



STEADMAN PHILIPPON RESEARCH INSTITUTE

ORTHOPAEDIC RESEARCH JOURNAL

2019-2021



STEADMAN PHILIPPON RESEARCH INSTITUTE

STEADMAN PHILIPPON RESEARCH INSTITUTE MISSION

BUILDING ON OUR LEGACY OF EXCELLENCE IN ORTHOPAEDIC SPORTS MEDICINE, STEADMAN PHILIPPON RESEARCH INSTITUTE IS UNLOCKING THE SECRETS OF HEALING, FINDING CURES AND ENHANCING LIVES THROUGH GLOBAL LEADERSHIP IN REGENERATIVE MEDICINE, SCIENTIFIC RESEARCH, INNOVATION AND EDUCATION.

Dear Friends,

I am pleased to share our fourth edition of Steadman Philippon Research Institute's (SPRI) *Orthopaedic Research Journal*, a celebration of the scientific research being performed at SPRI. After taking a break with this publication due to COVID-19, I am especially thrilled to present these updates to you. In spite of the pandemic, our dedicated scientists, researchers, technicians and physician collaborators have been busy conducting important scientific research, continuing to lead the way for advancements in orthopaedics, sports medicine and healthy aging.

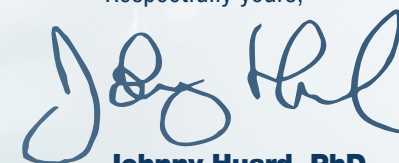
Picking up where our third edition left off, this year's publication will present key scientific and research updates from August 2019–July 2021. Each SPRI department—including the Center for Outcomes-Based Orthopaedic Research, Linda & Mitch Hart Center for Regenerative and Personalized Medicine, Department of Biomedical Engineering, Department of Imaging Research and Department of Education—has selected their top highlights of the past two years to share with you.

While we have broadened our scope—SPRI is now underway on five federally funded clinical trials and investigating new applications for our research—our main focus remains constant: to produce imperative bench-to-bedside research, accelerate clinical translation and get our discoveries to patients faster and safer. In our clinical trials with our physician partners at The Steadman Clinic, we are actively translating clinical discoveries in real time. It is exciting, and I'm proud of the work we've accomplished so far.

SPRI's mission to find cures and enhance lives inspires the work we do each day. Our team is motivated, innovative and committed to conducting high-impact scientific research.

Thank you for your support of Steadman Philippon Research Institute. As we celebrate our science, I would be remiss if I did not acknowledge how vital our research partners, community and friends are in helping SPRI achieve such great success in research. I speak for all of the SPRI team when I express my gratitude for your support.

Respectfully yours,



Johnny Huard, PhD
Chief Scientific Officer

ORTHOPAEDIC RESEARCH JOURNAL 2019-2021

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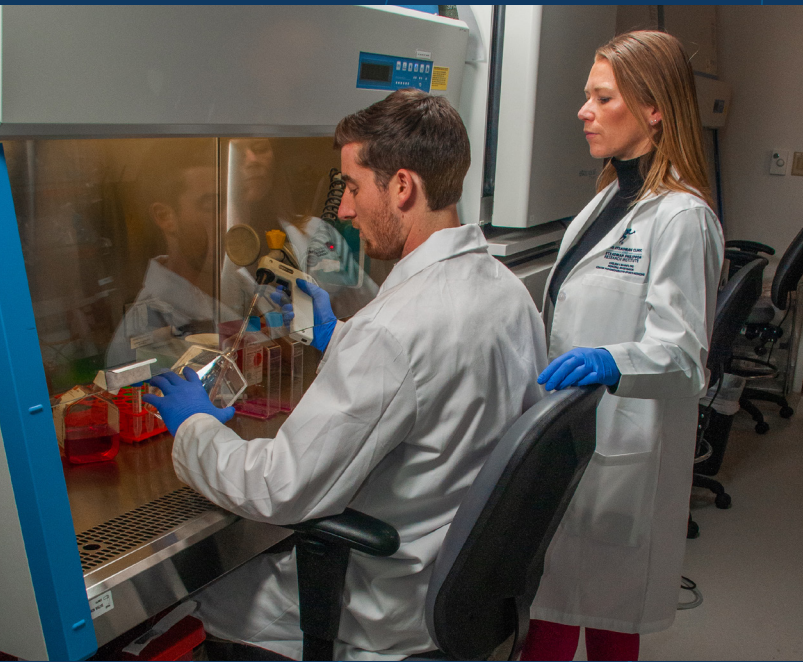
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RESEARCH AND EDUCATION DEPARTMENTS

SPRI is comprised of several distinct departments that are committed to enhancing patient lives and keeping people active. Scientists, researchers and technicians not only conduct science within their departments, but also in collaborative, cross-disciplinary projects across the institute and with physicians at The Steadman Clinic. The result is a multifaceted research organization committed to team science.

