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Capabilities

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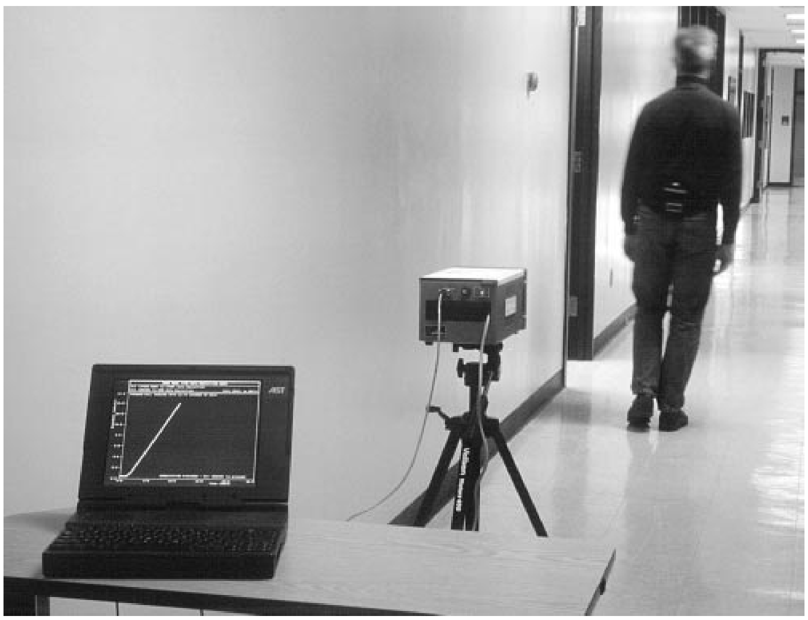

The D.U.R.S.(Direct Ultrasound Ranging System) designed in the Northwestern University Rehabilitation Engineering Research Program can easily be set up in a hallway and can enable a clinician to record data about a person's gait. Near real time processing of data allows changes to be implemented and tested immediately.

Exploring a Direct Ultrasound Ranging System to Make Gait Analysis Faster and More Economical

By Richard F. ff. Weir, PhD

Producing quantitative data to substantiate hypotheses is a major focus of the research conducted at the Northwestern University Prosthetics Research Laboratory and Rehabilitation Engineering Research Program (NUPRL &RERP). A number of people in rehabilitation feel there is a critical need to understand and analyze gait in order to more effectively develop and use prostheses and orthoses. However, the science of gait analysis has traditionally required large investments in the instruments to measure various elements of gait, the training of personnel to use those instruments and the operation of such gait analysis laboratories.

Albert H. Burstein, PhD identified the problem in his remarks during a National Institutes of Health (NIH) Gait Research Workshop, March 9, 1977 at the Children's Hospital Health Center, San Diego, California, when he noted, "I would say right now we have almost no clinically-useful diagnostic tools that can be taken outside of the very heavily-financed research laboratory (to use in gait analysis)." We feel Burstein's views still hold today. We are developing a low-cost, simple gait analysis system called the D.U.R.S. (Direct Ultrasound Ranging System).

D.U.R.S can measure a number of parameters

The D.U.R.S. makes it possible to estimate the instantaneous velocity profile of the body center of mass during walking. D.U.R.S. can also measure parameters including the average walking velocity, instantaneous acceleration, average step length, cadence, amplitude of the relative velocity fluctuation about the average velocity and a number of symmetry indices. D.U.R.S. was designed to measure specific parameters based on the fact that a person's freely-selected average walking speed and cadence is one of the

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Exploring Direct Ultrasound Ranging
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better indicators of how well a person walks. Both speed and cadence decreases in times of injury and pain and increases in ratio to healing and recovery. Richards et. al., (1992) show that gait speed, cadence and stride length are gait parameters which continue to improve with physical therapy in stroke patients. In 1993, Richards et. al. used gait speed to assess the effectiveness of different rehabilitation techniques for facilitating ambulatory recovery in stroke patients. Gait parameters such as gait speed and stride length have also been utilized to assess the effectiveness of exercise programs for improving ambulation in the elderly. Andriacchi et. al. (1977) showed that analyzing the interrelationship, of gait speed, cadence and stride length, is important for characterizing normal and abnormal gait.

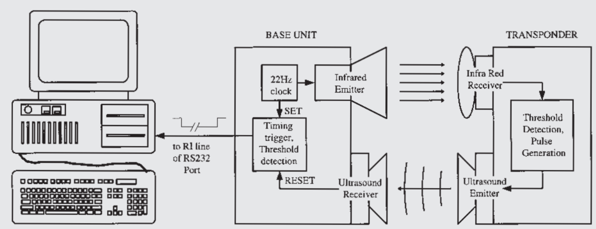
Gait analysis devices are typically expensive, complex

These measurements are difficult to make in the clinical setting because gait analysis devices are typically expensive, complicated to use, not very mobile and require a dedicated staff of technicians to process the enormous amount of data gathered. If one must travel to a center large enough to have a gait lab, costs are further increased. The D.U.R.S. is inexpensive by comparison with other devices, portable and automates the processing so it is simple enough that clinicians can operate the device without the assistance of technicians, and the results are generated in real time.

