2005

HPER Biomechanics Laboratory 2004 Annual Report: A Surveillance of the Neuromuscular System, Issue 3

Nebraska Biomechanics Core Facility
University of Nebraska at Omaha

HPER Biomechanics Laboratory 2004 Annual Report

A Surveillance of the Neuromuscular System

Featured Topics in this Report:

Message from the Director

HPER Biomechanics Lab Director, Nick Stergiou, PhD.

Our laboratory was established for the purpose of developing a new understanding of the dynamical aspects of human movement. The laboratory is a flourishing enterprise where engineers, scientists and clinicians get together to gain additional insights on healthy and abnormal gait. The laboratory uses techniques from biology, engineering and mathematics to understand the complexity of the neuromuscular system. Such techniques have revolutionized the way we perceive how the neuromuscular system controls human movement.

Our laboratory has earned a national and international reputation of excellence in basic and clinical research. Several domestic and international visitors have toured our facilities and collaborated with our research team. Our annual report is designed to give you a brief look at who we are and what we do. We hope that after reading about us that you will want to come to the HPER Biomechanics Laboratory and visit us in person as well.

Nicholas Stergiou, PhD

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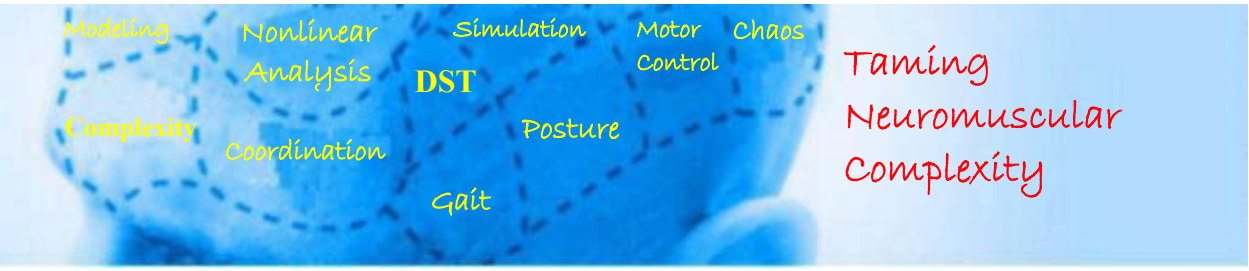
http://www.unocoe.unomaha.edu/hper/bio/home.htm



2004 - A Great Year for External Funding: THREE GRANTS AWARDED TO DR. STERGIOU

In July 2004, Dr. Stergiou and his collaborators received two Nebraska Research Initiative (NRI) grants.

The first NRI grant, with $433,966 in funding, has Dr. Stergiou as the principal investigator with Dr. Foster (University of Nebraska/Lincoln-Engineering), and Drs. Heidel, Matache and Wang (all of the University of Nebraska/Omaha-Mathematics) as his partners. The title of this grant is "A Biomedical Devise for Prognostic and Diagnostic Measures of Pathological Locomotive Bio-Rhythms."

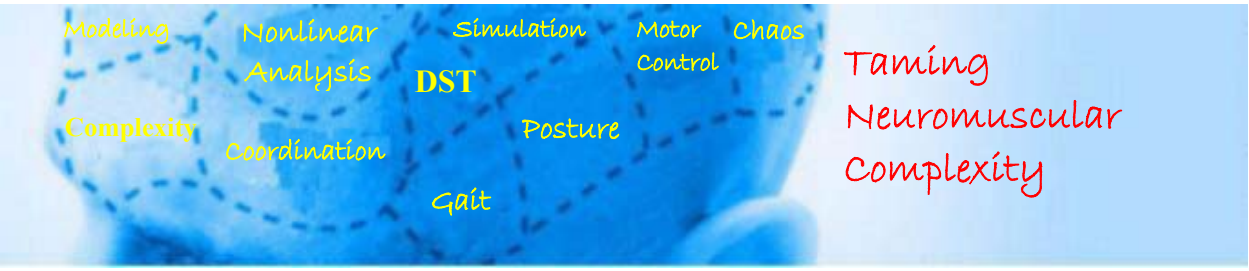
On the second grant with $1,185,852 in funding, Dr. Stergiou is co-principal investigator along with Dr. Oleynikov and Marsha Morien (of the University of Nebraska-Medical Center) and Drs. Farritor, Hallbeck and Platt from the University of Nebraska/Lincoln-Engineering. The title of this grant is "New Robotic Surgical Tools for Minimal Access Surgery."