Linda & Mitch Hart Center for Regenerative and Personalized Medicine (CRPM): Formerly the Center for Regenerative Sports Medicine (CRSM), the CRPM is focused on the basic science of regenerative medicine. CRPM's team of scientists, researchers and technicians conduct research designed to translate discoveries into practical treatments, including integral participation in each of SPRI's clinical trials.

Department of Biomedical Engineering (BME): SPRI's BME team enhances patient care by focusing on injury and re-injury mechanisms and prevention, develops and validates novel surgical treatments and rehabilitation techniques and teaches advanced research protocols using state-of-the-art biomedical research techniques and technologies. The department includes a Robotics Laboratory and cutting-edge Biomotion Laboratory.

Center for Outcomes-Based Orthopaedic Research (COOR): SPRI's robust outcomes database is now tracking nearly 45,000 surgeries. The center conducts evidence- and outcomes-based research using actual clinical data, which helps both physicians and patients in making better and more informed treatment decisions.

Department of Imaging Research (IR): The IR team develops and evaluates noninvasive imaging techniques of the joints for the purpose of directing and monitoring clinical treatment and outcomes; the department enhances the clinical relevance of biomechanics research.

Department of Education: SPRI's Education team administers and coordinates the clinical fellowships and international scholars programs, hosts conferences and international academic meetings, produces and distributes publications and educational media and organizes educational outreach programs with local Colorado students.

SPRI BioAI Center (SBAC): Formerly the SPRI Microbiome Center, the BioAI Center is a technologically advanced department utilizing Niche Dynamics, Biomic Integration and Panomics to inform clinically relevant results that complement the other research departments within SPRI.

CLINICAL TRIALS AND FEDERAL FUNDING UPDATE

SPEAKING IN CLINICAL TRANSLATION: CLINICAL TRIALS BECOME STAPLE OF SPRI PROGRAM

Since its founding, Steadman Philippon Research Institute (SPRI) has been dedicated to conducting bench-to-bedside research and accelerating clinical translation. Bench-to-bedside research takes therapies and techniques researched first at the lab bench, through the process of validation and ultimately to the patient at their bedside. Although the concept is simple, traditional clinical translation occurs at a 17-year cycle pace, meaning the latest treatments and therapies can be nearly two decades away from reaching the patient. But at SPRI, accelerating this cycle and getting cutting-edge treatments to patients faster and safer has always been a priority; it is exemplified in SPRI's ongoing clinical trials.

In early 2019, SPRI received its first federal award—a four-project grant from the Department of Defense (DoD) including clinical trials focused on enhancing patient outcomes through the use of orthobiologics and therapeutics. Since this historic first, the SPRI team has been awarded additional federal funding from the DoD and National Institutes of Health (NIH), including a major clinical trial award called the Regenerative Medicine Innovation Project (RMIP). The five-year, multi-step clinical trial builds upon SPRI's pioneering therapeutic and biologic research, expanding upon the clinical trials underway from the DoD. Led by Chief Scientific Officer Johnny Huard, PhD as principal investigator, the RMIP includes co-principal investigators in Marc J. Philippon, MD—SPRI Chairman and Managing Partner of The Steadman Clinic—and Scott Tashman, PhD—Director of SPRI's Department of Biomedical Engineering. This award is exemplary of SPRI's mission of team science, as all SPRI departments and several physicians from The Steadman Clinic are participating in the trial.

SPRI's trials are wholly unique in that each trial takes a three-prong approach to testing treatment efficacy—using outcomes research to see how well patients are doing after treatment, conducting functional movement testing and advanced imaging, and studying the underlying biological mechanisms in play. Effectively, SPRI's clinical trials can



RECEIVING THESE MAJOR AWARDS IS THE RESULT OF SPRI'S COMMITMENT TO CONDUCTING HIGH-IMPACT RESEARCH FOR DECADES—SPRI IS A GLOBAL LEADER IN ORTHOPAEDIC AND SPORTS MEDICINE RESEARCH AND IS ONE OF THE MOST PUBLISHED ORGANIZATIONS IN THIS RESEARCH SPACE.

determine not only if treatments are working, but also how and why they are working. SPRI is now underway on five clinical trials and has seven NIH awards and two DoD contracts—a tremendous accomplishment for a small scientific research institute with no federal awards prior to 2018. But what is perhaps more impactful about these grants is that SPRI is able to accelerate its clinical translation—patients are participating in these trials while scientists and physicians are validating the treatments and therapies in nearly real time, with the goal of these treatments becoming the standard of care and reaching more patients faster.

Receiving these major awards is the result of SPRI's commitment to conducting high-impact research for decades—SPRI is a global leader in orthopaedic and sports medicine research and is one of the most published organizations in this research space. With pilot studies funded by philanthropy, SPRI was able to conduct valuable research that led to the awarding of federal grants. And as the team accelerates the clinical translation cycle, new pilot studies are launched regularly, positioning the team for future clinical trials and major awards.