As a starting point for the D.U.R.S., we used a device built by Karcnik, et. al. (1992). The current version evolved out of a prototype built by Licameli (1994). Originally conceived as a means to provide prosthetists with a low cost method of measuring gait parameters when fitting and adjusting the alignment of lower limb prostheses, it appears that the D.U.R.S. may have additional applications. We foresee a situation where a surgeon prescribes surgery to correct a gait anomaly and then monitors the post operative recuperation using the D.U.R.S. in conjunction with a video camera. Full workup, at a full gait laboratory would be performed prior to and following the surgery. Further visits to the surgeon would be required only if the D.U.R.S. indicated something out of the ordinary. The system can be set up in a matter of minutes in any corridor and data is available in more or less real time allowing changes to be made and tested then and there.

The D.U.R.S. consists of three main components: a transponder, which is fixed to a belt worn by the subject; a base unit that emits infrared pulses and receives ultrasound pulses; and a computer to display and process the results. The emitted infrared pulse triggers the transponder, mounted on the subject, to emit an ultrasound pulse back to the receiver on the base unit. The time between emission of the infrared pulse from the emitter and the triggering of the transponder can be considered to be instantaneous. However, the ultrasound pulse, travelling at the speed of sound in air, which is around 344 meter/second at room temperature, cannot be considered to be instantaneous.

By calibrating for the speed of sound in air, the time of-flight of the ultrasound pulse to travel from the transponder to the base unit can be converted into a measurement of the distance between the base and the transponder units. In the actual system, the base unit triggers the computer to start a counter when it emits the infrared pulse. The arrival at the base unit of the ultrasound pulse triggers



Above is the schematic of the current D.U.R.S. unit designed by research engineers at Northwestern University PRL & RERP.

the computer to stop counting. Having previously calibrated the computer for a known number of counts per second, the computer converts this count into the time-of-flight for the ultrasound pulse. A distance measurement is then computed using the speed of sound [distance = Speed

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Northwestern University Prosthetic and Orthotic Programs Celebrate Anniversaries

By Jan Little

The 20th century drawing to a close prompts review of progress in that century. In the April 1995 issue of *Capabilities*, A. Bennett Wilson, Jr., and Eugene Murphy, PhD told the story of the meeting of military, Veterans Administration and university personnel at Thorne Hall on the Northwestern University Campus in 1945. This meeting initiated development of programs in prosthetic-orthotic research and education in many areas of the nation.

As the three Northwestern University programs, the Prosthetics Research Laboratory (NUPRL), Prosthetic-Orthotic Center (NUPOC) and Rehabilitation Engineering Research Program (NURERP) celebrate significant anniversaries, it gives us the opportunity to learn how they grew.

Part I: Three Pioneers share their memories of the beginning of the programs

NUPRL Began in a Basement

The Prosthetics Research Laboratory (NUPRL) was established by Dr. Clinton Compere in the basement of the old Rehabilitation Institute of Chicago building at 401 E. Ohio in the summer of 1956. Northwestern University, through Dr. Paul Magnuson, founder of the Rehabilitation Institute of Chicago, and Dr. Paul Klopsteg, NU Technological Institute, had been involved in the launching of the federally funded prosthetics research program in the U.S. in 1945. Northwestern had a VA sub-contract for research from 1945 to 1947.

Although some education in prosthetics and orthotics was conducted at RIC and Northwestern from the time that RIC opened, the initiation of a formal education program in prosthetics came in 1958. As a result of activities subsequent to the Thorne Hall meeting, the Veterans Administration had established the first school at the University of California/Los Angeles in 1952, followed by a second school at New York University in 1956. Perhaps establishment of the third school at Northwestern, funded by the Vocational Rehabilitation Administration (VRA) was influenced by Ralph Storrs, who pointed out that a local school would allow him to teach without travelling to both coasts. Storrs, a principle in Pope Brace Company, Kankakee, IL, was regularly invited to lecture at both UCLA and NYU.

Rehabilitation Engineering Centers Established

In 1972, Northwestern University was the recipient of a National Rehabilitation Engineering Center grant from the National Institute on Handicapped Research (NIHR), later renamed the National Institute on Disability and Rehabilitation Research (NIDRR). This program was one of the first centers designated by NIHR to be the national focus for study of a specific area of biomedical and rehabilitation engineering. The Northwestern University Rehabilitation Engineering Research Program (NURERP), co-directed by Dr. Compere and Dr. Dudley S. Childress, had two areas of focus: orthopaedic implants -- particularly knee and hip -- and assistive technical aids for persons with profound physical disabilities. Dr. Jack Lewis, who also served half-time on the Civil Engineering faculty, was project director of the orthopaedic implant research.

In this issue of *Capabilities*, we are exploring the early history of the three programs. No history could begin without a description of Dr. Clinton L. Compere, who created the concepts for the programs and inspired the people who initiated them. We are fortunate to have the people who were instrumental in the early days recall their memories of the initiation of the three Northwestern University programs.

Dr. Clinton L. Compere

When Paul B. Magnuson, MD founded the Rehabilitation Institute of Chicago, Clinton L. Compere, MD, played a significant role in launching the Institute and establishing programs to benefit people with amputations. Perhaps the program dedication for the 7th World Congress of the International Society for Prosthetics & Orthotics, Chicago, 1992, in

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Prosthetic, Orthotic Programs Anniversaries
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which Dudley S. Childress, PhD, honored Dr. Compere, best summarizes his contributions in building the foundation for the Northwestern University programs in prosthetics and orthotics.