Almost a month later, Dr. Stergiou received federal funding as a principal investigator from the National Institute on Disability and Rehabilitation Research (NIDRR). Dr. Stergiou with his co-investigators from the Munroe-Meyer Institute of the University of Nebraska Medical Center, Regina Harbourne and Dr. Wayne Stuberg, began working on this grant in December of 2004. The grant is funded for three years for $450,000 and its title is "Investigation of the dynamics of development of sitting postural control in infants with cerebral palsy."

Robotic Surgery Research is Funded by the Nebraska Research Initiative

Laparoscopy is a minimally invasive surgical technique that has been an invaluable tool for diagnosing abdominal pathology. It can be performed with manually operated graspers. It can also be performed with robotic surgical systems such as the daVinci™ Surgical System from Intuitive Surgical. The novel abilities of such systems in terms of precision and efficiency have recently received great attention. However, the best method for training surgeons in robotic laparoscopy has yet to be identified. Funds from the Nebraska Research Initiative have been awarded to our research team to develop a patient-specific virtual reality training simulator. Prior to surgery, patient's scans will be converted into a virtual reality model of the patient that can be manipulated in a virtual environment. The surgeon can then

Surgical suite utilizing the daVinci™ Surgical System for minimal access surgery.



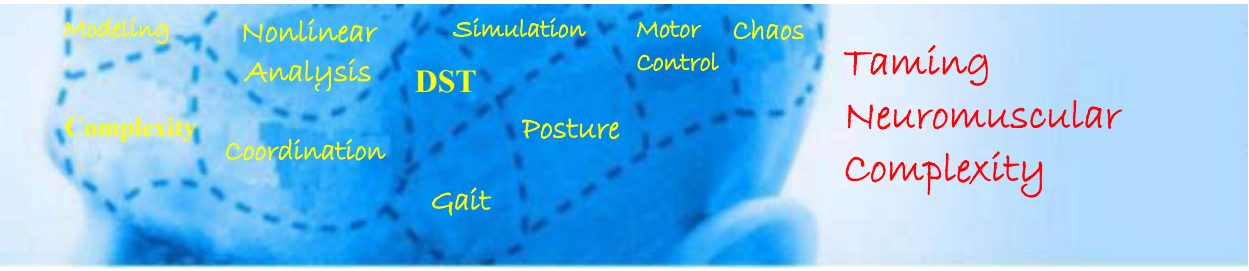
practice that patient's surgical procedures prior to the actual surgery. Graduate student Tim Judkins is heading the laboratory's efforts toward this project. Tim has a BS degree in computer engineering from Virginia Tech and an MS in biomedical engineering from Marquette University. He is now pursuing his PhD in biomedical engineering from the University of Nebraska-Lincoln (UNL) under the guidance of Dr. Stergiou. The grant from the Nebraska Research Initiative will also foster the formation of the Center for Advancement of Surgical Technology (CAST). CAST is a collaborative effort between UNO, UNMC, and UNL to facilitate interaction and collaborative research between surgeons, physicians, life scientists, engineers, and computer scientists specifically interested in contributing to work on the advancement of surgical technology. Currently, this collaboration has resulted in two patent-pending technologies and work is continuing on other devices. Current CAST members are Dr. Dmitry Oleynikov (UNMC), Dr. Shane Farritor (UNL), Dr. Susan Hallbeck (UNL), Dr. Stephen Platt (UNL), Dr. Nick Stergiou (UNO), and administrator Marsha Morien (UNMC).

Close up of the robotic tool and surgical table.

