SPRI NEWS
WINTER/SPRING 2024
STEADMAN PHILIPPON RESEARCH INSTITUTE

A CLOSER LOOK AT BIOMECHANICAL ENGINEERING AT SPRI

LEARN MORE ABOUT SPRI'S IMPACTFUL MULTI-LABORATORY RESEARCH PROGRAM

FOUR LABS, ONE TEAM

Steadman Philippon Research Institute (SPRI) conducts hundreds of biomechanics studies each year, taking a multidisciplinary approach to its research program. The Department of Biomedical Engineering (BME), directed by Scott Tashman, PhD, is comprised of several labs including Robotics, Biomotion, Advanced Imaging and Surgical Skills. Together, these four laboratories produce a comprehensive research portfolio that ranges from surgical technique testing to advanced computational modeling using machine learning applications.

SPRI's BME Team includes several research scientists and engineers, alongside research fellows and research assistants. SPRI's international research scholars and physicians in The Steadman Clinic's fellowship program work closely with the BME team. The department is extremely productive, completing hundreds of studies and labs each year, and supporting all of SPRI's federally funded clinical trials.

In this edition of *SPRI News,* we'll investigate on-mountain biomechanics studies, explore some of BME's cutting-edge laboratories, delve into recent developments in robotics and introduce you to one of the department's research scientists.

SPRI TAKES IT TO THE SLOPES WITH BIOMECHANICS RESEARCH

CANTING STUDY INVESTIGATES EQUIPMENT MODIFICATIONS ON BALANCE AND BIOMECHANICS IN SKIING

With its location at the base of Vail Mountain, it's not surprising that SPRI's scientists and researchers conduct ski-related studies. SPRI and the Steadman Clinic partner with the U.S. Olympic & Paralympic Committee (USOPC) and several physicians are lead doctors for the U.S. Ski Team—Drs. Randy Viola, Tom Hackett, David Kuppersmith and Sonny Gill. Locally, the organizations partner with Ski & Snowboard Club Vail (SSCV), and many team members are avid skiers as well, several of whom were competitive collegiate skiers themselves.

The BME department is currently underway on several skiing-focused studies, including "The Influence of Equipment and Personalization on Balance and Lower Limb Biomechanics during Skiing." The purpose of this study is to reduce the incidence in falls—and fall-related ski injuries—during alpine skiing through personalized equipment modifications to optimize musculoskeletal biomechanics and improve balance. This study is an essential component of SPRI's Injury Prevention Research Program and is led by Justin Hollenbeck, MS, who is uniquely qualified to lead the study as a bioengineer and certified ski instructor.

STUDY REACHES THIRD PHASE OF RESEARCH

This winter, BME researchers underwent the third phase of the equipment-focused study. In the first two phases, the team focused on understanding the impacts of ski equipment modifications on stance and balance biomechanics, including specific attention to the discrepancy in injury rates and the biomechanical differences between men and women. This included precision measurements in SPRI's Biomotion Laboratory that indicated a personalized approach to canting angle would be necessary for all skiers. Through evaluation of these modifications in the laboratory, the team discovered that on-slope experiements would be necessary to truly identify the proper personalized canting adjustment to improve skier balance and biomechanics while skiing.

With the first two project phases complete, the research team designed the third phase to include four key elements:

- **Personalized canting adjustments to accommodate each skier's unique starting alignment**
- **Biplane X-ray measurements to assess the effect of canting on alignment in the ski boot**
- **On-slope resting to demonstrate improvements in skiing activity**
- **Focus on high-level skiers to reduce the variability in technique between test runs**

As professional ski boot fitters have become more commonplace as a means to create a custom fit for unique skiers, SPRI partnered with the Foot Foundation, an organization that developed a custom, incline-adjustable platform that skiers perform dynamic squats on, while an expert boot fitter assesses their movement to select the ideal canting adjustment. Enrolled participants were prescribed a personalized canting insole, which will then be analyzed through SPRI's Dynamic Stereo X-ray to scan biplanar images. These images will assess the alignment of the ankle bones while the subject is standing and will be scanned via computer tomography. From this point, 3D models of each foot will be created.

In the final phase of this study, currently underway, research subjects meet the BME team on Vail Mountain, where they are instrumented with wearable sensors that measure the muscle activation in their legs and the movements of their legs while they ski. The team aims to complete this testing phase before April 2024 with results reviewable this summer.