Childress wrote: "*Sir Isaac Newton remarked that if he saw farther, it was because he stood on the shoulders of giants. Dr. Clinton Compere was one of the giants of orthopaedics, prosthetics and orthotics, and rehabilitation. Much of the work in Chicago in these field stands on his shoulders. Many regard him as the father of professional prosthetics and orthotics in Chicago.*"

"*First of all an excellent physician, surgeon and humanitarian, Dr. Compere gave freely of his time and energy to the development of national programs in prosthetics/orthotics education, prosthetics/orthotics research, rehabilitation engineering, and orthopaedics research. He established the first amputee clinics in Chicago and worked with Dr. Paul Magnuson in the establishment of the Rehabilitation Institute of Chicago (RIC), one of the first rehabilitation hospitals in this region. His work behind the scenes created an institution, unusual at the time, because of the strong cooperative efforts between orthopaedics, physical medicine and rehabilitation, engineering , and other medical and scientific disciplines.*"

"*The many orthopaedic surgery residents who were fortunate to train under his guidance from 1949 through 1982 will long remember Dr. Clinton as their surgical mentor. His influence lives on. As Henry Adams said, 'A teacher affects eternity; no one can tell where his influence stops'.*"

"*Compere's mentorship extended to some of the first rehabilitation engineers in North America, long before the concept of biomedical engineering had crystallized. He always had warm and cordial relationships with prosthetists, orthotists, engineers, and other technical persons associated with rehabilitation and orthopaedics. His concern was to serve his patients in the best way possible.*"

"*Born in Texas, Compere received the M.D. degree from the University of Chicago in 1937. A battalion surgeon in the South Pacific, he was chief of the amputee section of McGuire Army Hospital when discharged in 1946. He entered the practice of orthopaedic surgery in 1947. He was a surgeon who was willing and able to take on difficult orthopaedic cases. Always interested in prosthetic fittings, he led a team of eight Chicago surgeons to the first UCLA pilot course in prosthetics in 1952. Dr. Clinton was a caring, sensitive physician. A trademark was that he listened to his patients and always took plenty of time with them. He frequently appeared to have a gruff manner, but that was all superficial. He was a quiet man who often worked effectively in the background without fanfare.*"

Dr. Clinton Compere was the driving force behind Northwestern prosthetic and orthotic programs.

That Dr. Compere was the inspiration for the programs in prosthetics and orthotics at Northwestern University was affirmed by three professionals that shared his dreams.

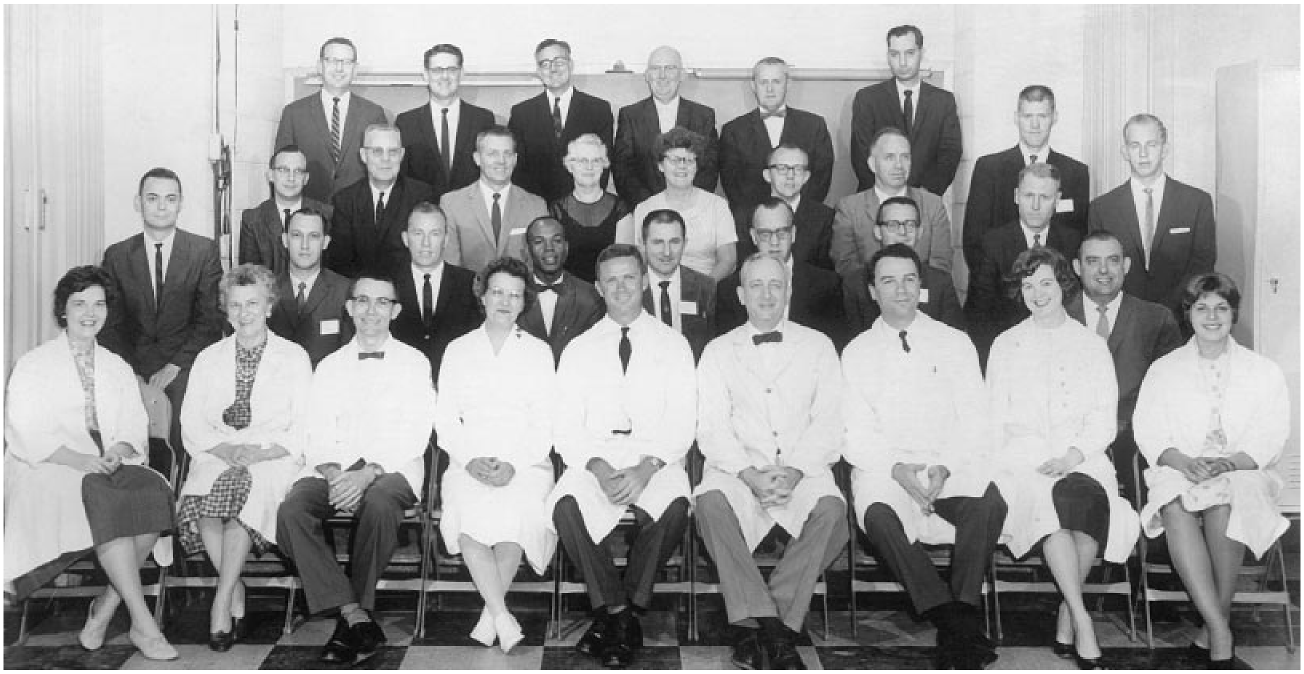
Hildegarde Myers, RN, RPT

Miss Myers, who served as the Director of Physical Therapy of the Rehabilitation Institute of Chicago for the first 20 years of its history, was there when the seeds of the institution which became NUPOC were sown by Dr. Clinton Compere. Miss Myers, although she worked as a physical therapist during her Army career, was commissioned as a nurse when she enlisted in 1942 during World War II . There were no commissions for physical therapists at that time. Her unit first served in Texas, then, as the war progressed, her unit was moved to Milne Bay and then Helandia in New Guinea. The unit later moved to Leyte, then Manila in the Philippine Islands.