Federal Grant is Awarded for the Study of the Development of Posture in Children with Cerebral Palsy

The continuous hard work of Dr. Stergiou and his colleagues from the Munroe-Meyer Institute, Regina Harbourne and Dr. Wayne Stuberg, on the development of posture in children was recently rewarded with a large federal grant. Our research team received a three year $450,000 grant from the US Department of Education and the National Institute on Disability and Rehabilitation Research. The title of the grant is "Investigation of the dynamics of development of sitting postural control in infants with cerebral palsy" and work began last December. In the past, this collaboration has led to innovative ways to evaluate the development of sitting posture in children. This grant enables our research to move forward in establishing baseline data for the diagnosis of movement disorders and the examination of treatment efficacy. Our research team also develops clinical tools that can assist in determining effective treatments for children with movement dysfunction and early detection of disabilities. In this work, we use techniques from the mathematical theory of

Our typical set up for capturing sitting development on a padded force plate.



chaos to determine variables that describe the stability and complexity of the posture of the developing child. Graduate students Joan Deffeyes and Clint Wutzke are among the HPER Biomechanics Laboratory graduate students that work on this project. Joan received a MS in Mechanical Engineering from Stanford and she is currently pursuing her doctorate under the direction of Dr. Stergiou. Clint completed his BS in Kinesiology and Psychology at the University of Lethbridge in Alberta, Canada and he is working toward his MS in Exercise Science.

Infants developing typically (at age 4 months) and infants who are at risk/diagnosed for cerebral palsy, ages 5 months to 2 years are needed for research investigating sitting development and effects of physical therapy treatment. Call Reggie Harbourne, Munroe-Meyer Institute Physical Therapy Department, (559-6415 or rharbour@unmc.edu), or Lisa Holst in the UNO Biomechanics lab, (554-3075 or lholst@mail.unomaha.edu) for additional information.

David Miller and Max Kurz inserting our device into his shoe and testing the devise while on the treadmill.

The Nebraska Research Initiative Funds our Innovative Research in Gait Analysis

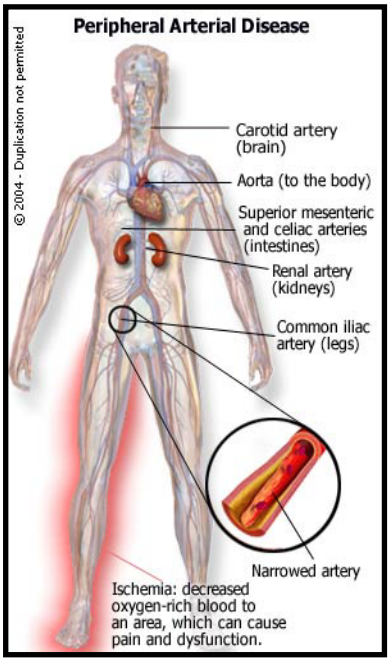
Biotechnology is a buzzword today. Many non-invasive medical tests that we have now are the result of biotechnology, such as electrocardiography (EKG) to diagnose heart function. Another tool is a mobile heart monitoring apparatus that helps a distant cardiologist make a diagnosis from information sent over the phone while the person is in their own home. Gait analysis can be very helpful for diagnosis of several movement disorders such as Parkinson as well as rehabilitation from joint arthroplasty or ligament reconstructions. However, there are only a handful of gait analysis labs in Nebraska. The clinicians running these sophisticated and expensive laboratories also need extensive technical training in order to collect, process and interpret the data. Funds from the Nebraska Research Initiative in the amount of $433,966 have been awarded to our research team of principal investigator Dr. Stergiou and his associates Drs. Foster (UNL), Heidel (UNO), Matache (UNO) and Wang (UNO) to further develop simple biotechnology for locomotion with a concept similar to that of a mobile heart monitor. Our wearable biomedical instrument can measure how a person normally walks throughout a day. For instance, a person's doctor could gauge the amount of improvement from gait measurements taken before and after therapy. At this time, the data collected with the wearable devise is seamlessly imported to a

