

**Michael R. Carhart, Ph.D.**  
**Principal**

**Professional Profile**

Dr. Michael Carhart is a Principal in Exponent's Biomechanics practice and is based in the Test and Engineering Center in Phoenix, Arizona. Dr. Carhart's expertise is in the biomechanics of human injury and accident reconstruction, specializing in the areas of musculoskeletal dynamics, occupant dynamics, human injury tolerance, vehicular rollover, and occupant-to-glazing interaction. He has a decade of experience analyzing accidents and injuries associated with transportation, falls, and the workplace. Dr. Carhart has researched human motion, loading, and injury potential through the analysis and interpretation of the crash-test responses of anthropomorphic test devices (ATDs), the development and application of computational models of the human body, and statistical analyses. His research efforts in rollover include restraint evaluations and the performance of laminated glass as it relates to occupant loading and containment, and involve computer modeling, component-level testing, and full-scale rollover testing. Dr. Carhart has also applied rehabilitation engineering approaches to affect functional recovery following spinal cord injury, including electrical stimulation and sensorimotor training.

Prior to joining Exponent, Dr. Carhart was a Research Scientist at the Arizona BioDesign Institute at Arizona State University (ASU), and a consultant with Forensic Dynamics, LLC. Dr. Carhart has undergraduate and graduate teaching experience in biomechanics, biomedical instrumentation, computer modeling, and microcomputer applications in bioengineering.

**Academic Credentials and Professional Honors**

Ph.D., Bioengineering, Biomechanics Emphasis, Arizona State University, 2000  
B.S., Biomedical Engineering, Milwaukee School of Engineering (*high honors*), 1991

Arch T. Colwell Merit Award, Society of Automotive Engineers; Sachiko Yahashi Memorial Award, International Society for Skiing Safety; Regent's Graduate Academic Scholar, ASU; Presidential Scholar, Milwaukee School of Engineering; Tau Beta Pi; Eta Kappa Nu; Phi Kappa Phi

**Patents**

US Patent Application 20070129653: Spring-Over-Muscle Actuator, World Intellectual Property Organization WO/2004/096083, (with T. Sugar).

## Articles and Published Abstracts

Heller M, Newberry W, Smedley J, Eswaran S, Croteau J, Carhart M. Occupant kinematics and injury mechanisms during rollover in a high strength-to-weight ratio vehicle. SAE World Congress, 2010-01-0516, Society of Automotive Engineers, Warrendale, PA, 2010.

Raasch C, Carhart M, Ivarsson BJ, Lucas S. Development of lower neck injury assessment reference values based on comparison of ATD and PMHS tests. SAE World Congress, 2010-01-0140, Society of Automotive Engineers, Warrendale, PA, 2010.

Welch T, Bridges A, Gates D, Heller M, Stillman D, Raasch C, Carhart M. An evaluation of the BioRID II and Hybrid III during low- and moderate-speed rear impact. SAE World Congress, 2010-01-1031, Society of Automotive Engineers, Warrendale, PA, 2010.

Richards D, Carhart M, Scher I, Thomas R, Hurlen N. Head kinematics during experimental snowboard falls: Implications for snowboard helmet testing. Journal of ASTM International 2008; 5(6), Paper ID JAI101406.

Scher I, Richards D, Carhart M, Thomas R, Hurlen N, Lam T. Pediatric head and neck injuries in snow sports: Evaluating the influence of helmets. Journal of ASTM International 2008; 5(4), Paper ID JAI101400.

Heller M, DiJorio S, Kuzel M, Carhart M, Ciccarelli L. Effect of shoe type on kinematics of stair negotiation in women. Proceedings, International Conference on Contemporary Ergonomics, April 2008.

Luepke P, Carhart M, Croteau J, Morrison R, Loibl J, Ridenour J. An evaluation of laminated side window glass performance during rollover. SAE World Congress, 2007-01-0367, and Transactions Journal of Passenger Cars, Society of Automotive Engineers, Warrendale, PA, 2007.

Pierce J, Carhart M, Bare C, Blakeslee A, Heald J. Retention characteristics of production laminated side windows. SAE World Congress, 2007-01-0376, and Transactions Journal of Passenger Cars, Society of Automotive Engineers, Warrendale, PA, 2007.

Ashby B, Lai W, Carhart M, Newberry W, Weaver B, Corrigan C. Compressive neck preloading during the airborne phase of vehicle rollover. SAE World Congress, 2007-01-0377, and Transactions Journal of Passenger Cars, Society of Automotive Engineers, Warrendale, PA, 2007.

Raasch C, Carhart M. Comparison of ATD upper and lower neck flexion/extension moments, and implications for neck injury criteria. 5<sup>th</sup> World Congress on Biomechanics, Munich, Germany, July 29–August 4, 2006.

Richards D, Carhart M, Raasch C, Pierce J, Steffey D, Ostarello A. Incidence for thoracic and lumbar spine injuries for restrained occupants in frontal collisions. Proceedings, 50<sup>th</sup> Annual Association for the Advancement of Automotive Medicine, Chicago, IL, October 16–18, 2006.