FUTURE APPLICATIONS FOR SKIING INJURY PREVENTION RESEARCH

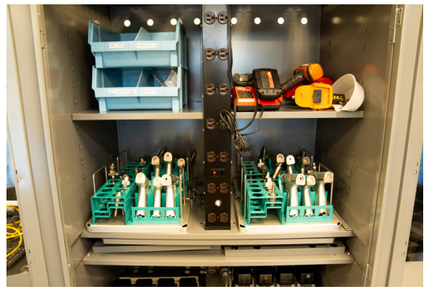
As the research team completes its third phase of research this spring, the team looks to expand the program further, including investigating how equipment-related interventions like canting can reduce lower limb injury risk among youth and adult competitive ski racers. Competitive racers have a higher rate of skiing-related lower limb injuries, and it's unclear how equipment modifications affect this risk. Stay tuned for more information about the expansion of this equipment study.

Biplanar X-ray images are collected to assess the effect of canting insoles on skeletal alignment inside the ski boot

THE IMPACT OF KNEE BRACES AND SKIING

In addition to its Injury Prevention Skiing Program, SPRI's BME team is also investigating the effect of knee braces on skiers that experience knee pain. The study, "The effect of knee brace unloading force on ski biomechanics and pain in skiers with anterior knee pain" is focused on determining if wearing an extension-assist knee brace while skiing impacts the way the skier's legs move, how the skier's muscles flex to move their legs and if the brace contributes a pain reduction for individuals who have pain in the front of their knee during skiing.

The BME team is currently completing the testing phase of this research project. After processing and analyzing the large data set, the team plans to submit a manuscript to a high-impact journal in Fall 2024.



Philanthropy Gives BME's Labs a New Look

A Generous Philanthropic Donation Takes Surgical Skills Lab to the Next Level

One of the differentiating elements of SPRI's Biomedical Engineering Department is the Surgical Skills Laboratory. Co-located with The Steadman Clinic, the Surgical Skills lab is an essential aspect of SPRI's clinical fellowship programs. These fellows—who join SPRI out of their orthopaedic residency programs—hone their skills in the laboratory, where they practice techniques and treatments under the mentorship of their attending faculty, surgeons from The Steadman Clinic. The lab is a key resource for SPRI's biomechanics studies (in the adjacent Robotics lab) and it is also used as an education tool for local students participating in SPRI's educational programming, ski patrollers and other visitors.

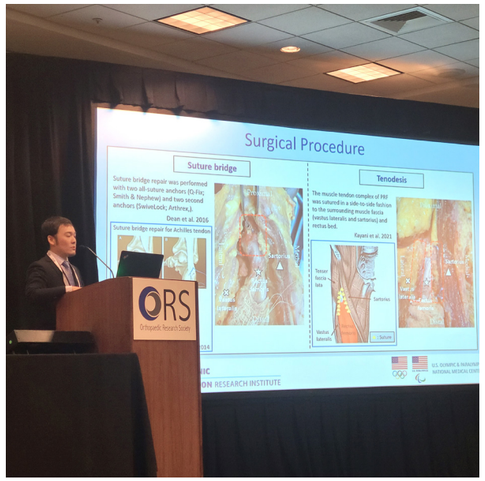
Thanks to a generous philanthropic donation from Ann Smead and Michael Byram, the Surgical Skills Lab has undergone several renovations, including an overhaul of the lab's layout, creating an open space with worktables centered in the room for greater collaboration during labs and learning experiences. Additionally, state-of-the-art surgical equipment and instrumentation was purchased, replicating what will be used in clinical operating rooms. The lab acquired a C-arm fluoroscopy system for image-guided procedures, and medical device manufacturers sent new implants for use in the lab. Finally, a 4K video system was implemented to facilitate international collaboration and training from the lab.

INTRODUCING THE DONNA M. GIORDANO & FAMILY CENTER FOR BIOMOTION RESEARCH

Located on the first floor of Vail Health Hospital, SPRI's Biomotion Laboratory is proud to announce its new name—the Donna M. Giordano & Family Center for Biomotion Research. Ms. Giordano's philanthropic gift supports the research and programs conducted in the laboratory, including SPRI's clinical trials, biomotion research projects and the SPRI Golf Sports Medicine Program.

SPRI's Biomotion Lab is one of the most advanced biomotion facilities in the United States, and the first U.S.-based lab to implement a state-of-the-art flat panel Dynamic Stereo X-ray (DSX) system. This lab collaborates closely with the department's Advanced Imaging team, combining 3-Tesla Magnetic Resonance Imaging (MRI) with DSX scans from which unique computational models are created for an unparalleled, personalized view into each research subject.

Stay tuned for the Summer edition of *SPRI News*, where we'll share how philanthropy makes a significant impact at SPRI—from our essential labs to groundbreaking pilot research.



