Capabilities
Communicating the Science of Prosthetics and Orthotics
Volume 11, Number 2, Summer 2002

Gait Biomechanics and Prosthetic Management of Children with Proximal Femoral Focal Deficiency (PFFD)

By Stefania Fatone, PhD

The following article describes work undertaken by Stefania Fatone toward her doctoral thesis which was completed at La Trobe University in Melbourne under the guidance of Timothy Bach, PhD (Head, National Centre for Prosthetics and Orthotics), Professor H. Kerr Graham, MD (Director, Hugh Williamson Gait Analysis Laboratory, Royal Children's Hospital, Melbourne) and Ian Torode, MD (Department of Orthopaedics, Royal Children's Hospital, Melbourne).

Introduction: What is PFFD?

Proximal Femoral Focal Deficiency, more commonly referred to as PFFD, is a rare, congenital lower limb deficiency of unknown cause affecting the formation of the hip joint (acetabulum and proximal femur) and surrounding musculature (Figure 1).

Physical examination alone is not diagnostic and cannot determine severity of the deficiency. Early in life, an x-ray will confirm that the femur is short with the proximal third of the femoral shaft, neck, trochanteric area and head seemingly absent. However, the area between the femoral head and shaft is usually occupied by a cartilage anlage in which ossification is delayed making it undetectable on x-ray. Serial x-rays taken over the first year or two of life will clarify the actual severity and detail the development of the deficiency.

As with many congenital limb deficiencies, the degree of deficiency may vary considerably among individuals. Many systems have been proposed to classify these variations. It has been observed that only the number of cases seen limits the potential number of categories (1)! Most systems attempt to classify PFFD and related femoral deficiencies based on anatomical features of the acetabulum and proximal femur identifiable on x-ray. While no single system of classification has achieved universal acceptance, the most commonly acknowledged system is that of Aitken (2). Aitken identifies four classes (A through D) based on serial x-ray examination of the formation of the femoral head and acetabulum, with A being the least severe form of deficiency and D the most severe.

PFFD results in severe limb length inequality and hip joint instability. Treatment can be both surgical and/or prosthetic and is aimed primarily at restoring function, in particular, the ability to walk. PFFD occurs in approximately 1 in 52,000 births (3). It most commonly occurs in only one limb but may, in approximately 10 to 15% of cases, occur in both lower limbs (4). There is a high incidence of associated anomalies, with the most common being fibular hemimelia (absence of a portion of the fibula) (5). Associated anomalies complicate management of the PFFD child and in some instances may contraindicate certain surgical options. Bilateral cases are often left untreated since, if the limbs are of approximately the same length, the child can usually ambulate effectively and painlessly without intervention.

Management of PFFD

The biomechanics of gait in unilateral PFFD depend greatly on the type of treatment undertaken and can be al-

Continued on page 2

Management of Proximal Femoral Focal Deficiency

Continued from page 1

most as variable as the deficiency itself. Where the decision is made to leave the limb surgically unrevised the issue of limb length inequality is addressed prosthetically using some form of extension prosthesis. Where the decision to revise the limb is made, there are two main options available (Figure 2). Traditionally, the most common revision procedure has been the Syme's ankle disarticulation with knee fusion, which results in the functional equivalent of a knee disarticulation (through-knee) amputation. To ensure that knee joint axes are at approximately equal heights at maturity, ankle disarticulation and knee fusion may be accompanied by epiphysiodesis (halting the growth plate) of the opposite knee. The other, more controversial option is to convert the limb to a functional transtibial equivalent using the Van Nes (Tibial) Rotationplasty procedure (6). This procedure involves turning the ankle and foot 180° about a vertical axis, so that ankle dorsiflexion simulates knee flexion. This makes it possible for the rotated ankle to voluntarily control a mechanical knee during gait. Regardless of the choice of revision surgery, it is generally accepted that when the limb is surgically revised and, provided the femur is not fused to the pelvis, the knee should be fused. This creates a single skeletal lever with which to control the prosthesis. Where the knee is not fused, stability of the proximal knee joint relies upon the prosthetic socket and the flexion-abduction orientation of the thigh persists. Regardless of the surgical procedure chosen, most authors prefer to operate early, such as when the toddler demonstrates the interest and ability to stand (7).

