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HPER Biomechanics Laboratory 2003 Annual Report, Issue 2

Nebraska Biomechanics Core Facility
University of Nebraska at Omaha

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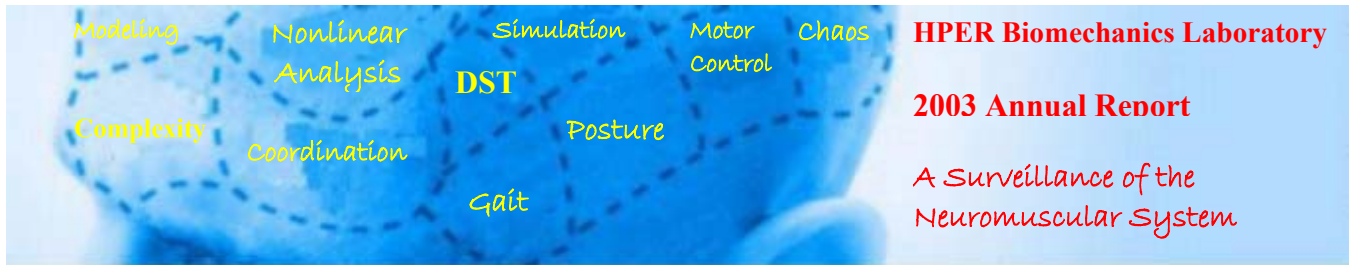
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Featured Topics in this Report:

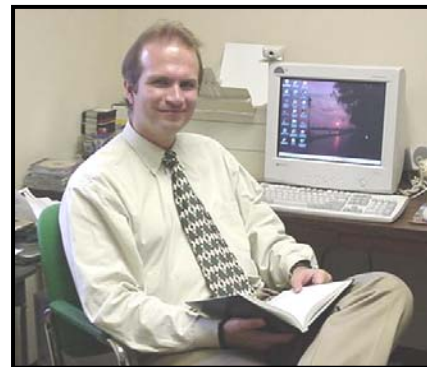
- Can chaos be used for stability in walking Robots?
- Promising insights on the development of posture in infants.
- The effect of Parkinson’s disease in stair negotiation.
- How certain are the elderly in selecting a stable gait pattern?
- Collaboration with UNMC to improve Robotic Surgical Techniques.
- Helping High School students and K-12 teachers appreciate math and science.
- Max Kurz receives three awards for 2003.
- New Textbook published.
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- 2003 Publications and Presentations

HPER Biomechanics Scientific Staff

Dr. Nicholas Stergiou, PhD
 Dr. Dan Blanke, PhD.
 Chris Hurt, Intern
 Dimitris Katsavelis, B.S.
 Georgios Korellis, B.S.
 Max Kurz, M.S.
 Kenji Narazaki, B.S.
 Melissa Scott-Pandorf, B.S.
 Clint Wutzke, B.A/Sc.

Message from the Director

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.



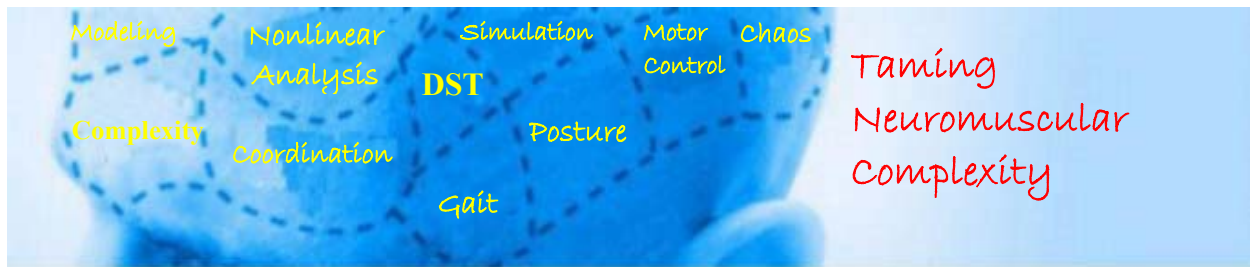
HPER Biomechanics Lab Director, Nick Stergiou, PhD.