PUBLISHING HONORS CONTINUE A LEGACY FOR STEADMAN PHILIPPON RESEARCH INSTITUTE



A REFLECTION BY

DAN DRAWBAUGH, CEO OF SPRI
AND THE STEADMAN CLINIC

**WITH OVER THIRTY YEARS OF HISTORY,
SPRI IS PROUD TO HOST AN ORTHOPAEDIC
OUTCOMES DATABASE WITH NEARLY
45,000 PATIENT SURGERIES BEING
TRACKED—NO ORTHOPAEDIC RESEARCH
DATABASE IN THE WORLD IS AS
RICH, LARGE AND LONG STANDING.
COMPLEMENTED BY LEADING-EDGE
REGENERATIVE MEDICINE RESEARCH,
BIOMEDICAL ENGINEERING AND
ADVANCED IMAGING STUDIES, SPRI HAS
BUILT A LEGACY OF CUTTING-EDGE,
IMPACTFUL SCIENCE.**

In the science and medicine communities, we are acutely aware of the importance of publishing our discoveries in peer-reviewed journals. This essential step in the scientific process is not just about contributing to the important conversations in orthopaedics and sports medicine; it's also about sharing our discoveries with others, communicating our findings, and letting other scientists and physicians know about our evidence-based treatments. Publishing continues our cycle of research, discovery and education, and it has become a hallmark of SPRI's achievements. Here are some key highlights:

In 2018, the *Journal of the American Academy of Orthopaedic Surgeons (JAAOS)* published an article entitled "Orthopaedic Academic Activity in the United States Bibliometric Analysis of Publications by City and State" to analyze the academic output of orthopaedic publications. *JAAOS* audited the 15 highest ranked orthopaedic journals between 2010–2014 and revealed that per capita, Vail, Colorado was the leader of publications per surgeon.

At the end of 2020, the peer-reviewed journal of *Arthroscopy* published "The Top 50 Most Influential Articles in Hip Arthroscopy," which named SPRI Chairman Dr. Marc J. Philippon as the author of the most influential paper of all time. Dr. Philippon's leading paper received 464 citations—146 more citations than the second paper on the list. Also remarkable, Dr. Philippon was an author on six of the top ten papers featured in the study.

In May 2021, *Arthroscopy* published, "The Top 100 Most-Cited Articles on Arthroscopy; Most Popular Topic is Rotator Cuff Rather Than Cartilage in the Last 5 Years," which highlighted the 100 most-cited articles on arthroscopic surgery published from 1950–2020. The results of this study indicated that the most prolific institution was SPRI (5% of the most-cited articles) and the most prolific first author was Dr. Philippon (4% of the articles).

These publication honors not only indicate that great science is being conducted at SPRI, but also that the work being done is significant, leading and repeatedly validated by these high-impact, peer-reviewed journals. More than any other institution, the field of orthopaedic sports medicine looks to SPRI's evidence-based medicine research to inform their clinical decision making.

**CONGRATULATIONS TO OUR SCIENTISTS, RESEARCHERS AND PHYSICIAN
PARTNERS ON THESE TREMENDOUS HONORS.**



MARC J. PHILIPPON, MD
Managing Partner
Sports Medicine, Hip Disorders, Hip Arthroscopy
Chairman, Steadman Philippon Research Institute



MATTHEW T. PROVENCHER, MD, MBA
Complex Shoulder, Complex Knee & Sports Surgery



LESLIE B. VIDAL, MD
Shoulder, Hip, Knee & Sports Medicine Specialist



DUSTIN ANDERSON, MD
Orthopaedic Interventionalist, Sports, Spine &
Regenerative Medicine, PM&R & Pain Medicine



RANDY W. VIOLA, MD
Hand, Wrist, Elbow & Orthopaedic
Trauma Specialist



RAYMOND H. KIM, MD
Adult Joint Reconstruction, Knee & Hip Arthroplasty



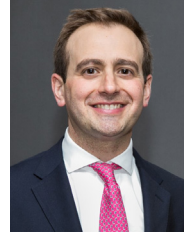
JONATHAN A. GODIN, MBA, MD
Shoulder, Knee, Hip & Sports Medicine Surgeon



JOSEPH J. RUZBARSKY, MD
Shoulder, Knee, Elbow & Hip Preservation Surgery



DAVID C. KARLI, MBA, MD
Spine, Sports, Rehabilitation & Regenerative
Medicine Specialist



DAVID A. KUPPERSMITH, MD
Internal Medicine



KAVI SACHAR, MD
Hand, Wrist & Elbow Surgery



JOHN H. PELOZZA, MD
Complex Neck & Lumbar Spine Surgery,
Minimally Invasive Spine Surgery & Disc
Replacement Surgery



TOM R. HACKETT, MD
Complex Knee, Shoulder & Elbow Surgeon



JOEL M. MATTA, MD
Hip Disorders: Preservation,
Replacement & Fractures



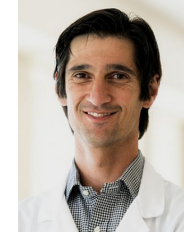
JARED T. LEE, MD
Aspen Medical Director
Shoulder, Hip, Knee & Sports Medicine