SPRI'S ROBOTICS LABORATORY SHARES RESEARCH

TEAM PRESENTS AT ORTHOPAEDIC RESEARCH SOCIETY ANNUAL MEETING

The Robotics Laboratory had a productive conference at the 2024 Orthopaedic Research Society (ORS) Annual Meeting in Long Beach, California, including three podium presentations. These included:

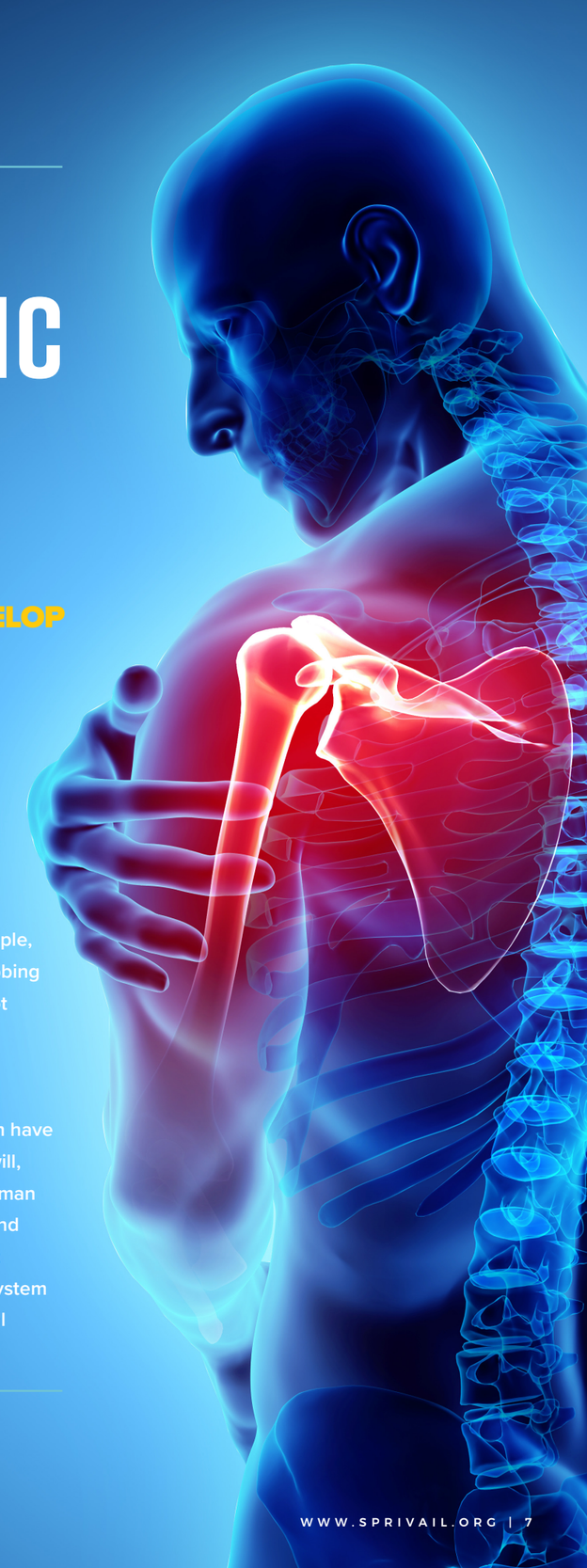
- ***Tibio-Talar Augmentation of Deltoid Ligament Repair: A Robotic Investigation of Ankle Stability***
- ***The Relationship Between Medial Meniscus Extrusion and Medial Meniscus Posterior Root Forces in the Setting of Meniscotibial Ligament Insufficiency***
- ***Surgical Repair for Proximal Rectus Femoris Avulsion: Biomechanical Study***

Robotics Engineering Manager Alex Brady, MS, Research Engineer Justin Hollenbeck, MS and International Research Scholar Haruki Nishimura, MD, PhD presented these abstracts at the annual meeting.

(TOP) Justin Hollenbeck, MS, Research Engineer
(MIDDLE) Haruki Nishimura, MD, PhD, International Research Scholar
(BOTTOM) Alex Brady, MS, Robotics Engineering Manager

BUILDING A NOVEL DYNAMIC SHOULDER SIMULATOR

PHILANTHROPIC GIFT USED TO DEVELOP DIFFERENTIATING TECHNOLOGY



Rotator cuff tears, shoulder instability and glenohumeral arthritis are major orthopaedic problems. Shoulder surgeons at The Steadman Clinic are at the forefront of developing innovative surgical techniques to improve treatments for these challenging conditions, but these new treatments require extensive testing before they are applied to patients.

Traditional biomechanical testing involves either providing simple, unidirectional loads to the shoulder or moving the arm by grabbing it with the robot in SPRI's Robotics Laboratory, but these do not precisely recreate physiological loading or motion.