Back in the United States, Miss Myers, like Dr. Compere, was discharged from the Army in 1946. She joined the staff of Hines VA Hospital, just west of Chicago and attended night school to work toward certification as a physical therapist.

After taking time off to finish her physical therapy education at the University of Wisconsin, she returned to the Chicago area to work at the Veterans Administration Regional Office. "I don't remember the exact address any more", Miss Myers admits. "But, it was across the river from the Union Station (on the west side of Chicago's Loop)." It was there that Miss Myers began working with Dr. Compere.

She recalls aiding Dr. Compere to establish the amputee clinics that were held in a large room in the old warehouse



In this photo, circa 1962, Miss Myers is shown fourth from the left in the first row. Other pioneers that current NUPOC and NURERP staff recognized were (left to right in the first row) Susan Moulder Strainus, Eleanor Manikowski, Clarke Sabine, Miss Myers, Dr. Jack Armold, and H. Blair Hanger. If you know any others in the photo, we'd appreciate hearing from you.

building housing the VA Regional Center. To advance treatment of their patients, Dr. Compere sent Miss Myers to the training courses that had been started at the University of California at Los Angeles and at New York University. "It was so exciting!" Miss Myers recalls, "We learned all about the latest methods and the latest prosthetics -- then I got to go back to Chicago and help put them into practice with our amputee patients." She recalls this period as the time when prosthetists were only starting to use suction sockets instead of the cumbersome harnesses previously used. She tells about how upper limb prostheses were often made, then sent to the patient through the mail. She mused that this delivery method caused many upper limb amputees to put the prosthesis in the closet without ever trying it on. Cosmetic hands were being introduced.

"Veterans got good care, good prostheses and training in how to use them," she said. "The poor civilians didn't get any of that." So it was exciting news to Miss Myers when Dr. Compere told her that Dr. Magnuson was establishing a rehabilitation center in Chicago to serve the civilian population. Dr. Compere urged her to move from the Veterans Administration to the new center, the Rehabilitation Institute of Chicago (RIC). It, too, was housed in a former warehouse -- at 410 East Ohio Street in Chicago.

RIC opened in 1954 with a ready source of patients. The majority of the patients seen at RIC were amputees who had previously been seen by Miss Myers and Dr. Compere using borrowed space at Northwestern Memorial Hospital's physical therapy department. The amputee clinic was one of the first programs at the new rehabilitation hospital.

Even before the VRA established what later became known as NUPOC, Miss Myers was among those on Dr. Compere's staff who began teaching classes to share the knowledge acquired while attending the prosthetic schools at UCLA and NYU. She recalls that both University of Illinois and Northwestern University schools of physical therapy requested a full week of

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training for each class. In addition, classes for other physical therapists, prosthetists and doctors were established. She tells how Bill Sobbe, who was a prosthetist at J.E. Hanger Laboratories and, himself a lower limb amputee, made practice legs so she could demonstrate deviations in gait to her classes. The film they made is still used today in prosthetic education.

Miss Myers was also involved in history in clinical practice. She worked with Richard Shearer, the first person to use a self-contained myoelectric upper-limb prosthesis. Gradually, Miss Myers' responsibilities as Director of Physical Therapy for the Rehabilitation Instititute of Chicago became increasingly heavy and she passed her teaching responsibilities on to others.

Robert G. Thompson, MD

Shortly after completing his orthopaedic residency in 1952, Dr. Thompson joined Dr. Clinton Compere, Dr. Edward Compere and Dr. William Schnute as a partner in their orthopaedic surgery practice group. Dr. Thompson tells of how Dr. Paul Magnuson, who was called to a national post at the Veterans Administration by President Truman, convinced the federal government that VA hospitals should be located next to teaching universities, rather than in small towns as was the practice in the 1940s. Dr. Magnuson was instrumental in establishing what later became Lakeside Veterans Administration Medical Center (VAMC), across the street from Northwestern Memorial Hospital (NMH), and Westside VAMC, near the University of Illinois Hospital. Perhaps it is indicative of Dr. Magnuson's influence on both the VA and Northwestern that paintings of him hang in Lakeside VA, RIC and Passavant Hospital. According to Dr. Thompson, Compere and Magnuson felt that services available to veterans with amputations should also be made available to civilians. The criteria for the civilian hospital was that it, like Lakeside VAMC, should be as near to NMH as possible. The site nearest for one of the first civilian rehabilitation centers in the Midwest, the Rehabilitation Institute of Chicago, was an abandoned book warehouse located at 401 E. Ohio Street.

Prosthetics in the 1950s had not changed significantly from the time of the Civil War

Dr. Thompson was among the eight surgeons who accompanied Dr. Compere to UCLA to work with new prostheses developed at that institution with funding and support from the VA. Like Miss Myers, Dr. Thompson was eager to return to Chicago and share his newly acquired knowledge with his patients. "Prostheses, prior to those developed at UCLA, had not changed significantly from the time of the Civil War," Dr. Thompson said.