Figure 1. *Characteristic clinical appearance of PFFD.*

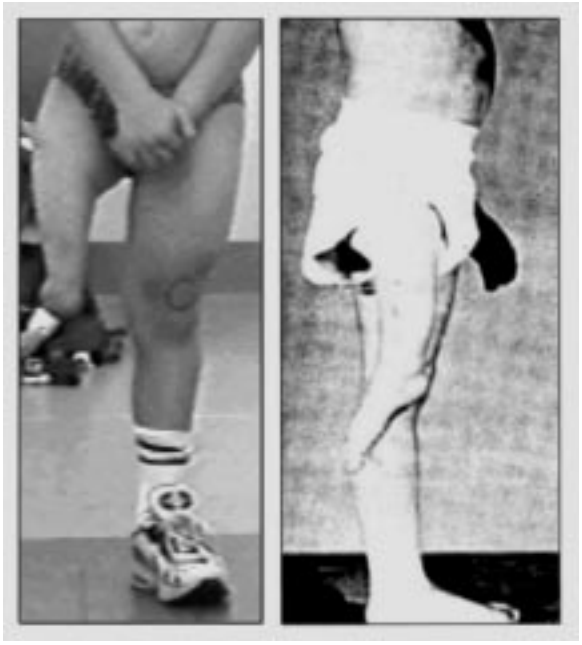

Figure 2 *The two most common revision surgeries for PFFD limbs: (a) Syme's ankle disarticulation and knee fusion and (b) Van Nes (tibial) rotationplasty and knee fusion.*

Biomechanics of Gait in Unilateral PFFD

We analyzed the gait of 9 children with unilateral PFFD (8). We believe that pelvic and hip kinematics are consistent

Continued on page 6

Capabilities (ISSN 1055-7156) is published in Spring, Summer, Autumn and Winter by Northwestern University's Rehabilitation Engineering Research Program. Program Director, Dudley S. Childress, Ph.D. Editor & Designer, Jan Little, MS.

Subscription is free to all individuals interested in prosthetics and orthotics. For contribution guidelines and advertising inquiries, write to the address below. Address subscription information, address changes and other correspondence to: *Capabilities,* Northwestern University RERP, 345 E. Superior St., Room 1441, Chicago, IL 60611.

This work was funded by the National Institute on Disability & Rehabilitation Research (NIDRR) of the Department of Education under grant number H133E980023. The opinions contained in this publication are those of the grantee and do not necessarily reflect those of the Department of Education.

Dudley S. Childress, PhD, Director of the Northwestern University Rehabilitation Engineering Research Center, answers a question during the State of the Science meeting held May 17 and 18 in Chicago.

Prosthetics & Orthotics: Looking at Where Are We Now and Discussing Future Directions

By Jan Little

William Peterson, Project Manager, National Institute on Disability and Rehabilitation Research (NIDRR) described the State of the Science Meeting focusing on prosthetics and orthotics as a method of producing "a snapshot of the field" which can help NIDRR best use resources and determine future projects. The meeting, held at Northwestern University May 17 and 18, 2002, provided an opportunity to discuss many aspects of the field of prosthetics and orthotics.

The State of the Science meeting is a new requirement for RERCs (Rehabilitation Engineering and Research Centers) funded with NIDRR grants and are intended to stimulate discussion and creative thinking about a specific research area. Over 50 people representing various disciplines in prosthetics and orthotics participated in the meeting.

Each session of the meeting was introduced by two raconteurs who discussed current practices in a broad topic area followed by a discussion of that topic. Dr. Childress said the goal with the agenda was to step back and look at the broad picture of prosthetics and orthotics.

"We wanted to avoid starting from the particulars such as prosthetic feet or AFOs and so forth. Therefore, we generalized the topics. Science has the capacity to help solve particular problems through the development of general concepts (e.g. theories and models)." Childress continued that, "Donald Stokes, in his book, Pasteur's Quadrant believed that productive people like Pasteur solve practical problems and at the same time advance science (knowledge and understanding). This approach seems like a useful one for P & O. Stokes thought research and development need not be – and frequently is not – a linear process that only moves from basic research to development and finally to use."

Topics chosen to stimulate discussions were: Interface Mechanics, Attachment and Alignment; Enhancement and Evaluation of Functional Performance; Reaching and Manipulation; International Issues/Low-Income Countries; Fabrication, Materials and Safety; and Long Range Research and Clinical Practice.

Continued on page 4

State of the Science Meeting
Continued from page 3

In the Recapitulation Session on Friday, a number of topics were identified for further consideration. One recurring theme was the need for collaborative efforts between commercial industry, manufacturers, funding providers, clinicians and researchers. Such collaboration is essential if the prostheses and orthoses being developed for future use effectively meet the needs of those who will use them. In addition, such collaboration will assist engineers in designing the product and may play a role in persuading funding agencies to pay for advancements in the field of prosthetics and orthotics.

Another topic that recurred during the discussions was that of better understanding of the demographics of the population served. This understanding would aid in the development of outcome measures that can be used in a scientific manner. Such measures might be an important tool to enable prosthetists and orthotists better match equipment with the physical, activity and environmental situations of the user. Outcome measures might also be useful in helping funding agencies determine when additional cost is justified by greater value to the person using the prosthesis or orthosis.

Another need that emerged from discussions was that of more research in orthotics. Although people who use orthoses outnumber users of prosthetics, those attending the meeting observed that it seems more research is conducted in the field of prosthetics.