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.

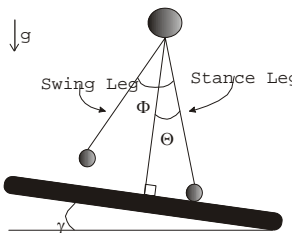
Our laboratory has earned a national and international reputation of excellence in basic and clinical research. Several domestic and international visitors have toured our facilities and collaborated with our research team. Our annual report is designed to give you a brief look at who we are and what we do. We hope that after reading about us here 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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Can Chaos be used for Stability in Walking Robots?



Engineers tend to eliminate variability in the walking patterns of legged robots that navigate in terrestrial

environments. This is based on the idea that variability creates noise in the robotic system that can lead to an unstable walking pattern. Recently, Max Kurz and Dr. Stergiou have argued that variability may actually be an advantageous property for a walking control system. This argument is based on their recent study that appeared in *Clinical Biomechanics*. This investigation demonstrated that variability in human walking is not random noise. Rather variations from one step to the next have a special structure that can be described using the mathematical theory of chaos. Chaos in gait is advantageous because it provides the walking system with controlled flexibility to overcome unforeseen disturbances in the terrestrial environment. These observations have inspired Max Kurz and Dr. Stergiou to develop bipedal robots that utilize chaos as a control scheme for stable walking. Results from their simulations indicate that a bipedal walking robot, with chaos built into the system, does provide a

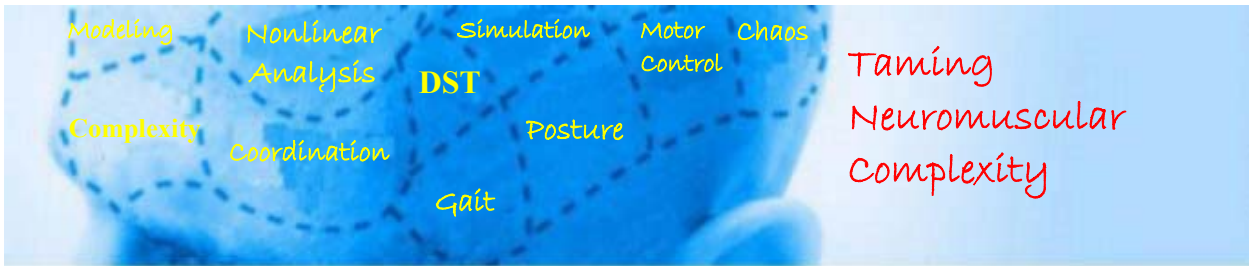
mechanism for asserting stability in uncertain terrestrial environments. These robotic simulations have also provided insights on how the loss of chaos in human gait patterns are related to movement disorders. Future robotic models are focused on: 1) developing intelligent agents that utilize chaotic control, and 2) determining how changes in biomechanical variables influence the observed chaotic walking pattern. 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.

Promising Insights on the Development of Posture in Children

Collaborative research between the Munroe-Meyer Institute at UNMC and the HPER Biomechanics



Laboratory has lead to innovative ways to evaluate the development of sitting posture in children. This research is currently establishing baseline data for the diagnosis of movement disorders and the examination of treatment efficacy. The research team uses mathematical techniques from chaos theory to



determine variables that describe the stability and complexity of the postural control system of the developing child. Our current research has offered promising insights on the development of posture in normal children, and children that have movement disorders (cerebral palsy, spina bifida and Down syndrome). The goal of this project is to provide clinical tools that assist in determining effective treatments for children with movement dysfunction and early detection measures of disabilities.