computer. Our software can then analyze the health of the person's neuromuscular system. This unique software is based on the mathematical theory of chaos and fuzzy logic. With this information, neurologists, orthopedists and others can make better diagnosis and treatment plans for their patient. Graduate students Max Kurz and David Miller are among the HPER Biomechanics Laboratory graduate students that work on this project. Max received his MS from UNO and is currently pursuing his Doctorate under the guidance of Dr. Stergiou. Dave Miller got his MS in Biomedical Engineering from Arizona State University and his BS in Biological Systems Engineering from the University of Nebraska - Lincoln. He is currently pursuing his Doctorate in Biomedical Engineering at UNL under the guidance of Dr. Stergiou. Our biomedical device is currently under review for patent rights.

Collaboration with University of Nebraska Medical Center Department of Surgery on the Effects of Peripheral Arterial Disease on Gait

Peripheral arterial disease (PAD) is a debilitating disease affecting 8 to 12 million people in the Unites States. When an individual walks, there is an increase in the metabolic demand of the muscles in the legs. This results in increases in blood flow to the necessary muscles for the individual to be able to continue to walk. However, a PAD patient is unable to meet the metabolic demand of the muscles due to atherosclerotic obstruction in the vessels. The result is intermittent claudication, otherwise known as, pain occurring in the legs that subsides with rest due to reperfusion of the muscles. A PAD patient may not be able to walk more than 10 feet at a time. In addition, some of the most extreme cases result in amputation. Staff from the HPER Biomechanics Laboratory and in particular graduate student Melissa Scott-Pandorf, in collaboration with Dr. Iraklis Pipinos of the UNMC and Veterans Affairs General Surgery Departments, is evaluating the effect that PAD has on gait. They are using state of art video and force analysis to understand how these patients are affected. This research is unique because no other laboratory has ever examined, in such detail, how these patients walk. Gait studies in other pathological populations have found altered walking patterns specific to the

Gait analysis on treadmill.



pathology and ways for improvement of surgical techniques and rehabilitation. However, such developments are not currently available for PAD patients. Our investigations will address this problem and will evaluate the efficacy of surgical techniques and pharmacotherapy.

Omaha Media Features Dr. Nicholas Stergiou

On April 30, 2004, the Gait Analysis Service of the HPER Biomechanics Laboratory and Dr. Stergiou's early research on running shoes was featured on the Channel Seven KETV News http://www.theomahachannel.com/health/3255400/detail.html.
The feature highlighted how our service can help someone to properly select shoes in order to prevent injury during workouts. This community outreach project is directed toward both the casual and professional athlete.

In December 2004, Dr. Stergiou was honored as the feature article on UNO's main web page titled: **Nicholas Stergiou: Research in Motion.**
http://www.unomaha.edu/news/features/stergiou_n.php
Research in Motion, the first feature on UNO's new website, gives a terrific synopsis of how Dr. Stergiou began his work, which combines his love of physics with his love of sports. It continues with a description of the research and community service Dr. Stergiou and his graduate assistants perform in the HPER Biomechanics Lab.

Dr. Stergiou Participates in a NIH Review Panel

Dr. Stergiou received an invitation to be a reviewer from the National Institutes of Health/National Center of Medical Rehabilitation Research. He accepted this significant invitation and participated in a Review Panel during 2004. This Panel examined grants submitted for a Request for Application titled Biomechanical Modeling of Movement. The National Center of Medical Rehabilitation Research (NCMRR) specifically wishes to encourage research in the area of making daily life and health better for those people with disabilities. The first part of a review is done by the grant writer's peer group. Frequently this group's members are nationally recognized leaders in academia. NIH looks for group constituents to have a broad perspective in their approach to research. Members are chosen for their leadership abilities and their use of diverse fields of science in their work.

Prestigious Teaching Award to Dr. Stergiou

Dr. Nicholas Stergiou received the prestigious University of Nebraska at Omaha - 2004 College of Education Alumni Outstanding Teaching Award. This award was established to honor distinguished teaching in the classroom. Outstanding teaching awards are chosen by a committee of peers from each college on the UNO campus. Dr. Stergiou mentors and advises students interested in biomechanics and exercise science. He helps students achieve quality careers in the private sector or pursue further graduate education. He is also

successful in securing funding for students who work in the laboratory. For these reasons, Dr. Stergiou was selected from his peers for this prestigious award.