Participants also called for increased education in several settings. In education of practitioners, a need was expressed for inclusion of learning to measure outcomes in addition to increased emphasis on communication skills and evaluation of psychosocial aspects of the clients' life. More education for surgeons and physiatrists in prosthetics and orthotics was also suggested in the discussions.

Another question raised in the discussions was whether State of the Science prosthetics and orthotics need to be more expensive than previous products. A suggestion was that less expensive materials and technologies be explored. International applications of the prosthetic-orthotic science, it was pointed out by some, would particularly benefit from utilizing more economical materials and technologies.

Exploration of the State of the Science was much broader and more in depth than can be reported in a brief article. A complete report of the meeting will be available at a later date. How copies can be obtained will be announced in a future issue of *Capabilities*.

Participants (outside the RERC) in the meeting were: Michael Brncick, CP, Hanger P & O, Hazelcrest, IL; James H. Campbell, PhD, CO, Becker Orthopedic Appliance Company, Troy, MI; Hector Casanova, CP, Center for International Rehabilitation (CIR), Chicago, IL; John R. Fisk, MD, Southern Illinois University (SIU) School of Medicine, Springfield, IL; Mark D. Geil, PhD, Georgia Tech University, Atlanta, GA; Hugh Herr, PhD, Massachusetts Institute of Technology, Cambridge, MA; Vern Houston, PhD, CPO, Department of Veterans Affairs, New York, NY; Kelly James, P.Eng, Biomech Designs Ltd, Edmonton, Alberta, Canada; Geza Kogler, PhD, CO, SIU School of Medicine, Springfield, IL; Samuel E. Landsberger, ScD, RERC on Technology for Children with Orthopedic Disabilities, Rancho Los Amigos, Downey, CA; Robert D. Lipschutz, CP, Rehabilitation Institute of Chicago (RIC), Chicago, IL; Jan Little, MS, NURERC, La Crosse, WI; Robert H. Meier, III, MD, Amputee Services of Colorado/O'Hara Regional Center for Rehabilitation, Thorton, CO; John Michael, Med, CPO, CPO Services, Portage, IN; Morris Milner, PhD, P Eng, CCE, Ontario Reha-

"The State of the Science Meeting focusing on prosthetics and orthotics is a method of producing a snapshot of the field to help us best use our future resources "

William Peterson, Project Manager, National Institute on Disability and Rehabilitation Research (NIDRR)

Continued on page 5

NUPOC NEWS

Learning About the Profession…

An Introduction to Prosthetics and Orthotics for Suppliers and Manufacturers

By Mark Edwards

For the past five years, Northwestern University's Prosthetics and Orthotics Center has offered a unique form of education in the profession. A three-day educational seminar for customer service people, product sales people, regional managers, design researchers, persons in marketing, attorneys, and others has allowed an opportunity for introductory education in prosthetics and orthotics.

The Suppliers and Manufacturers course serves a genuine need to large and small businesses in the profession. Often new people are hired by companies such as Otto Bock, Ossur, Fillauer, Camp, College Park, Don Joy, etc. based on skills and training that have little to do with prosthetics or orthotics. These new employees typically know little about the profession beyond their limited company knowledge or specialty. Also, the transitory nature of sales positions and increased corporate buy-outs has put companies in a constant environment of change.

NUPOC has offered this special course to introduce people to the terms, theories, and practical applications of prostheses and orthoses. Feedback from the inaugural course and all previous courses has given the NUPOC faculty a chance to fine-tune this course to meet the needs of the attendees. Current lecture topics include: medical terminology, normal and pathological gait, common materials, spinal, lower and upper limb orthotics, demographics and causes of amputation, lower limb prosthetics, upper limb prosthetics, patient demonstrations and interviews.

A pre-test gives participants an understanding of their limited vocabulary of the profession. The pre-test is used to identify areas of learning that can be focused on during the course. At the completion of the course, a post-test is given to allow participants to use for self-evaluation.

The Suppliers and Manufacturers course is the only one of its kind offered in the United States. The faculty have also traveled nationally and internationally to offer this program to suppliers in the profession. NUPOC strives to keep up with the changing healthcare management systems. Providing innovative and unique educational programs gives NUPOC an edge in staying on top as a premiere center in caring for persons with disabilities. ❖

State of the Science Meeting
Continued from page 4

bilitation Technology Consortium, Toronto, Canada; Camille M. O'Reilly, BSN, RN, CRRN, RIC, Chicago, IL; William Peterson, MS, NIDRR; Maciej Pokora, PhD, SIU School of Medicine, Springfield, IL (visitor from Warsaw, Poland); Donald Shurr, CPO, PT, University of Iowa Hospitals and Clinics, Iowa City, IA; M. Barbara Silver-Thorn, PhD, Marquette University, Milwaukee, WI; William K. Smith, MD, CIR, Chicago , IL; Melvin L. Stills, CO, American Prosthetics, Inc., Clive, IA; Terry J. Supan, CPO, FAAOP, SIU School of Medicine, Springfield, IL; T. Walley Williams, III, MA, Liberating Technologies, Inc., Holliston, MA and Yeonchi Wu, MD, CIR, Chicago, IL. In addition, over 25 students and staff members from NUPRL, NURERP and NUPOC attended the sessions. ❖