PETER J. MILLETT, MD, MSC
Shoulder, Knee, Elbow Surgery & Sports Medicine



C. THOMAS HAYTMANEK JR., MD
Foot, Ankle & Trauma Surgery



WAQQAR KHAN-FAROOQI, MD
Foot, Ankle & Trauma Surgery



THOS A. EVANS, MD
Orthopaedic Interventionalist of Spine &
Joint, Regenerative Medicine Specialist &
Anesthesiologist



ARMANDO F. VIDAL, MD
Complex Knee, Shoulder & Sports
Medicine Specialist



THEA WOJTKOWSKI, MD
Hip Replacement & Trauma Surgery



Dr. Leslie Vidal works with 2019–2020 Sports Medicine Fellow Dr. Joe Cooper in the operating room

THE STEADMAN CLINIC: VAIL AND FRISCO



LESLIE B. VIDAL, MD

Dr. Leslie Vidal joined The Steadman Clinic from Denver on August 1, 2019. She specializes in shoulder, hip, knee and sports medicine, and practiced in Denver for nearly two decades before joining The Steadman Clinic. Her husband, Dr. Armando Vidal, joined the practice in May 2019. Her appointment gave The Steadman Clinic its first female orthopaedic surgeon. A Colorado native, Dr. Vidal completed medical school at Boston University School of Medicine and her residency at the Hospital for Special Surgery in New York City. She completed her fellowship at the University of Pittsburgh Medical Center (UPMC), where she trained under Dr. Marc Philippon, who was then the Director of Sports Medicine/Hip Disorders at UPMC. Board-Certified by the American Board of Orthopaedic Surgery, Dr. Vidal practices at The Steadman Clinic's Vail and Frisco locations. She is a member of the SPRI Sports Medicine Fellowship faculty.



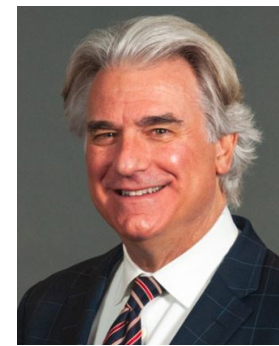
JONATHAN A. GODIN, MBA, MD

On October 1, 2019, Dr. Jonathan Godin joined The Steadman Clinic from Roanoke, Virginia. He is a board-certified surgeon specializing in shoulder, knee, hip and sports medicine surgery. Dr. Godin attended medical school at the University of Michigan and completed his residency at Duke. While in residency, Dr. Godin earned his MBA from The Wharton School at the University of Pennsylvania. Dr. Godin completed his sports medicine fellowship at Steadman Philippon Research Institute, joining several of The Steadman Clinic's physicians who have returned to practice at the clinic after their fellowship including Drs. Randy Viola, Peter Millett, Tommy Haytmanek, Jared Lee and Joseph Ruzbarsky. Dr. Godin now serves as a faculty member of the SPRI Sports Medicine Fellowship.



KAVI SACHAR, MD

Dr. Kavi Sachar joined The Steadman Clinic in June 2020 from Hand Surgery Associates in Denver, where he'd practiced since 1997. He specializes in hand, wrist and elbow surgery and is focused on restoring function through innovative open and arthroscopic techniques. Dr. Sachar attended Rensselaer Polytechnic Institute (RPI)/Albany Medical College's six-year medical program and completed his residency at Brown University. Dr. Sachar completed his fellowship at the Indiana Hand Center under Dr. James Strickland. He is board certified by the American Board of Orthopaedic Surgery and is a member of the American Society for Surgery of the Hand, American Academy of Orthopaedic Surgeons, Carpe Diem Hand Club and Rocky Mountain Hand Society.



JOHN H. PELOZA, MD

Board-certified orthopaedic surgeon Dr. John Pelozo joined The Steadman Clinic on February 15, 2021. A spine surgeon specializing in complex neck and lumbar spine surgery, minimally invasive spine surgery and disc replacement surgery, Dr. Pelozo has been on the forefront of spine surgery advancements and techniques for decades. He earned his MD from Northwestern University School of Medicine and completed his residency and internship at the University of Texas Southwestern Medical School. Dr. Pelozo was a sports medicine and knee surgery fellow under Dr. J. Richard Steadman in Lake Tahoe before he moved The Steadman Clinic and SPRI to Vail. Dr. Pelozo completed his International Spine Fellowship under Dr. David Selby.

2019-2021 NEW PHYSICIANS JOIN THE STEADMAN CLINIC

SINCE THE LAST EDITION OF THE *ORTHOPAEDIC RESEARCH JOURNAL*, THE STEADMAN CLINIC HAS ADDED NINE PROVIDERS TO ITS ROSTER, INCLUDING FIVE PHYSICIANS IN THE STEADMAN CLINIC'S NEW ASPEN LOCATION.