NASA Visits HPER Biomechanics Lab

For over 40 years, NASA has been aspiring to develop better ways to evaluate and restore neuromuscular health in astronauts returning to Earth's gravity. Currently the HPER Biomechanics Laboratory staff and specifically Max Kurz, one of our doctoral students, are collaborating with Dr. Jacob Bloomberg who is a Senior Scientist at Johnson Space Center's Neuroscience Laboratory to meet these research strategies. Max Kurz was awarded the 2004-2005 NASA EPSCOR Scholarship to further explore the effect of gravity on the stability of locomotive patterns. NASA representatives, including Dr. Richard Williams, NASA's chief health and medical officer, and Dr. Desmond Lugg, chief of NASA's Medicine of Extreme Environments, visited the HPER Biomechanics Laboratory in October. While visiting, NASA guests reviewed our collaborative research currently focused in the following areas: 1) how micro-gravity influences neuromuscular stability, 2) how alterations in other Newtonian forces (heel-strike collisions, inertia, etc.) influence neuromuscular stability, 3) the development of biomedical devices for the rapid assessment of neuromuscular health, 4) the use of virtual reality interfaces for the testing of nervous system's functionality, 5) development of virtual reality interfaces for exercise adherence while in space. The NASA representatives were very impressed by our research work so far and they encouraged us to apply for further funding by NASA.

Walking, a Neural Network and a Simple Robot

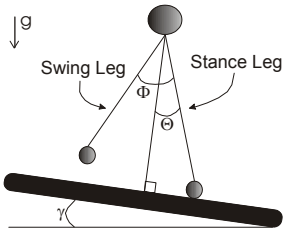


Figure 1. Passive dynamic walking model that has a chaotic gait pattern.

Gait analysis reveals that each person has a different way of walking. Even in the same person, analysis reveals there are variations from one step to the next. These variations have a special structure that can be described using the mathematical theory of chaos. Using this theory, our work has focused on how gait is organized to overcome unforeseen disturbances in the terrestrial environment. Robotic walking control systems do not have this ability to maintain stability over uneven surfaces as we walk. Max Kurz and Dr. Stergiou were inspired to develop a virtual bipedal robot that utilizes chaos as a control scheme for stable walking. The results of their initial simulations showed convincingly a stable walking robot, as well as giving insights on how the loss of chaos in human gait patterns are related to movement disorders.

One of our goals in future robotic models is to develop intelligent agents that utilize chaotic control. Toward this end, Max Kurz and Dr. Stergiou proposed that the nervous system may use well-timed joint actuations to switch to more stable gait patterns when

unforeseen disruptions are encountered.

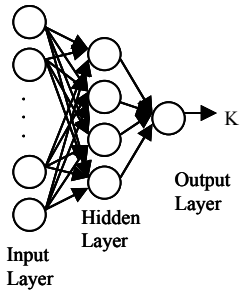


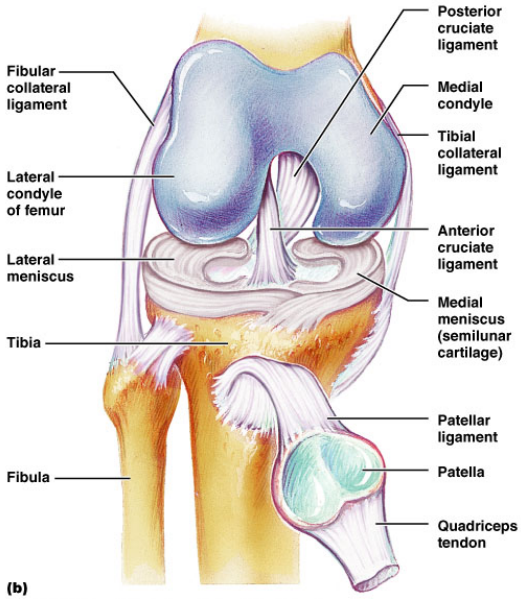
Figure 2. Schematic for the ANN that determines a stiffness value for modulating hip actuation.