Management of Proximal Femoral Focal Deficiency

Continued from page 2

within the PFFD population despite variability in the degree of severity and treatment (8,9,10). Regardless of surgical treatment, hip motion **on the affected side**, is characterized by a 'pause' in hip extension during mid-stance, absent stance phase hip abductor moment, and absent terminal stance power generation. **On the sound side**, there is increased power generation at the hip in early stance and mid-stance vaulting at the ankle to assist with toe-ground clearance of the prosthetic limb during swing.

In the sagittal plane, the mid-stance 'pause' in hip extension – actually a decrease in the rate of hip extension during mid-stance - coincided with increased anterior pelvic tilt (Figure 3a) suggesting that hip extension was hampered by a flexion contracture and compensated for by changing the pelvic orientation. Our results suggested that abnormal hip and pelvic motion in mid-stance was more pronounced in the PFFD subjects who had moderate hip flexion contracture, and less severe in those who did not have a hip flexion contracture (8).

Visually, PFFD gait is marked by excessive lateral trunk flexion (often referred to as Trendelenburg gait), which is due to the inadequate abductor mechanism (11). Even if present, the abductor muscles cannot be effective where the hip joint is so unstable. This was reflected in the absence of coronal plane hip moments in our PFFD subjects (Figure 3b).

Usually amputees use hip musculature to compensate for lack of knee and ankle muscle activity (12), however, the deficient nature of the PFFD hip hinders compensatory use on the affected side as demonstrated by reduced power generation at the hip (Figure 3c) (8). There is also very little power generation at the knee or ankle on the affected side. Our results suggest that the sound limb may be generating the power required for prosthetic swing phase, since at the time of terminal stance on the affected limb, the sound limb exhibited increased hip power generation. Simultaneous rapid internal rotation of the affected side pelvis with respect to the sound hip transferred power to the affected limb (8). This interpretation of the motion analysis data could be substantiated by EMG data, however EMG data was not acquired in this study.

Given the osseous defect and muscular abnormalities, motion between the pelvis and femur in PFFD is unique. This movement has been previously described as 'telescoping' (11). Telescoping refers to the displacement that occurs between the pelvis and residual femur during weight bearing. In order to measure motion of the hip, current motion analysis systems generally incorporate an anthropometric model of the pelvis based on measurements of normal anatomy. While these models prove reasonable in able-bod-

Continued on page 7

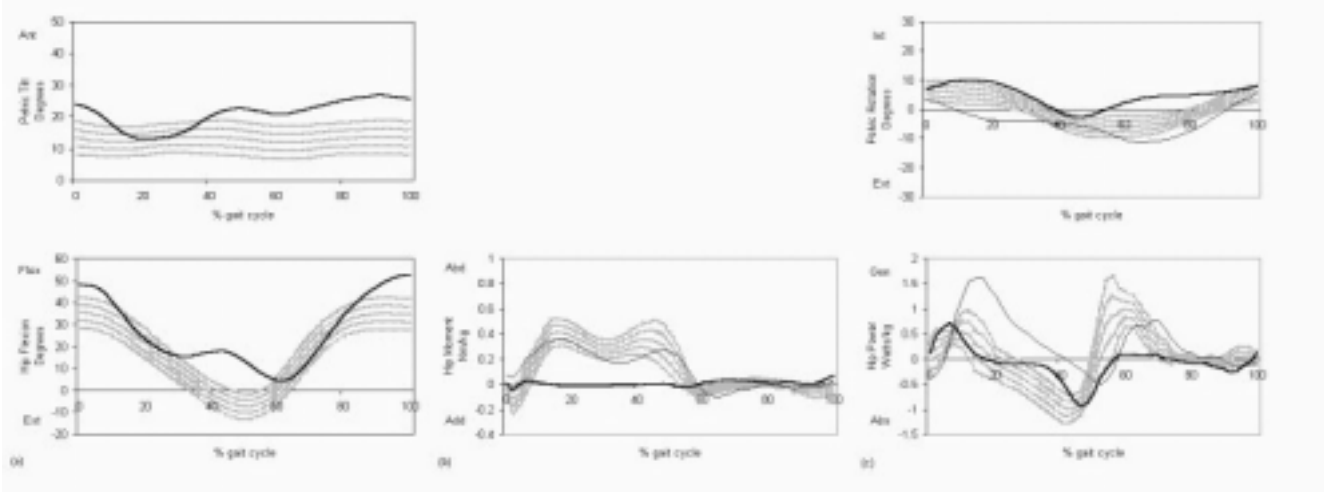

Figure 3 *(a) Effect of hip flexion contracture on hip and pelvic kinematics. Example of the mid-stance 'pause' in hip extension that occurred at the same time as increased anterior pelvic tilt in the affected limb of children with PFFD. Shaded lines represent one standard deviation about the normal mean for children of the same age as the PFFD subjects. (b) Effect of deficient hip musculature on coronal plane hip kinetics. Stance phase hip abductor (Abd) moment was absent on the affected side (thick line). (c) Reduced power generation (Gen) by the hip on the affected side (thick line). Compensated for by increased hip power generation on the sound side (thin line) at the time of terminal stance on the affected limb. Simultaneous rapid internal rotation of the affected side pelvis with respect to the sound hip transferred power to the affected limb.*