A new era in how amputees were treated began with the Compere team. Prostheses were prescribed for the individual. Dr. Thompson recalls how the team insisted on specifying the exact type of socket, joint, foot and other components for the individual. The prosthetist would then fabricate the prosthesis. "Then we'd give it to Miss Myers, who would train the patient how to use it." The success rate for this individualized treatment was so significant, Dr. Thompson reports, that at one time, the State of Illinois sent all amputees funded by the state under workers compensation programs to RIC.

Teaching was a high priority to Dr. Compere, Dr. Thompson said. Classes for doctors and prosthetists began as early as 1954. Funding at the time was provided by the Veterans Administration until the Northwestern School was formally funded by the Vocational Rehabilitation Administration in 1958.

The programs initiated by the Veterans Administration at UCLA and New York University were inspirational to Dr. Compere. When the Rehabilitation Institute of Chicago opened on Ohio Street in 1954, Dr. Compere soon established a Prosthetics Research Laboratory. The laboratory began in the basement of the building during the summer of 1956 and, by February of 1957, Dr. Compere had convinced Colin McLaurin, a young Canadian engineer with an extensive background in prosthetics and orthotics, and Fred Hampton, the prosthetist who teamed with McLaurin in many prosthetic innovations, to come to Chicago to guide development of the laboratory.

Dr. Thompson continued to practice at both NMH and RIC. He watched as the programs, including prosthetic research, outgrew 401 E. Ohio. RIC eventually moved to a building designed specifically to house the rehabilitation treatment, research and education programs. Dr. Thompson continues to stay active at NUPOC by teaching courses about orthopaedic surgery at NUPOC.

Colin A. McLaurin, ScD

Colin McLaurin, the "young Canadian engineer with an extensive background" who was convinced to come to Northwestern by Dr. Compere, was working at an aviation company in Ontario at the time he received the call from Dr. Compere. Previously, however, McLaurin had used his engineering talents to create solutions to problems faced by people with amputations at Sunnybrook Hospital in Toronto, Ontario, Canada. This facility was funded by the Canadian department for veterans affairs.

Dr. McLaurin tells how Dr. Compere was instrumental in convincing Dr. Robert Stewart, who was with the Veterans Administration in Washington, to provide funding for the Prosthetic Research Center by citing the historical support for the establishment of such a Center at Northwestern. Dr. Magnuson, in his work at the National VA Medical Department, had been a strong proponent for research. Indeed, federally-funded prosthetics research programs had grown out of the meeting at Thorne Hall on the Northwestern University campus in 1945 in which Dr. Magnuson and Dr. Paul E. Klopsteg had played significant roles.

Dr. McLaurin soon found that he had no end of challenges to develop prosthetic components that would answer the needs of patients at RIC and the VAMC. He was joined by Fred Hampton, a prosthetist with whom McLaurin had worked in Canada. "We picked up the problems that the commercial firms did not feel occurred frequently enough for them to develop products as solutions", McLaurin said. Perhaps the people with hip disarticulations and hemi-pelvectomies with whom McLaurin and Hampton worked were among the first such people to receive prosthetic solutions to their needs. McLaurin recalls working with a person with a hemi-corporectomy -- amputation of both lower limbs and the pelvis. He and Hampton also traveled to Grand Rapids, Michigan to collaborate with Dr. George T. "Tom" Aitken on developing electrical prostheses for children.

Some solutions were just plain simple logic...

"There was one young girl -- 9 or 10, I suppose -- for whom we devised an electric limb, the geometry of which was such that the sweep moved to her mouth. It allowed her to feed herself," McLaurin told us. "Some solutions were just plain simple logic -- like the time Fred Hampton and Fred Sammons were trying all kinds of things to keep harnesses for upper extremity prostheses from twisting. I walked in and said, 'Try using a ring' and the ring-type harness became widely used."

Other early developments involved development of prostheses for people with Symes amputations, use of silicone gels rather than plaster for taking casts, built-in adjustability for the pylons used in transtibial amputations and what became known as the Northwestern Knee.

Like everyone on Dr. Compere's team, McLaurin and Hampton, with their knowledge of biomechanics and research procedures, were automatically faculty members at NUPOC. The growth of NUPOC was guided by Dr. Warren Perry, Jack Armold, PhD, and Charles Fryer, MA before Dudley Childress was appointed Director in 1988.

Colin McLaurin left Northwestern University in August of 1963 to return to Toronto, Canada and develop a rehabilitation engineering research center at Ontario Crippled Children's Hospital. He also developed a rehabilitation engineering center at the University of Virginia from which he recently retired. Fred Hampton has retired to Margate, Florida, near Jackson Memorial Hospital, where he practiced after leaving Northwestern. ❖

In the next issue of Capabilities, we will share more memories of the early years of the three programs with other pioneers.