WELCOME TO THE STEADMAN CLINIC, ASPEN

THE STEADMAN CLINIC OPENED ITS NEWEST LOCATION ON DECEMBER 1, 2020. THE PRACTICE IS HOME TO FOUR ORTHOPAEDIC SURGEONS AND AN INTERVENTIONAL PAIN MANAGEMENT PHYSICIAN AND IS LOCATED IN ASPEN VALLEY HOSPITAL. SURGEONS FROM THE STEADMAN CLINIC, VAIL ALSO ROTATE INTO THE CLINIC TO SEE PATIENTS FROM ASPEN AND THE ROARING FORK VALLEY.

THE STEADMAN CLINIC WILL OPEN AN ADDITIONAL LOCATION IN BASALT, COLORADO (LOCATED 20 MINUTES FROM ASPEN) IN EARLY 2022, WHICH WILL FEATURE A CLINIC, AMBULATORY SURGERY CENTER, SPRI REGENERATIVE MEDICINE LABORATORY AND REHABILITATION SERVICES. THE STEADMAN CLINIC, ASPEN AND PHYSICIANS FROM THE VAIL LOCATION WILL PROVIDE MEDICAL AND SURGICAL TREATMENT IN THE BASALT LOCATION.



JARED T. LEE, MD

Dr. Jared Lee joined The Steadman Clinic from Bighorn Medical Center in Cody, Wyoming. Dr. Lee attended the University of Washington for medical school and completed his residency at the Harvard Combined Orthopaedic Residency Program where he also served as Administrative Chief Resident at Massachusetts General Hospital. He completed his sports medicine fellowship at Steadman Philippon Research Institute in 2013. Dr. Lee played collegiate football at Brigham Young University and played in the National Football League (NFL) after signing as a free agent with the Cincinnati Bengals. Board-certified by the American Academy of Orthopaedic Surgeons, Dr. Lee serves as Medical Director of The Steadman Clinic, Aspen and specializes in shoulder, hip, knee and sports medicine.



WAQQAR KHAN-FAROOQI, MD

A member of The Steadman Clinic, Aspen, Dr. Khan-Farooqi is a board-certified orthopaedic surgeon who specializes in foot, ankle and trauma surgery. Dr. Khan-Farooqi earned his MD from Stanford Medical School and completed his residency training at the University of Washington, Harborview Medical Center. He completed his subspecialty training in foot and ankle surgery with a focus on athlete care at OrthoCarolina in Charlotte, North Carolina. Dr. Khan-Farooqi is married to Dr. Thea Wojtkowski, a fellow orthopaedic surgeon at The Steadman Clinic, Aspen.



THEA WOJTKOWSKI, MD

Dr. Thea Wojtkowski joined The Steadman Clinic's Aspen location on December 1, 2020. She is a board-certified orthopaedic surgeon who specializes in hip replacement and trauma surgery. Dr. Wojtkowski attended Stanford University for her ungraduated degree, where she met her husband, Dr. Waqqar Khan-Farooqi, who practices at The Steadman Clinic, Aspen. She attended the University of Washington for both her medical school and orthopaedic residency and has practiced in Hawaii, North Carolina, Washington and Colorado. She currently serves as the medical director for the Aspen Valley Ski Club.



DUSTIN ANDERSON, MD

Dr. Dustin Anderson is an orthopaedic interventionalist who specializes in sports and spine regenerative medicine, physical medicine and rehabilitation, and pain medicine. He practices from The Steadman Clinic, Aspen and focuses on nonoperative care for disorders of the joints, bones, nerves and muscles. Originally from Wisconsin, Dr. Anderson earned his MD from the Medical College of Wisconsin and completed his residency and fellowship at the University of Colorado Anschutz Medical Campus.



JOSEPH J. RUZBARSKY, MD

Dr. Joseph Ruzbarsky is a shoulder, knee, elbow and hip preservation surgeon at The Steadman Clinic, Aspen. Dr. Ruzbarsky earned his MD from the University of Pennsylvania and completed his surgical internship at New York-Presbyterian/Weill Cornell Medical Center. He attended the Hospital for Special Surgery in New York City for his orthopaedic surgery residency before joining Steadman Philippon Research Institute for his sports medicine fellowship. Dr. Ruzbarsky completed an additional fellowship year at SPRI in the hip preservation & reconstruction fellowship.

HAPPY RETIREMENT TO DRs. CLANTON AND CORENMAN



THOMAS O. CLANTON, MD
FOOT, ANKLE & SPORTS MEDICINE



DONALD S. CORENMAN, DC, MD
SPINE & NECK SPECIALIST

IN DECEMBER 2020, DR. THOMAS O. CLANTON, VETERAN FOOT AND ANKLE SURGEON OF THE STEADMAN CLINIC, RETIRED AFTER ELEVEN YEARS AT THE PRACTICE. DR. CLANTON TREATED HUNDREDS OF PROFESSIONAL, OLYMPIC AND COLLEGIATE ATHLETES IN HIS CAREER, AND WAS ONE OF THE MOST SOUGHT-AFTER SURGEONS IN HIS SPECIALTY. ALTHOUGH DR. CLANTON CLOSED HIS PRACTICE IN DECEMBER 2020, HE HAS CONTINUED WORKING WITH SPRI TO COMPLETE ONGOING RESEARCH AND OFFER HIS MEDICAL EXPERTISE TO THE INSTITUTE'S GRANT EFFORTS.