Newberry W, Lai W, Carhart M, Richards D, Brown J, Raasch C. Modeling the effects of seat belt pretensioners on occupant kinematics during rollover. SAE World Congress, SAE 2006-01-0246, and Transactions Journal of Passenger Cars, Society of Automotive Engineers, Warrendale, PA, 2006.

Yamaguchi G, Ashby B, Lai W, Carhart M, Richards D, Corrigan C. Occupant mechanics in rollover simulations of high and low aspect ratio vehicles. SAE World Congress, SAE 2006-01-0451, and Transactions Journal of Passenger Cars, Society of Automotive Engineers, Warrendale, PA, 2006.

Scher I, Richards D, Carhart M. Head injury in snowboarding: Evaluating the protective role of helmets. Journal of ASTM International 2006; 3(4), April (Paper ID JAI14203). Also in: Skiing Trauma and Safety, Sixteenth Volume, ASTM STP 9034, 2006.

Huang H, He J, Herman R, Carhart M. Modulation effects of epidural spinal cord stimulation on muscle activities during walking. IEEE Transactions on Neural Systems and Rehabilitation Engineering 2006; 14(1), March.

Scher I, Richards D, Carhart M. Head contact after catching an edge: An examination of snowboarding helmets. Knee Surg Sports Traumatol Arthrosc 2006; 14.

Ganley K, Willis W, Carhart M, He J, Herman R. Epidural spinal cord stimulation improves locomotor performance in Low ASIA C, wheelchair-dependent, spinal cord-injured individuals: Insights from Metabolic Response. Topics in Spinal Cord Injury Rehabilitation 2005; 11(2), Fall.

Richards D, Scher I, Vijayakumar V, Carhart M, Larson R, Taylor S, Corrigan C. Repetitive head loading: Accelerations during cyclic, everyday activities. Proceedings, 20<sup>th</sup> Congress of the International Society of Biomechanics, July 2005.

Scher I, Richards D, Vijayakumar V, Carhart M, Corrigan C, Jaekel D. Coronal head accelerations during vigorous activities of daily living. Proceedings, Summer Bioengineering Conference, American Society of Mechanical Engineers, June 2005.

Lai W, Ewers B, Richards D, Carhart M, Newberry W, Corrigan C. Evaluation of human surrogate models for rollover. SAE World Congress, SAE 2005-01-0941, and Transactions Journal of Passenger Cars, Society of Automotive Engineers, Warrendale, PA, 2005.

Newberry W, Carhart M, Lai W, Corrigan C, Croteau J, Cooper E. A computational analysis of the airborne phase of vehicle rollover: Occupant head excursion and head-neck posture. SAE World Congress, 2005-01-0943, and Transactions Journal of Passenger Cars, Society of Automotive Engineers, Warrendale, PA, 2005.

Yamaguchi G, Richards D, Larson R, Carhart M, Cargill R, Lai W, Corrigan C. Development of a computational method to predict occupant motions and neck loads during rollovers. SAE World Congress, SAE 2005-01-0300, and Transactions Journal of Passenger Cars, Society of Automotive Engineers, Warrendale, PA, 2005.

Yamaguchi G, Carhart M, Larson R, Richards D, Pierce J, Raasch C, Scher I, Corrigan C. Electromyographic activity and posturing of the human neck during rollover tests. SAE World Congress, SAE 2005-01-0302, and Transactions Journal of Passenger Cars, Society of Automotive Engineers, Warrendale, PA, 2005.

Carhart M, He J, Herman R, D'Luzansky S, Willis W, Dilli S. Epidural spinal cord stimulation facilitates functional walking recovery following incomplete spinal cord injury. IEEE Transactions on Neural Systems and Rehabilitation Engineering 2004; 12(1), March.

Willis W, Carhart M, D'Luzansky S, Thompson A, He K, Thresher K, Herman R. Metabolic and performance effects of electrical stimulation of the spinal cord and peripheral nerve on locomotion. Society for Neuroscience Abstracts, Program No. 824.17, 2003.

Carhart M, D'Luzansky S, He J, Abbas J, Herman R, Willis W. Gait performance with spinal cord stimulation and Reflex-FES in an incomplete spinal cord injured person. Society for Neuroscience Abstracts, Program No. 824.18, 2003.

Kuchi P, Hiremagalur R, Huang J, Carhart M, He J, Panchanathan S. DRAG: A database for recognition and analysis of gait. Proceedings, International Society for Optical Engineering (SPIE), Vol. 5242, November 2003.

Carhart M, Willis W, Thompson A, Huang H, D'Luzansky S, Thresher J, Herman R, He J. Mechanical and metabolic changes in gait performance with spinal cord stimulation and Reflex-FES. Proceedings, 25<sup>th</sup> Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Vol. 2, September 2003.