The Effect of Parkinson's Disease on Stair Negotiation

Control of the body's position is essential for preventing falls from occurring when negotiating stairs. This



Michael J. Fox solicited the U.S. Congress and researchers to concentrate their efforts on uncovering the cause of Parkinson's.

is even more challenging in populations with movement disorders. The study of the mechanisms used by these populations to overcome such challenges can lead to a better understanding of the control systems responsible for these debilitating diseases. A recent

investigation in the HPER Biomechanics Laboratory has identified that individuals with Parkinson's disease have different movement strategies for negotiating stairs compared to their healthy counterparts. It seems that in Parkinson's patients, proximal joints (i.e. hip) are more affected than distal joints (i.e. ankle). Future investigations are attempting to address the relationship between these differences and changes in the nervous system in patients with Parkinson's disease. We also hope to use our findings to develop powerful diagnostic tools for the evaluation of the efficacy of treatments and drugs in such patients. In this work, the HPER Biomechanics Lab's personnel have collaborated with Dr. Markopoulou, a neurologist from the University of Nebraska Medical Center.

How Certain Are The Elderly In Selecting A Stable Gait Pattern?

Based on feedback from bio-sensors in the human body, we are able to select a stable walking pattern in any given terrestrial environment. However, the quality of the feedback provided by these bio-sensors tends to diminish as we age. This may result in an unstable gait that can result in a fall. Recently, in *Neuroscience Letters*, HPER Biomechanics' personnel presented their



efforts to explore how aging influences the certainty of the neuromuscular system for selecting a stable locomotive pattern. The results from their investigation indicate that the elderly tend to be less certain that a selected movement strategy will result in stable walk. Future investigations are exploring how mathematical measures of certainty can be used to predict susceptibility to falls. This information may lead to new prognostic measures that can identify individuals that have a greater probability of falling.



Collaboration with UNMC to Improve Robotic Surgical Techniques

The University of Nebraska Medical Center was one of the earliest U.S. institutions that introduced the daVinci™ Surgical System. Using this system, the Robotic Minimally Invasive Surgery Laboratory at UNMC has been studying robotic laparoscopy. 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. 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 not been established. Current



methods of assessing laparoscopic skills often include quite subjective evaluation in which experts in the field are required as referees. The primary reason for this problem is that proper objective and measurable variables that can clearly distinguish experts from novices (i.e. reveal residents' proficiency) have not been found. Thus, objective approaches cannot be employed in skill assessment and/or training development. A recent collaboration established between the HPER Biomechanics Laboratory and Dr. Dmitry Oleynikov, Director of the Robotic Minimally Invasive Surgery Laboratory, is addressing this problem. Using biomechanical analyses, they investigate ways to quantify residents' proficiency for practical skills in robotic



laparoscopy. These collaborative efforts have stepped up a notch with the addition of a Graduate Assistant Position specifically for this work. This year's Graduate Assistant is Kenji Narazaki who has an undergraduate degree in mechanical engineering and is now pursuing his Master's degree in Biomechanics with Dr. Stergiou.

Helping High School Students and K-12 Teachers Appreciate Math and Science



Dr. Stergiou and Dr. Mitchell (UNO Teacher Education) continue to work together on a variety of projects to help

high school students understand and appreciate the applications of science and math. They hope to motivate and inspire students to pursue careers in science and math. Their efforts have been ongoing since 1997 and within the last few years the project has grown due to a \$4.9 millions 5-year grant from the National Science Foundation for the Banneker 2000 Community of Excellence in Math and Science (CEMS). This past summer the HPER Biomechanics Laboratory had three high school students participating in CEMS. Each student conducted an investigation with the help of laboratory staff. Student investigations included the mechanics of

stair negotiation and treadmill walking in Parkinson patients, and kinematic strategies during running with and without footwear. Each student will also prepare a presentation that they will present in the spring. Not only do the students benefit from the CEMS program, but K-12 teachers have been involved as well. These teachers take courses such as Biomechanics from Dr. Stergiou. Then, they incorporate what they learn in their classrooms. So, when they teach their students about projectiles they may use an example from sports Biomechanics instead of canons. The students seem to enjoy the new applications their teachers have to offer.