Full Presentation Schedule for NUPRL&RERP Faculty and Staff

Northwestern University faculty and staff were well represented at the annual meeting of American Academy of Orthotists and Prosthetists (AAOP), March 12 in San Francisco. Craig Heckathorne, MSc presented a paper co-authored with staff members of The Institute of Rehabilitation and Research (TIRR) in Houston, Texas. Heckathorne, in collaboration with TIRR staff Diane J. Atkins, OTR, D. C. Y. Heard, MSE, and W. H. Donovan, reported on "Partial Results from TIRR Upper-Extremity Bilateral Prosthetic Survey". Heckathorne also joined Dudley S. Childress, PhD, and RIC staff members, Judy Meredith, OTR, Jack Uellendahl, CPO and Yeongchi Wu, MD, in presenting "Seven Year Follow-Up of a Person with Bilateral Shoulder Disarticulations". Also presented at the AAOP meeting was "How Shoes Alter Prosthetic Foot Mechanics" by Childress and Erick Knox.

In continuing educational efforts at Northwestern University, Steven A. Gard, PhD, presented "An Investigation of Foot Clearance Issues in Normal and Amputee Gaits" to the Department of Biomedical Engineering at the Technological Institute and Dudley Childress, PhD, lectured on human gait to the medical students at Northwestern University Medical School.

Janet Jhoun, MS, Richmond Chan, PhD, Steven A. Gard, PhD, and Richard Weir, PhD, presented poster sessions at the North American Society of Gait and Clinical Movement 1997 Conference held in Chicago, April 10-12. Dudley Childress, PhD, made a podium presentation. The event was sponsored by Children's Memorial Hospital, the Rehabilitation Institute of Chicago, Rush-Presbyterian-St. Luke's Medical Center, the Medical University of Wisconsin and Shriner's Children's Hospital.

Jan Little, MS, presented "Disability and Aging: Your Client's Concerns and Fears" at the Thirteenth International Seating Symposium, January 24 in Pittsburgh, PA. The Symposium was co-sponsored by the University of Pittsburgh Medical School and the Sunnybrook Hospital, Vancouver, British Columbia.

Recent NUPOC Faculty Lectures

Lectures in February included Bryan Malas, CO, Director of Orthotic Education, Northwestern University Prosthetic-Orthotic Education Center (NUPOC), who delivered a lecture, "Normal Gait", to the Rehabilitation Institute of Chicago (RIC) Physical Medicine and Rehabilitation (PMR&R) Residents. Mark Edwards, CP, Director of Prosthetic Education at NUPOC, spoke about "Biomechanics of Trans-Tibial and Trans-Femoral Prostheses" to the PM&R Residents. May Cotterman, LPT, and Tom Karolewski, CP, presented a one-day seminar at the Danville, IL Veterans Administration Medical Center. The focus of the program was Upper and Lower Limb Prosthetics Update and was direct to the physicians, therapists and nursing staff of the Medical Center.

Childress Serves Hong Kong Polytechnic University

Dudley S. Childress, PhD, was the External Examiner for Yong-Ping Zheng, a PhD candidate at the Polytechnic University in Hong Kong in February. Zheng has been a graduate student with Professor Arthur F.T. Mak. Childress, during his visit from February 13 through 20, also conferred with the Board of Examiners in evaluating educational programs in orthotics and prosthetics at Polytechnic.

Publications by Northwestern Prosthetics and Orthotics Personnel

Laura A. Miller, MS and doctoral candidate, co-authored, "Analysis of a Vertical Compliance Prosthetic Foot", with Dudley S. Childress, PhD. The article was published in the January 1997 issue of the *Journal of Rehabilitation Research and Development*, Volume 34, No. 1, pp. 52-57. Childress also authored "The Interfaces Between Humans and Limb Replacement Components", Chapter 12 in the Osseointegration in Skeletal and Joint Replacement, pp. 158-169, 1996.

Laura Fenwick, CO, Mark Edwards, CP and Dudley Childress, PhD, wrote the chapter on orthotics and prosthetics in the *Encyclopedia of Disability and Rehabilitation.* The reference book, intended for students, clinicians, researchers and academic staffs, addresses various disability related topics including medical, psychological and social implications of various disabilities on the lives of people with disabilities and those who surround them. The nearly 800-page book was published by Simon & Schuster Macmillan, 866 Third Avenue, New York, NY 10022 and sells for $105.00.

Orthotic Management of the Developmental Forefoot

By Bryan S. Malas, CO, CPed
Director, Orthotic Education, NUPOC

For those who are implementing orthotic management for children, the growing question is whether to accommodate a forefoot varus, as shown in Figure 1, or whether to use an orthosis that maintains a parallel hindfoot to forefoot relationship. In order to successfully achieve optimal alignment, musculoskeletal and developmental milestones must be considered.

Understanding the development of the forefoot is critical to making proper decisions about orthotic management. Developmental changes occur to the forefoot from infancy to about the age of eight. Twelve to fifteen degrees of forefoot varus is present in the newborn and reduces to six degrees at about one year of age.[1,2] Reduction of forefoot varus continues until approximately the age of eight, when the child exhibits between 0-2º varus [3] which remains throughout life. Although the child is still growing at eight years, most authors agree that morphologically, the foot has a very similar presentation to that of adults. At this time, the child has also developed a mature gait, patterned closely to that of an adult. Considering this fact, orthotic management should then follow a pattern very similar to that of normal development. To mimic such a pattern, one must continually assess the growing child for developmental changes.