Management of Proximal Femoral Focal Deficiency

Continued from page 6

ied subjects, they are likely to be inaccurate in cases such as PFFD where the pelvis and hip are malformed and there is no easily identifiable axis of rotation at the hip. We developed a method of predicting the hip joint center (HJC) in children with PFFD that did not rely on anthropometric data (8). Instead, an optimization model was developed based on dynamic data. This model was found to provide reasonable estimates of HJC location in able-bodied children compared to other HJC models (8). This was used to measure telescoping of the PFFD limb and a meaningful relationship between telescoping and axial loading of the limb was established (Figure 4).

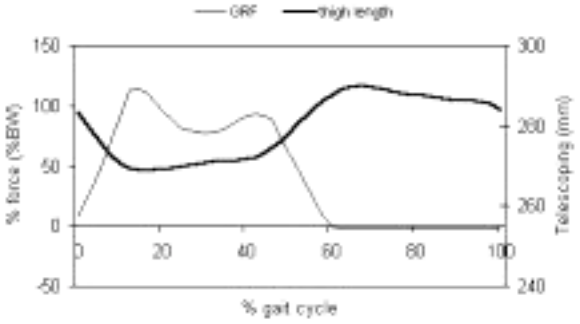

Figure 4 ***Relationship between axial loading (vertical ground reaction force – GRF) and telescoping of the residual limb (thigh length). Minimum thigh length coincides with the first peak of vertical ground reaction force.***

We investigated the effect prosthetic socket design might have in limiting telescoping of the PFFD limb (8). Based on Lehneis' ideas (13) we hypothesized that the higher trim line and larger radius of the posterior brim of the Ischial Containment socket would provide better support of the pelvis through the loading response phase of gait in children with PFFD thus reducing telescoping and improving gait biomechanics. We compared the effects of the Quadrilateral and Ischial Containment sockets on the gait kinematics and energy expenditure of five children with unilateral PFFD and Syme's ankle disarticulation. The results suggested that Ischial Containment sockets provide better support of the pelvis. Pelvic and trunk range of motion, telescoping, and vertical sacral displacement were reduced and velocity, stance duration asymmetry and energy expenditure improved when walking in the Ischial Containment socket compared to the Quadrilateral socket. Energy expenditure was 20% less in the Ischial Containment socket compared to the Quadrilateral socket (8).

Preliminary gait studies have indicated that subjects with Tibial Rotationplasty have a degree of prosthetic control not possible with a Syme's ankle disarticulation and transfemoral prosthesis (8,9,14). Fowler et al. (9) reported that most Tibial Rotationplasty subjects demonstrated stance phase knee flexion and stance phase knee extensor moments during loading response. Sheil et al. (14) reported that the Tibial Rotationplasty procedure encouraged a longer stride length, shorter stride time and therefore, faster velocity. Comparing the two surgical procedures, they also found that subjects with Tibial Rotationplasty maintained a closer to normal stance/swing ratio than the subjects with Syme's ankle disarticulation. We undertook pre- and post-operative evaluation of the Tibial Rotationplasty procedure in 2 young subjects that suggested that the rotated ankle demonstrated adaptation by functioning as a knee, as demonstrated by the presence of stance and swing phase knee flexion, relatively early in the post-operative period (8).

Compared to able-bodied children, and regardless of surgical treatment, children with PFFD incur a greater metabolic cost when walking (8). A number of authors have reported that the Tibial Rotationplasty procedure results in a more energy efficient gait when compared to the Syme's ankle disarticulation procedure. In fact, the Tibial Rotationplasty procedure has been reported as being 10 to 25% more energy efficient (15,16).

Conclusions

It has been demonstrated that the gait of children with PFFD differs from that of able-bodied children and that the differences are consistent despite variability in the severity and treatment of the deficiency. Pelvic and hip kinematics and hip kinetics are abnormal and the sound limb is used to compensate for lack of power generation on the affected side. Compared to able-bodied children, children with PFFD incur a greater metabolic cost when walking regardless of the type of surgical revision, although the Tibial Rotationplasty procedure was less energy expensive compared to the Syme's ankle disarticulation and knee fusion procedure. Our results suggested that Ischial Containment sockets decrease energy expenditure by providing better support of the pelvis in children with unilateral PFFD and Syme's amputation.