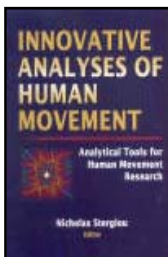
Max Kurz Receives Three Awards for 2003

Max Kurz is a doctoral student in the HPER Biomechanics Laboratory. Max received the 2003 NASA Columbia Memorial Scholarship. This is an award in memory of the Columbia crew, especially Creighton University graduate



Lt. Col. Michael Anderson. In recognition of Anderson's interests, Max was selected on the basis of his research in the physical sciences. Max will use the funding from this award to investigate the influence of gravity on the control of locomotion. Max also received the 2003 North American Society for the Psychology of Sport and Physical Activity (NASPSPA) Graduate Student Research Award in Savanna, Georgia. This award was for his research on the use of statistical entropy to explore uncertainty in the aging neuromuscular system to select stable walking patterns. This scientific investigation has recently been published in *Neuroscience Letters*. Max's third award was the 2003-2004 Presidential Fellowship from the Nebraska Board of Regents, one of the two given each year to the best graduate students at UNO.

New Textbook Published



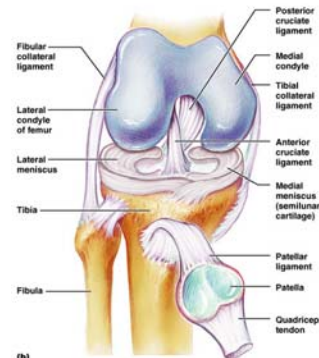
Dr. Stergiou has edited a new textbook entitled "*Innovative Analyses of Human Movement*". The textbook was published by Human Kinetics the summer of 2003. To read

more about this book go to www.humankinetics.com.

Collaborations in Orthopedics and Cerebral Concussion

Dr. Stergiou has been working for several years now with the Orthopedic Center of Sports Medicine (OCSM) at Ioannina-Greece. He currently holds the title of the OCSM Scientific Consultant. Dr. Stergiou visited OCSM twice last year. 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 ACL 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 reliable methods to quantify how stable the knee is during daily activities. They have also started exploring how ACL reconstruction affects long-term osteoarthritis of the knee and the function of the other joints.



Dr. Stergiou has also been working with Dr. Kevin Guskiewicz and Jim Cavanaugh, from the University of



North Carolina at Chapel Hill on the effects of cerebral concussion. This is a common athletic injury that has recently received a lot of attention especially in football. Their collaborative work has examined postural sway before and after a concussion. They use mathematical techniques from nonlinear dynamics to identify when the athlete should return

back to practice and competition. Current techniques they fail to identify when an athlete should return and have resulted in recurrent concussions that can lead to permanent neurological damage. Their work has recently been presented at the American Society of Biomechanics Annual Meeting.

Professional Journal Publications

1. Buzzi, U., Stergiou, N., Kurz, M., Hageman, P., & Heidel, J. (2003). Nonlinear dynamics indicates aging affects variability during gait. *Clinical Biomechanics*, 18, 435-443.
2. Georgoulis A., Papadonikolakis A., Papageorgiou C., Mitsou A, Stergiou N. (2003). Three-dimensional tibiofemoral kinematics of the anterior cruciate ligament deficient and reconstructed knee during walking. *American Journal of Sports Medicine*, 31(1), 75-79.
3. Harbourne, R., & Stergiou, N. (2003). Nonlinear analysis of the development of sitting postural control. *Developmental Psychobiology*, 42, 368-377.
4. Kurz, M. & Stergiou, N. (2003). The aging neuromuscular system expresses less certainty for selecting joint kinematics during gait in humans. *Neuroscience Letters*, 348, 155-158.
5. Kurz M., Stergiou N., Blanke D. (2003). Spanning set defines variability in locomotive patterns. *Medical Biological Engineering and Computing*, 41(2), 211-214.
6. Kurz M., Stergiou N. (2003). The spanning set indicates that variability during the stance period of running is affected by footwear. *Gait & Posture*, 17(2), 132-135.
7. Papadonikolakis, A., Cooper, L., Stergiou, N. Georgoulis, AD. & Soucacos, PN. (2003). Compensatory mechanisms in anterior cruciate ligament deficiency. *Knee Surgery Sports Arthrology and Traumatology*, 4, 235-243.
8. Ristanis S, Giakas G, Papageorgiou CD, Moraiti T, Stergiou N, Georgoulis AD. (2003). The effects of anterior cruciate ligament reconstruction on tibial rotation during pivoting after descending stairs. In press: *Knee Surgery Sports Arthrology and Traumatology*.