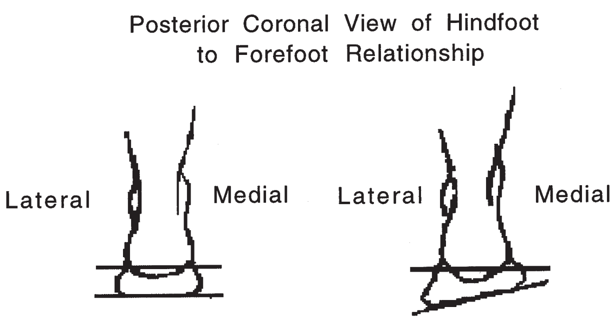

Figure 1

Primary assessment of the forefoot should focus on the amount of flexibility available. If the forefoot presents with a flexible deformity, correction should be introduced. A forefoot that presents with a fixed deformity, is subject to accommodative management. Many children with cerebral palsy, however, will exhibit excessive forefoot varus relative to a neutral subtalar joint[4]. Most of these children, if under the age of eight, will present with a flexible and reducible forefoot varus. The need for accommodative measures for children with this type of varus is not recommended. If the child is placed in an AFO that maintains a subtalar neutral position and a parallel hindfoot to forefoot relationship, the flexible forefoot will rest in a position parallel to that of the hindfoot upon weight bearing.

A child's natural development, age, and amount of flexibility of the forefoot are equally important considerations when assessing for proper orthotic treatment. The ideal position for the forefoot relative to the hindfoot coronally, when the child reaches the age of eight, is 0-2º. It stands to reason, then, that accommodating a developing flexible forefoot varus with medial wedging may potentially create two problems: 1) elimination of the progressive forefoot varus reduction from infancy to eight years of age; and 2) risk of creating a fixed forefoot varus. If the child presents a fixed forefoot varus, the predisposition to pes planus and subsequent posterior tibialis tendonitis/insufficiency is much greater. While accommodation may seem a reasonable solution for some, the potential long-term effects may be detrimental to the child. ❖

References

1. Waugh, K.G., J.L. Minkel, R. Parker, and V.S. Coon, 1983. Measurements of selected hip, knee and ankle joint motions in newborns. *Physical Therapy* 63(10):1616-1621.

2. Cusick, B.D. - unpublished findings and clinical experiences.

3. Tax, H.R., 1985. Podopediatrics, second edition. Baltimore, MD: Williams and Wilkins.

4. Hunt, G.C. and McPoil, T.G., 1995. Physical Therapy of the Foot and Ankle, Second Edition. New York, NY: Churchill Livingstone, Inc.

Malas and Edwards Named to National Committes in P & O

Bryan Malas, CO, has been NUPOC representative to the Committee of the National Association of Prosthetic and Orthotic Educators (NAPOE). The group accredits P & O educational courses through the Commission on Allied Health Education Programs (CAHEP). Mark Edwards, CP, was appointed for a three-year term on the National Commission on Orthotic and Prosthetic Education (NCOPE). NCOPE provide quality assurance for prosthetic and orthotic education programs. ❖

Exploring a Direct Ultrasound Ranging System to Make Gait Analysis Faster and More Economical

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x Time] and stored for later processing. Finally, since D.U.R.S. makes a distance measurement at a sampling rate of 22 Hz, i.e. once every 0.045 seconds, a measure of how the distance changes over time (i.e. velocity) can be obtained.

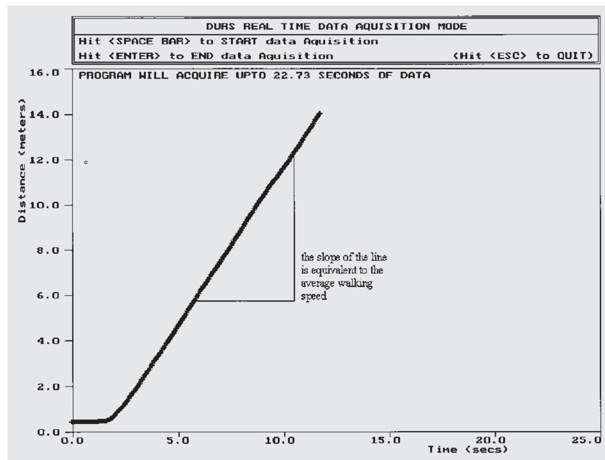
Measuring distance with ultrasound not a new concept

There is nothing new about the concept of using ultrasound to measure distance. Some Polaroid cameras measure the time taken for an ultrasound pulse, emitted from the camera, to travel to the object being photographed, and be reflected back to a sensor on the camera. This time-of-flight is then used to compute the distance to the object and to change the camera setting appropriately. The same use of reflected ultrasound signals is employed by numerous electronic measuring tapes. Major problems result from the fact that with reflected, or *indirect ultrasound ranging systems*, the pulse must travel twice the distance needed (out and back again). Because the magnitude of the pulse decreases in a manner inversely proportional to the square of the distance, the magnitude of the received pulse decreases far more rapidly than the distance increases. In addition, the reflected signal may also be scattered or absorbed by the reflecting surface. Since a pulse has to be received before a new pulse is transmitted, the maximum rate at which new pulses can be transmitted is cut in half.