DR. DONALD S. CORENMAN RETIRED FROM THE STEADMAN CLINIC IN MAY 2021 AFTER 20 YEARS OF SERVICE. DR. CORENMAN SPECIALIZED IN SPINE AND NECK SURGERY AND WAS DOUBLE BOARD CERTIFIED IN CHIROPRACTIC ORTHOPAEDICS AND ORTHOPAEDIC SURGERY. DURING HIS CAREER, DR. CORENMAN RAN AN EVIDENCE-BASED PRACTICE AND MAINTAINED A LARGE PATIENT DATABASE.

SPRI THANKS THESE PHYSICIANS FOR THEIR PARTNERSHIP AND WISHES THEM A WELL-DESERVED RETIREMENT.



(ABOVE) Dr. Clanton (BELOW) Dr. Corenman

LINDA & MITCH HART CENTER FOR REGENERATIVE AND PERSONALIZED MEDICINE

FACULTY AND STAFF

JOHNNY HUARD, PHD
DIRECTOR
CHIEF SCIENTIFIC OFFICER

SUDHEER RAVURI, PHD
DEPUTY DIRECTOR

CHELSEA S. BAHNEY, PHD
PRINCIPAL INVESTIGATOR
PROGRAM DIRECTOR OF BONE REPAIR
AND REGENERATIVE THERAPEUTICS

XUEQIN GAO, MD, PHD
PRINCIPAL INVESTIGATOR
PROGRAM DIRECTOR OF BONE AND
CARTILAGE REPAIR
AND STEM CELL BIOLOGY

PING GUO, PHD
PRINCIPAL INVESTIGATOR
PROGRAM DIRECTOR OF GENETIC
AND CELLULAR ENGINEERING

WILLIAM S. HAMBRIGHT, PHD
PRINCIPAL INVESTIGATOR
PROGRAM DIRECTOR OF HEALTHY AGING
AND DIAGNOSTICS

AIPING LU, MD
PRINCIPAL INVESTIGATOR
PROGRAM DIRECTOR OF MUSCLE REPAIR
AND STEM CELL BIOLOGY

NAOKI NAKAYAMA, PHD
PRINCIPAL INVESTIGATOR
PROGRAM DIRECTOR OF STEM CELL
ENGINEERING
AND CARTILAGE REGENERATION

NAOMASA FUKASE, MD, PHD
INTERNATIONAL RESEARCH SCHOLAR

YOICHI MURATA, MD, PHD
INTERNATIONAL RESEARCH SCHOLAR

KAITIE WHITNEY
CLINICAL TRANSLATION RESEARCH
COORDINATOR

ANNA LAURA NELSON, MS
PHD GRADUATE STUDENT

MICHAEL MULLEN
RESEARCH ASSOCIATE

VERENA OBERLOHR
RESEARCH ASSOCIATE

VICTORIA DUKE
RESEARCH TECHNICIAN

JOHN MITCHELL
RESEARCH TECHNICIAN

MATTHIEU HUARD
RESEARCH TECHNICIAN

HEIDI KLOSER
RESEARCH TECHNICIAN

KELSEY O'HARA
RESEARCH TECHNICIAN

ALYSON FIORENTINO
RESEARCH ASSISTANT

ALEX GOFF
RESEARCH ASSISTANT

IMALI KEGODE
RESEARCH ASSISTANT

CLINICAL TRIALS TEAM

SUZANNE LIV PAGE, JD
VICE PRESIDENT OF OPERATIONS

MICHAEL BEGG, DMSC, PA-C, ATC
CLINICAL TRIALS PHYSICIAN ASSISTANT

EMILY BENSTEAD, MS
SENIOR CLINICAL TRIALS COORDINATOR

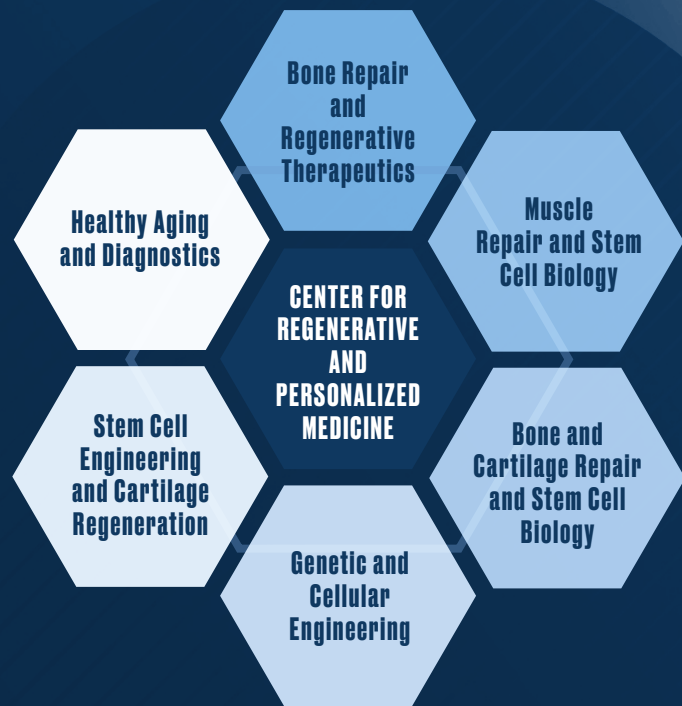
SARA ROBINSON, MS
CLINICAL TRIALS PROGRAM COORDINATOR