They were able to develop an artificial neural network (ANN) to add to their passive dynamic bipedal model (Figure 1). ANN consists of sixteen input neurons, four hidden neurons and one output neuron (Figure 2). The configuration of the ANN incorporates multiple time delays for each step. These time delays served as a cognitive memory so the ANN remembered where the last step was. The ANN was trained to select a hip stiffness that would transition between two different gaits. Using this model, we showed that a robust chaotic control scheme, facilitated by an ANN, can select the proper initial hip movement for a stable walk. Our next goal is to determine how changes in biomechanical variables (i.e. gravity, friction) influence the observed chaotic walking pattern.

This investigation was funded in part by the NASA Columbia Memorial Scholarship granted to Max Kurz. In their work, Max Kurz and Dr. Stergiou are collaborating with Dr. Jack Heidel, Chair of the UNO Math, and Dr. Terence Foster from UNL Engineering.

Sabbatical Strengthens Collaborations with Other Laboratories

Dr. Stergiou was awarded a Faculty Development Fellowship or "sabbatical" for the Spring of 2005. Dr. Stergiou will use some of his sabbatical time to conduct research at the Orthopedic Center in Sports Medicine (OCSM). The OCSM is located at the Ioannina Medical Center in Greece. He has been working for several years with OCSM and currently holds the title of the OCSM Scientific Consultant. This collaborative work has been presented in several conventions and has been published in several prestigious scientific journals. Their work has led to some very important findings regarding the knee's anterior cruciate ligament reconstruction. They found that current surgical techniques fail to restore rotation of the lower leg during dynamic activities of every day life (i.e. walking, turning). They also found that proper placement of the graft is essential for



subsequent knee stability. Currently, they are working in identifying the best surgical techniques that can keep the knee stable during daily activities. They have also started exploring how osteoarthritis of the knee is related with ligament damage.

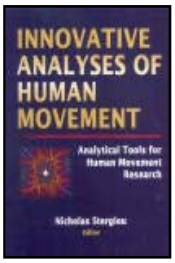
Our Lab Helps High School Students and Teachers

This program is geared toward getting High School students involved in Math and Science. It is part of the Banneker 2000 Community of Excellence in Mathematics and Science (CEMS) program, which is a 5-year $4.9 million grant from the National Science Foundation. This work is in collaboration with Dr. Carol Mitchell from the Teacher Education Department of the College of Education at UNO. This past summer the Biomechanics Lab had three CEMS students. They had projects related to leg stiffness during gait. The students examined healthy gait, Parkinson's Disease affected gait and ACL reconstruction affected gait. These students will finalize their research with a presentation in the spring.

Student explaining connector.

Not only do the students benefit from the CEMS program, but K-12 teachers have been getting involved as well. These teachers have been taking courses, such as Biomechanics from Dr. Stergiou. They learn how to use biomechanics in their classrooms in order to explain difficult issues. For example, they can teach students about projectiles using examples from sports biomechanics rather than cannons! The students seem to enjoy the new applications their teachers have to offer.

New Textbook Published



Dr. Stergiou has edited a new textbook entitled "***Innovative Analyses of Human Movement***". The textbook was published by Human Kinetics the summer of 2004. To read more about this book go to www.humankinetics.com.

Other Exciting News/Continuing Collaboration

Our lab had two guest speakers during the Fall of 2004. They were chosen to speak at UNO because of our inter-discipline philosophy, and our high curiosity regarding their current research projects. Dr. Jordan Green visited us in October from UNL with a presentation entitled "Motor Factors in Early Speech Development". He also uses an inter-discipline approach with his research in Communication Disorders. In his pursuit to study infants learning to speak, he uses the knowledge of disciplines including special education and biomechanics. His work is conducted at the Madonna Rehabilitation Hospital. He was recently awarded a $1.8 million grant from the NIH to study motor factors in early speech development. Dr. Green is the Corwin Moore Chair of Communication Disorders at the UNL Barkley Center.