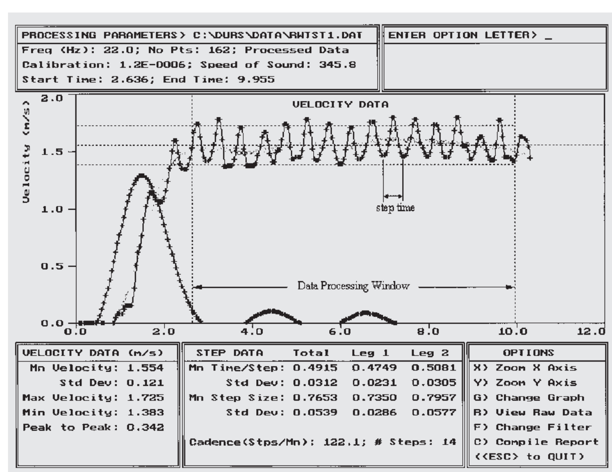
A back pack holds the D.U.R.S. Transponder at approximately sacral level as the subject walks away from the base unit.

For the above reasons, a *direct ultrasound ranging system* is preferable when trying to achieve higher sampling rates and longer distances. In a direct system, a transponder placed at the target emits an ultrasound pulse when it is triggered by a light pulse, usually an infrared pulse.

Direct systems have been used in commercially available static long distance measuring tapes, such as the Sonin 150. This device has a target and a source, but does not have the computer interface. According to the Sonin operating manual, the device is able to measure the fixed distance between these two components up to 45 m with 99.85% accuracy.



As the subject walks away from the base unit, his or her forward progression is updated in real time on the computer as shown in the photo above.



The velocity plot is automatically computed and displayed on the screen at the end of the walking trial.

To achieve this range, the Sonin is designed to initate a new distance sample immediately upon reception of the ultrasound signal or after a suitable period of time has elapsed without reception of a pulse. In effect, it has a sampling rate that varies with distance. To compensate for "lost" or "dropped" points, it waits until it receives a certain number of points and then computes and displays the average value of the distance. With this system, and in the case of the measurement of static distances, it is not critical for it to receive every transmitted ultrasound pulse. In a dynamic system, every transmitted pulse must be received to ensure an accurate measurement of how the distance changes with respect to time.

The use of a constant sampling rate in the D.U.R.S. imposes a maximum on the distance that can be measured. This maximum is controlled by the distance sound can travel within the designated sample interval and is around 15 meters or 50 feet.

Using the D.U.R.S. in the clinical setting

In the clinical setting, the subject usually wears the transponder posteriorly on the midline of the body at approximately sacral level (Sacral-2 vetebra). As the subject walks away from the base unit, his or her forward progression is updated in real time on the computer display, count data is stored to file for processing immediately following the trial. In essence, the transponder acts as a single active marker at the approximate level of the body center of mass.

At the end of the walking trial, the instantaneous walking velocity for that trial is computed and displayed on the computer screen. The velocity is obtained through differentiation and smoothing of the forward progression distance data.

A wealth of information may be obtained

The software algorithms used are similar to those developed at our laboratory for single marker gait analysis by Chan and Childress (1995). We believe that a wealth of information resides in the forward velocity profile. From this profile, gait parameters such as gait speed, cadence, stride length, step time and rate to achieve steady state walking, as well as other parameters can be calculated.

Accuracy of D.U.R.S. comparable to CODA 3

The accuracy of the D.U.R.S has been tested against the CODA 3 gait analysis system, which is used in the NUPRL&RERP Human Mechanics Measurement Laboratory. The velocity profiles obtained from the D.U.R.S. and the CODA 3 system are very similar. Both devices accurately measure the periodic fluctuation in the forward velocity of the body trunk that results from the rising and falling of the centre of mass during normal gait. The gait speed determined with the D.U.R.S. was consistently within 3% of the gait speed determined by the CODA 3 system. The current system can accurately measure distance out to 10 meters with a standard deviation of less than 1 mm. From 10 to 15 meters, the standard deviation increases to 5 mm.

A manufacturer to produce and distribute the D.U.R.S. will be selected after patenting procedures are completed. Although no price for the unit has been estimated, the comparative simplicity of the D.U.R.S. promises to make it a product well within the reach of many clinicians in terms of both cost and technical support needed to use the D.U.R.S. ❖

References

1. Andriacchi, T.P., Ogle, J.A., and Galante, J.O. (1977) " Walking Speed as a Basis for Normal and Abnormal Gait Measurements", *J. Biomechanics*, 10, pp. 262-268.

2. Chan, R. B., and Childress, D.S. (1977),"Gait: One-Marker Analysis" *Gait & Posture*, 4(2): pp. 175-176.

3. Karcnik, T. Kralj, A. and Munih, M. (1992). " Ultrasound Distance-Velocity Measurement Incorporated into FES Rehabilitative Systems". Proceedings of Fourth Vienna Mt. Workshop of Functional Electrostimulation, Sept. 23-27, pp. 48-51.

4. Licameli, J.N., (1994). "The Development of a Direct Ultrasound Ranging System for Quantification of Human Ambulation". Master of Science Thesis, Field of Biomechanical Engineering, Northwestern University, Evanston, Illinois.

5. Richards, C.L., Malouin, F., Dumas, F. and Wood-Dauphinee, S., (1992). The Relationship of Gait Speed to Clinical Measures of Function and Muscle Activation during Recovery Post Stroke, Proceedings of NACOB II, Chicago, Aug. 24-28, pp. 299-302.

6. Richards, C.L., Malouin, F., Wood-Dauphinee, S., Williams, J.I., Bouchard, J.P., and Brunet, D. (1993). "Task-Specific Physical Therapy for Optimisation of Gait Recovery in Acute Stroke Patients". *Arch. Phys .Med. Rehabil.*, 74, pp. 612-620.

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