FORMERLY THE CENTER FOR REGENERATIVE SPORTS MEDICINE (CRSM), THE LINDA & MITCH HART CENTER FOR REGENERATIVE AND PERSONALIZED MEDICINE (CRPM) BROADENED ITS NAME TO ACKNOWLEDGE THE ARRAY OF SCIENCE BEING CONDUCTED IN THE LAB.

Scientists and researchers are underway on numerous projects, including clinical trials funded by the National Institutes of Health (NIH), Department of Defense (DoD) and industry, alongside federally funded preclinical projects and pilot programs sponsored by philanthropy. The department is supported by eight full-time PhDs, five of whom serve as Principal Investigators and Program Directors. The team is led by Johnny Huard, PhD, who also serves as Chief Scientific Officer of SPRI.

Despite COVID-19's impact on 2020, the department has continued to produce high-impact science, earn major funding awards and reach significant milestones on its projects. In addition to its federal funding and industry grants, CRPM receives significant philanthropic funding each year, which is used to launch vital pilot studies and research programs. These pilot studies are often used to develop major grant applications, including numerous trials awarded by federal agencies.

Like all of SPRI's teams, CRPM is committed to conducting the highest impact team science, leveraging the expertise of the orthopaedic physicians at The Steadman Clinic and the strengths of the other scientific departments. Over the past several years, CRPM has worked to accelerate clinical translation and help scientific discoveries and proven treatments get to patients faster.



CENTER FOR REGENERATIVE AND PERSONALIZED MEDICINE PROGRAMS

CRPM includes several programs that investigate cellular science and regenerative medicine techniques and therapies. Each program is led by a subject matter expert in their program.

CRPM PROGRAMS:

- Bone Repair and Regenerative Therapeutics
- Muscle Repair and Stem Cell Biology
- Bone and Cartilage Repair and Stem Cell Biology
- Genetic and Cellular Engineering
- Stem Cell Engineering and Cartilage Regeneration
- Healthy Aging and Diagnostics

FEDERAL FUNDING AWARDS

NATIONAL INSTITUTES OF HEALTH (NIH) GRANTS

- **4** Primary Grants
- **3** Sub-award Grants
- **1** Regenerative Medicine Innovation Project (RMIP): Clinical Trial Underway

DEPARTMENT OF DEFENSE (DOD)

- **1** Contract: **3** Clinical Trials, **1** Clinical Study
- **1** Grant: **1** Clinical Trial

ABSTRACTS & PUBLICATIONS JULY 2019–JULY 2021

ABSTRACTS: 85
PUBLICATIONS: 73

A prolific publisher, CRPM has submitted dozens of abstracts and has published over 70 scientific papers since the last edition of the *Orthopaedic Research Journal*. The department celebrated a major collaborative publication in *Nature*, one of the top peer-reviewed scientific journals in the world:

“An aged immune system drives senescence and ageing of solid organs” was published in May 2021.



NAOKI NAKAYAMA, PHD
 PRINCIPAL INVESTIGATOR
 PROGRAM DIRECTOR OF STEM CELL ENGINEERING
 AND CARTILAGE REGENERATION

INTRODUCING DR. NOAKI NAKAYAMA

IN DECEMBER 2020, SPRI WELCOMED NAOKI NAKAYAMA, PHD TO THE CENTER FOR REGENERATIVE AND PERSONALIZED MEDICINE (CRPM).

Dr. Nakayama serves as Principal Investigator and Program Director of Pluripotent Stem Cell and Cartilage Regeneration. He has several major grants for which he serves as Principal Investigator, including “Articular cartilage tissue engineering with human pluripotent stem cells,” which was funded in early 2021 by the National Institutes of Health (NIH). Dr. Johnny Huard serves as Co-Investigator on the grant.

Prior to joining the team at SPRI, Dr. Nakayama served as Associate Professor at the Institute of Molecular Medicine at UTHealth from 2008–2019, and also worked as PI/Senior Scientist at the Australian Stem Cell Centre and Research Scientist/PI at the Department of Cell Biology for Amgen Inc.

Dr. Nakayama’s research interests include human and mouse pluripotent stem cell biology, biological restoration of joint cartilage and ligament using pluripotent stem-cell-derived embryonic joint progenitors, molecular basis of lineage specification and fate determination during joint development and proteostasis and degenerative disorders like osteoarthritis.