Dr. Rui-Ping Xia, a faculty member in Physical Therapy at UNMC, visited us in November. Her research focus on altered muscle tone in neurological disorders, parallels our ongoing interest in the biomechanical effect of Parkinson's disease on gait. Her presentation was titled "Physiological Mechanism of Rigidity in Parkinson's Disease".

- April 2004, the HPER Biomechanics Laboratory staff attended the 17th Annual Nebraska Biomedical Engineering Workshop. Graduate students Kenji Narazaki and Max Kurz each gave a presentation.
- June 2004, doctoral students Max Kurz and Reggie Harbourne presented abstracts at the annual NASPSPA meeting held in Vancouver, Canada.
- During 2004, doctoral student Max Kurz was invited to give several presentations from his doctoral research work. He gave presentations to the UNO Mathematics Department, the UNO Biology Seminar Series, and the Aeronautics and Space Science Section of the Nebraska Academy of Science Annual Meeting.
- In September 2004, the HPER Biomechanics Laboratory staff attended the American Society of Biomechanics conference held in Portland, Oregon. The lab presented current research topics they had been working on. In addition, Melissa Pandorf was elected the society's student representative.
- Science Coalition Web Site currently features Dr. Stergiou in its "Sneak A Peek Inside The Labs" section. The mission of the Science Coalition is to expand and strengthen the federal government's investment in university based scientific, medical engineering and agricultural research.
- Dr. Stergiou was invited last November to give two lectures at the University of Nevada Las Vegas (UNLV). He presented his recent research work on ACL and gait variability. His visit was supported by the Biodynamics Foundation established by Drs Bates and Dufek and the UNLV.

PROFESSIONAL JOURNAL PUBLICATIONS SINCE OUR 2003 ANNUAL REPORT

1. Stergiou N, Scott MM. (2005). Baseline measures are altered in biomechanical studies. *Journal of Biomechanics* 38(1):175-8.
2. Kurz MJ, Stergiou N, Heidel J, Terry Foster, E (2005) A template for the exploration of chaotic locomotive patterns. *Chaos, Solitons & Fractals*, 23(2):485-94.
3. Kurz MJ, Stergiou N, Buzzi UH, Georgoulis AD. (2004). The effect of anterior cruciate ligament reconstruction on lower extremity relative phase dynamics during walking and running. *Knee Surgery, Sports Traumatology, Arthroscopy* Online First.
4. Stergiou N, Moraiti C, Giakas G, Ristanis S, Georgoulis AD. (2004) The effect of the walking speed on the stability of the anterior cruciate ligament deficient knee. *Clinical Biomechanics* 19(9):957-63.
5. Kurz MJ, Stergiou N. (2004). Does footwear affect ankle coordination strategies? *Journal of the American Podiatric Medical Association*. 94(1):53-8.
6. Stergiou N, Bates BT, Kurz MJ. (2004) Subtalar and knee joint interaction during running at various stride lengths. *Journal of Sports Medicine and Physical Fitness*. 43(3):319-26.

CHAPTERS

1. Stergiou, N., Buzzi, U.H., Kurz, M.J., & Heidel, J. (2004). Nonlinear Tools in Human Movement. In: Stergiou, N. (Ed.) Innovative Analyses for Human Movement. Champaign, IL: Human Kinetics Publishers, pp. 63-90.
2. Kurz, M.J. & Stergiou, N. (2004). Mathematical Measures of Coordination and Variability in Gait Patterns. In: Stergiou, N. (Ed.) Innovative Analyses for Human Movement. Champaign, IL: Human Kinetics Publishers, pp. 163-186.
3. Kurz, M.J. & Stergiou, N. (2004). Applied Dynamic Systems Theory for the Analysis of Movement. In: Stergiou, N. (Ed.) Innovative Analyses for Human Movement. Champaign, IL: Human Kinetics Publishers, pp. 93-120.

