and Prosthetists annual meeting in Atlanta, GA, from March 24-27, 2012.

Grants Funded

Wu, Y. "Development of a Low-Cost Dilatancy-Based System for Orthotic Fabrication." U.S. Department of Education, National Institute on Disability and Rehabilitation Research (NIDRR). Funding Period: 10/01/2011 – 9/30/2014.

Grant Submissions

Gard, SA. "Effect of Prosthetic Foot and Ankle Stiffness on Standing and Walking." Submitted to the National Institutes of Health (NIH) for the October 2011 due date.

Gard, SA and **Boutwell, E**. "Effect of Prosthetic Compliance on Shock Absorption and Proprioception." Submitted to the National Institutes of Health (NIH) for the October 2011 due date.

Continued on page 4

Capabilities
ISSN 1055-7156
Northwestern University
Prosthetics/Orthotics Center (NUPOC)
680 North Lake Shore Drive, Suite 1100
Chicago, IL 60611

MAIN TEL: 312.503.5700
HELP LINE: 312.503.5709
FAX: 312.503.5760
E-mail: reiu@northwestern.edu
Website: www.nupoc.northwestern.edu

RETURN SERVICE REQUESTED

NON-PROFIT ORG.
U.S. POSTAGE
PAID
LA CROSSE, WI 54601
PERMIT NO. 588

Northwestern University Offers Master's in Prosthetics and Orthotics (MPO)

Northwestern University Prosthetics-Orthotics Center (NUPOC) is pleased to announce that the Feinberg School of Medicine unanimously approved the curriculum for a new Master's in Prosthetics-Orthotics (MPO) program. The NUPOC MPO is a competitive, 20-month postgraduate degree that offers a clinically focused education in a research-rich environment.

Building upon the innovative Blended Learning format developed for NUPOC's successful post-graduate Certificate programs in Prosthetics and Orthotics (P&O), MPO students will complete their first two quarters on-line from the convenience of their homes. After demonstrating proficiency in fundamental concepts, students move to Chicago for four intensively focused quarters (11 months) of supervised clinical education. During the on campus practicum, MPO students will apply their knowledge and develop skills in assessment, design, fitting, and evaluation of trial prostheses and orthoses for Educational Models who have amputations and other physical disabilities. The final quarter offers students the opportunity to focus on a specialty area before beginning their P&O residency.

Founded in 1958, NUPOC is the largest and oldest education program of its kind in the hemisphere, currently graduating approximately 40% of all nationally Certified Prosthetists and Orthotists in the USA. In 2010, Northwestern University's internationally distinguished prosthetics-orthotics research laboratories and educational programs merged and moved into a custom-designed, award-winning site in Chicago's historic, lakefront 680 Building.

To apply to NUPOC's MPO program or for additional information, please contact:
nupoc@nupoc.northwestern.edu
Or call 312-503-5700.