Carhart M, He J, Herman R, D'Luzansky S, Knight R. Epidural spinal cord stimulation and partial weightbearing therapy for the restoration of locomotion. Proceedings, 2<sup>nd</sup> Joint Conference of the IEEE Engineering in Medicine and Biology Society and the Biomedical Engineering Society, 2002.

Huang H, He J, Carhart M, D'Luzansky S, Herman R. Change of muscle activation pattern by epidural stimulation on a SCI patient. Proceedings, 2<sup>nd</sup> Joint Conference of the IEEE Engineering in Medicine and Biology Society and the Biomedical Engineering Society, 2002.

Carhart M, Yamaguchi G. Human lower extremity segmental parameters. In: Dynamic Modeling of Musculoskeletal Motion—A Vectorized Approach for Biomechanical Analysis in Three Dimensions. Kluwer Academic Publishers, Norwell, MA, 2001.

Carhart M, Yamaguchi G. Human lower extremity muscle parameters. In: *Dynamic Modeling of Musculoskeletal Motion—A Vectorized Approach for Biomechanical Analysis in Three Dimensions*. Kluwer Academic Publishers, Norwell, MA, 2001.

Carhart M. Biomechanical analysis of compensatory stepping: Implications for paraplegics standing via functional neuromuscular stimulation. Ph.D. Dissertation, Arizona State University, 2000.

Carhart M, Yamaguchi G. Estimation of muscle forces in normal human gait: Evaluation of the pseudoinverse method. *Annals of Biomedical Engineering*, Annual Fall Meeting of the Biomedical Engineering Society, Seattle, WA, 2000.

Carhart M, Yamaguchi G. Biomechanical analysis of compensatory stepping: Implications for paraplegics standing via functional neuromuscular stimulation. *Annals of Biomedical Engineering*, 2000.

Carhart M, Yamaguchi G. Exploring the feasibility of reactive stepping in paraplegics. 1<sup>st</sup> Annual Conference of the International Functional Electrical Stimulation Society (IFESS), 1996.

Carhart M, Yamaguchi G. Preparatory postural adjustments in perturbation induced stepping: A comparison to gait initiation. *Neuroscience Abstracts*, Vol. 1, No. 275.4, 1995.

Carhart M and Yamaguchi G. The motor control of stepping responses to postural perturbations. *Proceedings, 19<sup>th</sup> Annual Meeting of the American Society of Biomechanics*, 1995.

Carhart M, Yamaguchi G. The motor control of stepping responses to perturbations of posture: The automatic component. *Annals of Biomedical Engineering*, No. 319, 1994.

Carhart M, Yamaguchi G and Green J. Dynamic balance recovery: Stepping responses to postural perturbations. *Proceedings, 17<sup>th</sup> Annual Meeting of the American Society of Biomechanics*, 1993.

## **Presentations**

Carhart, M. Automotive side window glazing and occupant injury in rollover. ASM International, Phoenix Arizona Chapter Meeting, November 2008.

Scher I, Richards D, Carhart M, Thomas R, Lam T. Pediatric head and neck injuries: Evaluating the influence of helmets. 17<sup>th</sup> International Symposium on Skiing Trauma and Safety, Aviemore, Scotland, May 2007.

Richards D, Scher I, Carhart M. Kinematics of a snowboard fall: Implications for snowboard helmet testing. 17<sup>th</sup> International Symposium on Skiing Trauma and Safety, Aviemore, Scotland, May 2007.

Carhart M, Pierce J. Back to the basics: The inescapable physics of the rollover environment. American Bar Association, Emerging Issues in Motor Vehicle Products Liability Litigation, Phoenix, AZ, March 2007.

Carhart M. Analysis of prior glazing research: A biomechanical perspective. American Bar Association, April 2006.

Richards D, Carhart M, Scher I. A comprehensive look at helmet safety. Winter Conference of the National Ski Area Association, March 2006.

Richards D, Scher I, Carhart M. Snow helmets and head injury. Summer Meeting of ASTM Committee F27, 2005.

I Scher, D Richards, M Carhart. Head contact after catching an edge: An examination of snowboarding helmets. 16<sup>th</sup> International Symposium on Skiing Trauma and Safety, Arai, Niigata, Japan, April 2005.

Carhart M. Litigating the technical issues—Case studies in fires, explosions and biomechanics. Guest Faculty Member, Maricopa County Bar Association, October 13, 2004.

Carhart M. Changes in gait patterns with treadmill training and epidural spinal cord stimulation: Does biomechanics tell the story? Symposium on Motor and Metabolic Control During Walking, 23<sup>rd</sup> Annual Meeting, Southwest American College of Sports Medicine, November 8, 2003.

### **Professional Affiliations**

- Society of Automotive Engineers—SAE
- International Society of Biomechanics—ISB
- American Society for Testing and Materials—ASTM
- Southwestern Association of Technical Accident Investigators—SATAI
- National Association of Professional Accident Reconstruction Specialists—NAPARS
- The Institute of Electrical and Electronics Engineers—IEEE
- The IEEE Engineering in Medicine and Biology Society—IEEE-EMBS