SELECTED PRESENTATIONS AND PUBLISHED ABSTRACTS

1. Kurz MJ, N Stergiou and J Bloomberg (2005). Gravitational forces influence the local dynamic stability of human gait patterns. *Aeronautics and Space Science Section Nebraska Academy of Sciences Annual Meeting*, Lincoln, Nebraska.
2. Kurz MJ and N Stergiou (2004) A Parallel distributed processing model that utilizes a chaotic control scheme for controlling gait. *Nebraska Biomedical Engineering Research Workshop*, Lincoln, Nebraska.

3. Kurz MJ and N Stergiou (2004). A passive dynamic walking model indicates that gravity influences gait stability and bifurcations. *Aeronautics and Space Science Section Nebraska Academy of Sciences Annual Meeting*, Lincoln, Nebraska.

4. Narazaki K, D Oleynikov, A DiMarino, M Rentschler, N Stergiou. (2004). Objective Quantification of Proficiency in Robotic Laparoscopy with Bimanual Inanimate Tasks. *Nebraska Biomedical Engineering Research Workshop*, Lincoln, Nebraska.

5. Markopoulou K, MJ Kurz, UH Buzzi, N Stergiou (2004). Gait dynamics in Parkinson's disease. *Society for Neuroscience*, San Diego, California.

6. Kurz MJ, N Stergiou (2004). An artificial neural network that utilizes a chaotic control scheme for stable locomotion. *American Society of Biomechanics*, Portland, Oregon.

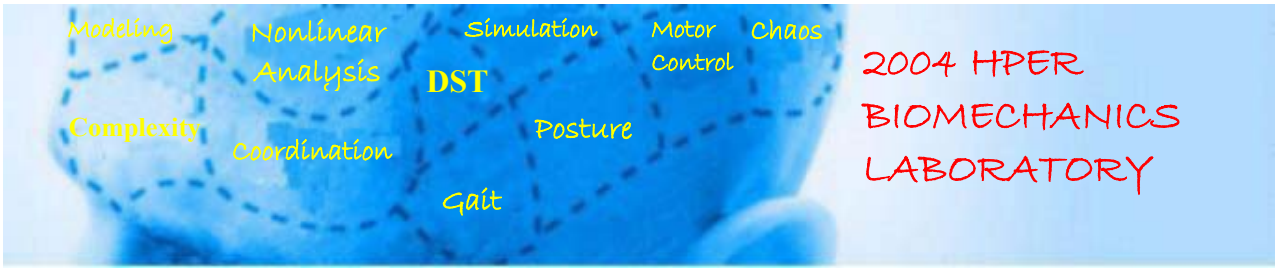
7. Kurz MJ, N Stergiou and D Blanke (2004). Does footwear influence the structure of chaotic gait patterns? *American Society of Biomechanics*, Portland, Oregon.

8. Korellis G, CJ Wutzke, MJ Kurz, and N Stergiou (2004). Nonlinear analysis of postural control in different positions. *American Society of Biomechanics*, Portland, Oregon.

9. Scott-Pandorf M.M., II Pipinos, N Stergiou. (2004). The Effect of Peripheral Arterial Disease on Gait: Unilateral Patients Affected and Nonaffected Limbs. *American Society of Biomechanics Upper Midwest Student Regional Meeting,* Portland, Oregon.

10. Kurz MJ and N Stergiou (2004). Walking with a chaotic gait pattern in a reduced gravity environment. *North American Society of the Psychology of Sport and Physical Activity Annual Meeting*, Vancouver, Canada.

11. Kurz MJ and N Stergiou (2004). Controlling bifurcations and chaos in a passive dynamic walking model. *North American Society of the Psychology of Sport and Physical Activity Annual Meeting*, Vancouver, Canada.



HPER BIOMECHANICS SCIENTIFIC STAFF
2003 - 2004

Back Row: Dr. Blanke, Melissa Scott-Pandorf, David Miller, Dr. Stergiou, Max Kurz
Front Row: Kimberly Ryland, Tim Judkins, Clint Wutzke
(Not Pictured: Rachel Tushner, Lisa Holst, Joan Deffeyes, Sara Myers and Natasha Kyvelidou)