Acknowledgements

Financial support for part of the work described in this article was received from the Hugh Williamson Orthotic and Prosthetic Unit, Royal Children's Hospital, Melbourne Australia in the form of The Ray McKernan Studentship for Orthotic and Prosthetic Biomechanical Research. I am also

Continued on page 9

Northwestern University PRL&RERP&NUPOC NEWS

NOTE: The Capabilities date designation has been changed from "January, April, July and October" to "Winter, Spring, Summer and Autumn" to more accurately reflect our quarterly nature. Volume and number designations remain the same.

Meier and Sam Test the Shape and Roll Prosthetic Foot in El Salvador

Margrit Meier, PhD, and Michel Sam, MS, have spent approximately one month in El Salvador fitting the Shape and Roll prosthetic foot to 13 people with lower limb amputations. The foot was developed in cooperation with the Center for International Rehabilitation (CIR). The Shape and Roll foot is one of a number of products or technologies being developed for use in nations with emerging economies. An in-depth article about the tests will be published in a future issue of *Capabilities.*

Dudley Childress Presents at the Second International Conference of Advanced Prosthetics

Dudley S. Childress, PhD, discussed "Automated Foot Alignment: Understanding Foot Function Makes it Possible" at the second International Conference of Advanced Prosthetics held in Newport Beach, California, April 18 and 19. The meeting, hosted by OSSUR, the Department of Orthopaedic Surgery of the College of Medicine, University of California – Irvine and the California State University, Domiguez Hills Prosthetic-Orthotic Program, was attended by over 350 people.

On June 6, Childress, PhD, presented the lecture he gave at the time he received the Paul B. Magnuson Award from the Department of Veterans Affairs Research and Development Service to the Executive Board of the Rehabilitation Institute of Chicago

(For details about the award please see page 10, *Winter/Spring 2002 Capabilities*)

Heckathorne and Fatone Present at the ACPOC Meeting

Craig W. Heckathorne presented the Hector W. Kay Memorial Lectureship at the Association of Children's Prosthetic and Orthotic Clinics (ACPOC) in Toronto, April 11-13. The lectureship is awarded on the basis of contributions to the field of prosthetics and orthotics for children. Stefania Fatone, PhD, presented a report of her research titled "Characteristics of PFFD Gait: Pelvic and Hip Biomechanics".

The same week, from April 17 to 20, Steven Gard, PhD, Rebecca Stine, MS, Gina Konz, MS, Steven Miff and Brian Ruhe attended the Seventh Annual Gait and Clinical Movement Analysis Society Meeting. The meeting was held in Chattanooga, Tennessee.

Kellie Lim Receives BS Degree, Andrew Hansen Receives PhD

Kellie Lim, who was the NIDRR Scholar at the NU Rehabilitation Engineering Research Center during the summer of 2000 has earned her Bachelor of Arts degree in Biological Science and Asian Studies from Northwestern University. Andrew Hansen was awarded his PhD in Biomedical Engineering at the June 21 ceremony in Evanston, Illinois.

While a NIDRR Scholar, Kellie conducted a research project titled "Quantitative and Subjective Analysis of Walking in an Individual with Bilateral Below-Knee Loss" under the mentorship of Steven A. Gard, PhD. Kellie has bilateral amputation of the lower limbs and amputation of her right

Continued on page 9

Continued from page 8

arm below the elbow and amputation of several fingers of her left hand. The amputations resulted from meningococcemia, a bacterial form of meningitis. Kellie also wrote an article for *Capabilities/July 2000* about her experience as a NIDRR Scholar.

Allison Boynton is 2002 NIDRR Scholar

Allison Boynton is the NIDRR Scholar for 2002 working with NUPRL & RERP. Ms. Boynton is involved with a pilot study investigating the effects of new, stance control orthotic knee joints on the gait of individuals who wear knee ankle foot orthoses. Her responsibilities include:

- fabricating and fitting test orthoses
- performing and interpreting gait analyses
- managing patient information

As a wearer of a below elbow prosthesis, Allison has always been interested in the field of orthotics and prosthetics.

Miss Boynton has completed the course preparing for certification in orthotics at the Northwestern University Prosthetics-Orthotics Center. Prior to returning to school, she worked as a certified prosthetist in a children's hospital in South Carolina.

Laura Miller Earns Certification

Laura A. Miller, MS, completed all requirements and passed the examination to qualify as a Certified Prosthetist. Laura has been on the faculty of NUPOC for a year. She is also completing her dissertation for her PhD in Biomedical Engineering from Northwestern University.

Steven Kurzman Writes Chapter in Recent Book on Prosthetics

Steven Kurzman, who conducted a part of his research toward his PhD in Cultural Anthropology in the Northwestern University RERP, wrote one of the chapters in a recently published book titled, *Artificial Parts, Practical Lives: Modern Histories of Prosthetics*. The lead editor of the book is Katherine Ott, PhD, a Curator in the Division of Science, Medicine, and Society of the Smithsonian National Museum of American History. The book is available from NYU Press and most booksellers.