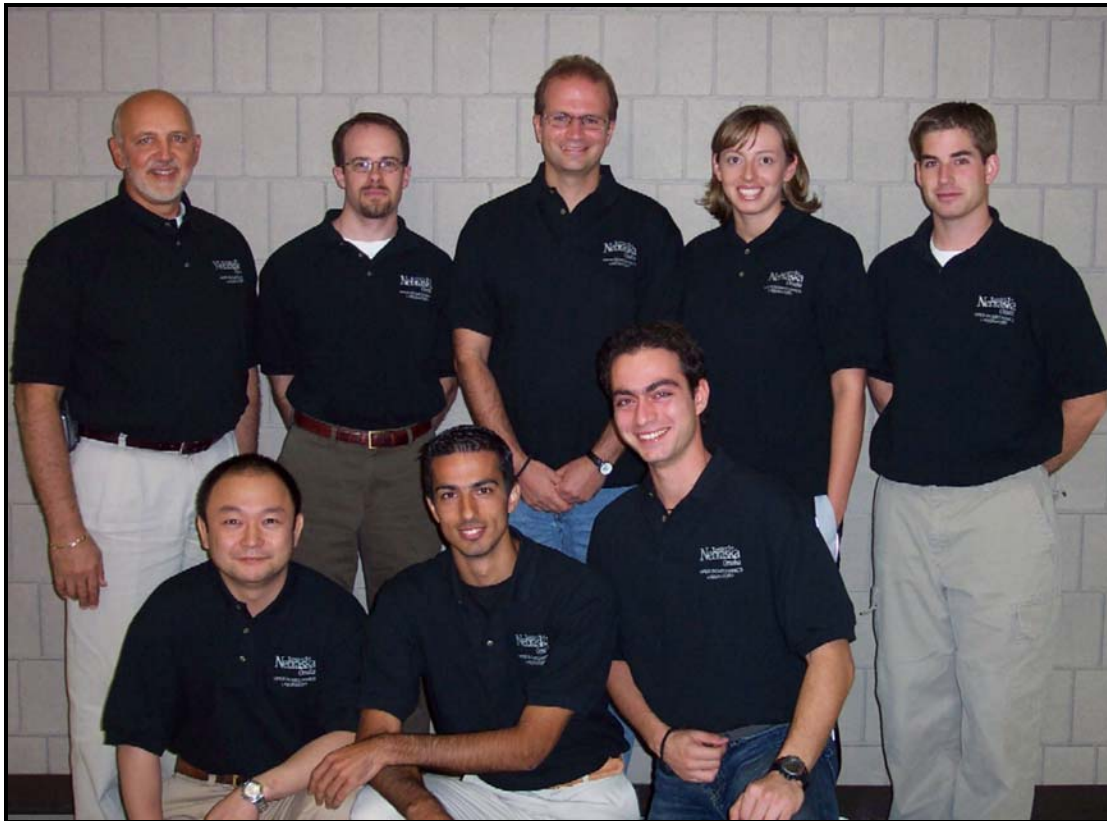
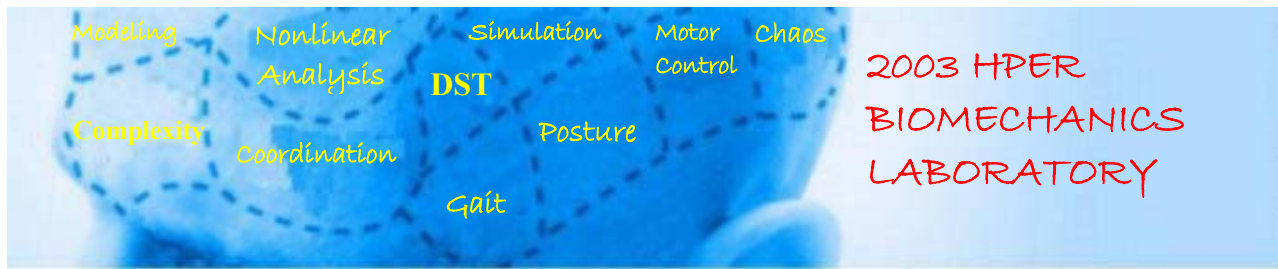