With philanthropic funding from Tina & David Wilson and Cynthia & Dan Helle, Alex Brady, MS and the Robotics lab team have begun building a unique Dynamic Shoulder Simulator, which will, for the first time, recreate natural 3D motion and loading of human shoulders by using advanced computer-controlled actuators and complex, real-time control algorithms to drive the muscles that generate movement in living humans. When completed, this system will lead to more rapid development and meaningful preclinical evaluation of treatments for shoulder injuries and pathology.

MEET COLIN SMITH, PHD

Dr. Colin Smith joined SPRI in 2022 as a Research Scientist, bringing expertise in computational modeling, movement biomechanics and dynamic imaging.

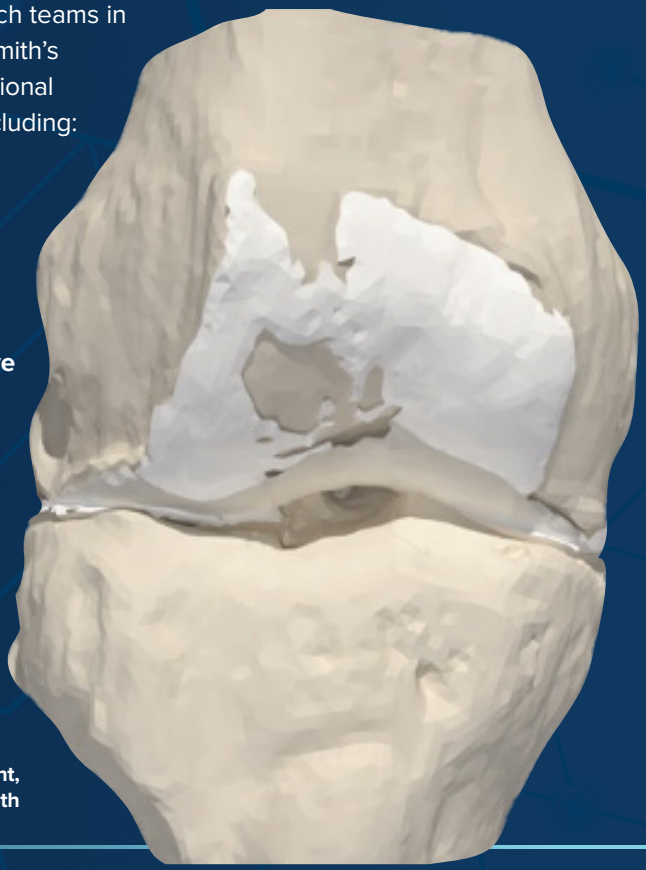
His research investigates the role of loading in the musculoskeletal system during full body movements on the causes and successful treatment of orthopaedic pathologies. He received his B.S. from Clemson University, and M.S. and Ph.D. from the University of Wisconsin-Madison in Mechanical Engineering. He was previously a visiting scholar to the National Center for Simulation in Rehabilitation Research at Stanford University and the Human Movement Biomechanics Lab at Katholieke Universiteit (KU) Leuven, Belgium. Prior to joining SPRI, Dr. Smith was a research fellow in the Laboratory for Movement Biomechanics at ETH Zurich, Switzerland, where he led two research teams focused on computational simulation of knee loading and developing an implantable sensor to measure tendon strain.

Dr. Smith's research program leverages novel sensing, imaging and simulation technologies in the SPRI Biomotion and Robotic laboratories to investigate the movement of musculoskeletal joints (hip, knee, shoulder, etc.) and loading of soft tissues (muscles, ligaments, cartilage) during functional movements. His research focuses on the role of mechanical loading in the development and progression of osteoarthritis and improving orthopaedic surgical techniques and rehabilitation protocols. He is the developer of OpenSim-JAM (Joint and Articular Mechanics), an award-winning open-source software framework for predicting the effect of orthopaedic treatments on musculoskeletal joint loading and function.

Dr. Smith works across BME's laboratories, working with the research teams in Biomotion, Advanced Imaging and Robotics. A primary goal of Dr. Smith's research is working to rapidly generate 3D patient-specific computational models and answer important biomechanical research questions, including:

- **Is asymmetric muscle strength the cause of asymmetric knee function after ACLR?**
- **Can targeted rehabilitation accelerate return to activity after ACL injuries?**
- **Does cartilage loading impact the effectiveness of regenerative medicine treatments for osteoarthritis?**

Dr. Smith uses a combination of lab (precision measurements), real world (wearable sensors) and virtual world (computer simulation) elements in his research. Future directions for Dr. Smith include working with the Linda & Mitch Hart Center for Regenerative and Personalized Medicine (CRPM) team to correlate cartilage loading to pain, biomarkers and cellular senescence, as well as investigating patient-specific predictions of osteoarthritis progression.



A 3D computational model of a knee joint, created by Dr. Colin Smith