Steven Kurzman wrote about his experiences in India and Cambodia in the January 2000 issue of *Capabilities*. ❖

Management of Proximal Femoral Focal Deficiency

Continued from page 7

indebted to my supervisors and mentors Dr Timothy M. Bach, Professor H. Kerr Graham and Mr Ian Torode for all their assistance during my PhD candidature.

References

1. Torode I.P. (1997) In: Broughton N.S. (Ed.) A Textbook of Paediatric Orthopaedics. W.B.Saunders Co. Lim.: London, U.K.

2. Aitken G.T. (1969) In: Aitken G.T. (Ed.) Proximal Femoral Focal Deficiency: A Congenital Anomaly. A Symposium. National Academy of Sciences, Washington D.C., pp. 1-22.

3. Rogala E.J., et al. *(1974) Journal of Medical Genetics, 11:221-233.*

4. Krajbich J.I. (1989) In: Kalamchi A. (Ed.) Congenital Lower Limb Deficiencies. Springer-Verlag: New York, U.S.A. Chapter 6, pp. 108-127.

5. Tooms R.E. (1987) Journal of the Association of Children's Prosthetic-Orthotic Clinics, 22(2):22.

6. Van Nes C.P. (1950) Journal of Bone and Joint Surgery, 32B(1):12-16.

7. Epps C.H. (1983) Journal of Bone and Joint Surgery, 65A(6):867-870.

8. Fatone S. (2000) Gait Biomechanics and Prosthetic Management of Children with Proximal Femoral Focal Deficiency (PFFD). PhD Thesis, La Trobe University, Australia.

9. Fowler E.G., et al. *(1999) Journal of Pediatric Orthopaedics, 19(6):720-731.*

10. Sutherland D.H. (1984) Gait Disorders in Childhood and Adolescence. Williams and Wilkins: Baltimore, U.S.A. Pp. 89-106.

11. *Pirani S.,* et al. *(1991) Journal of Pediatric Orthopaedics, 11(5):563-570.*

12. Bagley A.M. and Skinner H.B. (1991) Critical Reviews in Physical and Rehabilitation Medicine, 3(2):101-120.

13. Lehneis H.R. (1985) Clinical Prosthetics and Orthotics, 9(4):6-8.

14. *Sheil E.M.H.,* et al. *(1995) Gait and Posture, 3:107.*

15. *Alman B.A.,* et al. *(1995) Journal of Bone and Joint Surgery, 77A(12):1876-1882.*

16. *McClenaghan B.A.,* et al. *(1989) Journal of Bone and Joint Surgery, 71A(8):1178-1182.*

News from the Department of Veterans Affairs

VA Embraces Gait and Limb Technology

Coordinated by Robert M. Baum
Prosthetic Program Manager, P&SAS SHG,
VA Central Office, Washington D.C.

By: Robert M. Baum

The Department of Veterans Affairs has been focusing on improving the life style of veterans through a combination of gait technology and improvements in limb design. A great example of this can be found at the National VA Prosthetics Gait Lab in Long Beach, Ca. The Gait Lab was established in 1986 to collect instrumented stride patterns of veterans and active duty patients. It was the first full service gait lab in the VA system specializing in orthotic and prosthetic gait assessment. This has led to improved walking characteristics of some of the VA's most challenged veterans.

The Otto Bock C-Leg, the Endolite Adaptive knee, and the still experimental Ossur REO knee are excellent examples of state-of-the-art prosthetic knee units, which utilize ground breaking microprocessor fluid control knee designs to offer both swing and stance control and stability. An increasing number of these units are being fit on veterans with an impressive level of success.

Frederick Downs, Jr., Chief Consultant, Prosthetic and Sensory Aids Service Strategic Healthcare Group, VA Central Office, Washington DC, has requested The National VA Prosthetics Gait Lab to document and report the results of clinical gait studies related to veterans with such limbs. This resulted in the VA receiving the prestigious Thranhardt Award in Prosthetics for 2001, presented by the American Orthotic and Prosthetic Association (AOPA).

These clinical field reports from the gait lab have shown that patients can descend ramps with relative ease compared to their previous hydraulic limbs, including those patients with stance stability hydraulic limbs. Perhaps the most significant clinical advantage reported with microprocessor knees (in this case the C-leg) is the ability of some amputees to descend a staircase with a step over step gait, something that is nearly impossible in transfemoral amputees. Historically, prosthetists and therapists have taught transfemoral amputees to descend stairs one step at a time with first the amputated side followed by the sound side for each step negotiated.