Chapters

1. Kurz, M.J. & N. Stergiou (2003). Applied dynamical systems theory for the analysis of movement In: *Innovative Analyses of Human Movement*. N. Stergiou (Ed.) Human Kinetics:Champaign, IL, 93-120.
2. Kurz, M.J. & N. Stergiou (2003). Mathematical measures of coordination and variability in gait patterns. In: *Innovative Analyses of Human Movement*. N. Stergiou (Ed.) Human Kinetics:Champaign, IL, 163-186.
3. Stergiou, N., U.H. Buzzi, M.J. Kurz & J. Heidel (2003). Nonlinear tools in human movement. In: *Innovative Analyses of Human Movement*. N. Stergiou (Ed.) Human Kinetics:Champaign, IL, 63-90.

Selected Presentations and Published Abstracts

1. Cavanaugh, J., K. Guskiewicz, and N. Stergiou (2003). Effect of cerebral concussion on the complexity of center of pressure time series in collegiate athletes, *American Society of Biomechanics Annual Meeting*, Toledo, Ohio.
2. Hreljac, A., N. Stergiou, R. Imamura, J. Casebolt, and M. Sison (2003). Ankle and knee joint kinetics during running and sprinting, *American Society of Biomechanics Annual Meeting*, Toledo, Ohio.
3. Keenan, S., N. Stergiou, M. Kurz, J. Heidel, and D. Blanke (2003). The stability of the Lyapunov exponent at different sampling frequencies during treadmill walking, *American Society of Biomechanics Annual Meeting*, Toledo, Ohio.
4. Kurz, M.J. and N. Stergiou (2003). The aging neuromuscular system expresses uncertainty for selecting joint kinematics during gait, *North American Society of the Psychology of Sport and Physical Activity Annual Meeting*, Savannah, Georgia.
5. Kurz, M.J. and N. Stergiou (2003). A period doubling cascade that lead to a chaotic gait pattern in a passive dynamic walking model, *North American Society of the Psychology of Sport and Physical Activity Annual Meeting*, Savannah, Georgia.
6. Kurz, M.J., N. Stergiou and T. Foster (2003). Controlling bifurcations and chaotic gait with hip joint actuations in a simple walking model, *American Society of Biomechanics Annual Meeting*, Toledo, Ohio.
7. Scott, M.M. and N. Stergiou (2003). Baseline measures are altered in biomechanical studies, *American Society of Biomechanics Annual Meeting*, Toledo, Ohio.



2003-2004 HPER Biomechanics Laboratory Staff – (Left to Right) Front Row: Kenji Narazaki, Dimitris Katsavelis, George Korellis. Back Row: Dr. Dan Blanke, Max Kurz, Dr. Nick Stergiou, Melissa Scott-Pandorf, Clint Wutzke. Not pictured: Chris Hurt.