In gait assessments of the C-leg, performed at the National VA Prosthetic Gait Lab, C-Leg patients have undergone kinetic, kinematic and temporal evaluation under a variety of conditions. Additional videotape records have also been collected to document the patients preferred method of descending stairs and ascending and descending ramps. The qualitative data showed that every patient had both the ability and the preference of descending stairs in a step over step pattern while using the C-Leg. This compares to their previous conventional prosthesis where they either were unwilling to try or could do so only with considerable caution. The patients also reported that they felt a significant reduction in the amount of energy they had to expend while using the C-Leg. This was especially true when they attempted inclines with varying slopes.

The preliminary quantitative data obtained has also shown some potential benefits from C-Leg usage over a con-

Continued on page 11

Gait and Limb Technology
Continued from page 10

ventional prosthesis. Table 1 indicates the mean timing of events during the gait cycle for three patients that were tested. Of particular interest is the difference in time spent on the non-affected side from foot flat to heel off with the C-Leg versus the Mauch SNS. This timing difference quantitatively describes the act of vaulting (a compensatory mechanism designed to aid in ensuring that the affected limb is able to clear the floor during swing phase).

Additional quantitative data was gathered with respect to knee movement during stair descent. In Figure 1, the knee range of motion is pictured for both a C-Leg and Mauch SNS knee unit during one cycle of stair descent (from one heel strike to the ipsilateral heel strike). The notable differences between the motion patterns occur between 11 and 31% and 76 and 89%. During both of these periods, the data illustrates how the C-Leg knee unit flexes at a slower rate indicating a greater degree of possible control over the SNS knee unit.

"The mission of the National VA Prosthetics Gait Lab and our Prosthetic Affiliation for Clinical Excellence", says Ed Ayyappa, MS CPO, team leader, "will always be focused on improving the life style and performance of our veteran amputees. The prudent stewardship of available resources in future will most certainly include a role for comprehensive instrumented gait assessment and the provision of microprocessor knees for veterans who will truly benefit from them."

Left: The combination of fitting advanced technology limbs and performing clinical gait lab assessments on an increasing number of veterans, such as this patient wearing a microprocessor C-leg unit, is helping the VA match technology levels with the right patients and optimize roll-over timing, stance knee flexion and other walking patterns for people with amputations.

Today, several VA medical centers across the country have been trained in the assessment, fabrication, and fitting of this technology. ❖

Table 1: Mean Patient Stride Time Values

	AFF ® AHO	NAFF®NAHO
C-Leg		
Mean	0.22	0.21
S.D.	0.116	0.107
Mauch		
Mean	0.21	0.074
S.D.	0.021	0.0199

AFF = Affected Foot Flat, AHO = Affected Heel Off,

Figure 1. Knee Motion

Please send us your articles, success stories, comments or suggestions for future issues in the VA Presents. E-mail: *Robert.Baum@hq.med.va.gov* ***Address: PSAS SHG (113), 810 Vermont Ave., NW, Washington, DC 20420. Phone (202) 273-8515. Fax: (202) 273-9110.***

Capabilities
ISSN 1055-7156
Northwestern University Prosthetics Research Laboratory
and Rehabilitation Engineering Research Program
345 E. Superior Street, Room 1441
Chicago, IL 60611-4496

Non-Profit
U.S. Postage
PAID
Northwestern University

Please Notice Our New Phone Numbers

Phone Help Line: 312/238-6524
FAX: 312/238-6510
TTD: 312/238-6530
E-mail: reiu@northwestern.edu
web site =>http://www.repoc.northwestern.edu/

Change Service Requested

Resource Unit Information Request

Northwestern University PRL & RERP
345 E. Superior St., Room 1441
Chicago, IL 60611 USA
Allow two to three weeks for delivery

- ❒ Send me a copy of the latest *Activity Report*
- ❒ Start my subscription to *Capabilities*
- ❒ Association of Children's Prosthetic-Orthotic Clinics List
- ❒ Video List

Bibliographies of NUPRL&RERP Publications Available on the Following Topics:

- ❒ Above Knee Prosthetics
- ❒ Ambulation, Gait & Posture
- ❒ Biomaterials
- ❒ Below Knee Prosthetics
- ❒ Computer Aided Engineering/Design/Manufacturing
- ❒ Pediatric Prosthetics
- ❒ Prosthetic Feet
- ❒ Prosthetics & Orthotics: General
- ❒ Upper Limb Prosthetics & Orthotics

Other Sources for Prosthetic & Orthotic Information:

Consumer Information:
National Limb Loss Information Center
900 East Hill Avenue - Suite 285
Knoxville, TN 37915
Toll Free: (888)AMP-KNOW

Prosthetic-Orthotic Education:
National Commission on Orthotic and Prosthetic Education
330 John Carlyle Street - Suite 200
Alexandria, VA 22314
e-mail: info@ncope.org

General Information about Prosthetics & Orthotics:
American Orthotic & Prosthetic Association
330 John Carlyle Street - Suite 200
Alexandria, VA 22314
e-mail: info@aopanet.org

Name_____

Address_____