Dr. Nakayama has published over 50 research publications including more than 20 as a first author or corresponding author and holds two patents. Throughout his career, Dr. Nakayama has given more than 50 oral presentations and lectures.

Dr. Nakayama has joined the CRPM team in Fort Collins, Colorado, conducting preclinical research studies alongside three fellow PhD scientists running collaborative and complementary research programs.

An Update on SPRI’s Department of Defense Clinical Trials

In the last issue of SPRI’s *Orthopaedic Research Journal*, the organization announced the receipt of its first federal grant, a multimillion-dollar contract from the Department of Defense (DoD), which centered around four projects including three clinical trials and a clinical study. Since this first federal award, the team has received a second multimillion-dollar DoD award and several National Institutes of Health (NIH) grants. SPRI will also begin enrolling patients into three new clinical trials beginning in the third quarter of 2021.

DEPARTMENT OF DEFENSE (DOD) PROJECTS

The first DoD contract included four projects with a clinical translation focus. Below, please learn more about these projects and their current status:

1. Prospective Evaluation of Platelet-Rich Plasma and Bone Marrow Concentrate to Accelerate Healing after Anterior Cruciate Ligament Reconstruction

PRINCIPAL INVESTIGATORS:

- Johnny Huard, PhD
- Marc Philippon, MD
- Peter Millett, MD, MSc
- Scott Tashman, PhD
- Tom Hackett, MD
- Matthew Provencher, MD, MBA, CAPT, MC, USNR (Ret.)
- Armando Vidal, MD
- Leslie Vidal, MD
- Jonathan Godin, MBA, MD

PRIMARY OBJECTIVE:

To determine in a blinded, placebo-controlled trial how the injection of “biological products” into the knee may improve knee healing, function, and patient-reported symptoms following anterior cruciate ligament (ACL) reconstruction surgery

- 60 participants, aged 16–50
- 3-year study
- 24 patients currently enrolled

2. Biologically Regulated Marrow Stimulation by Blocking Fibrosis to Improve Cartilage Repair: A Mixed Retrospective and Prospective Cohort Study

PRINCIPAL INVESTIGATORS:

- Johnny Huard, PhD
- Marc Philippon, MD

PRIMARY OBJECTIVE: To determine if hip microfracture patients who took losartan will have improved articular cartilage repair as assessed on follow-up quantitative magnetic resonance imaging at least two years after surgery compared to patients who did not take losartan

- Underwent primary hip arthroscopy with microfracture between January 1, 2012 and June 30, 2019
- Unipolar or bipolar chondral defects on the acetabulum or femoral head
- Aged 18–60 at the time of surgery
- Institutional Review Board (IRB) approved
- 289 qualifying surgeries identified through database, medical record and imaging review
- Final test scans are being analyzed to determine the optimal quantitative MRI sequence to characterize hip cartilage quality
- Patient contract will begin in coming weeks, and subject assessments will be conducted over the remainder of 2021 and into early 2022

3. Senolytic Drugs Attenuate Osteoarthritis-Related Articular Cartilage Degeneration: A Clinical Trial

PRINCIPAL INVESTIGATORS:

- Johnny Huard, PhD
- Marc Philippon, MD
- Scott Tashman, PhD
- Thos Evans, MD

PRIMARY OBJECTIVE: The safety of administering Fisetin in subjects with knee osteoarthritis (OA)

SECONDARY OBJECTIVE: To evaluate the reduction of systemic senescent cells and pro-inflammatory and cartilage degenerating ASP markers; improvement in physical function of the Study Knee; improvement in patient-reported outcomes; improvement in the quality of articular cartilage in the Study Knee with quantitative magnetic resonance imaging (MRI)

- Knee OA patients age 40–80
- Investigational New Drug Application (IND) issued by Food and Drug Administration (FDA)
- 3-year study
- 74 patients currently enrolled

4. Optimization of Return-to-Duty Protocols after Knee Injury (Department of Biomedical Engineering)

PRINCIPAL INVESTIGATORS:

- Scott Tashman, PhD
- Matthew Provencher, MD, MBA, CAPT, MC, USNR (Ret.)

PRIMARY OBJECTIVE: To test whether high-demand activities, completed through an outdoor military-relevant terrain park, will more effectively identify functional deficits after knee injury (ACL reconstruction) than traditional RTP screening tests

- 50 ACL-reconstructed subjects; 50 uninjured subjects
- 3-year study
- Uninjured testing nearly complete

SPRI will begin recruiting patients for the new DoD award—a clinical trial—in Q3 2021.

A MONUMENTAL AWARD FOR GROUNDBREAKING INNOVATION

Team science and medicine is at the core of SPRI and The Steadman Clinic's synergistic relationship. With collaborative scientific departments and physician investigators committed to practicing evidence-based medicine, the two institutions are intertwined in their clinical translation efforts.

A Major Clinical Trial in Regenerative Medicine

In May 2020, SPRI learned that it had been awarded a prestigious grant from the NIH—an award called the Regenerative Medicine Innovation Project (RMIP). The RMIP is a five-year, multimillion-dollar matching grant that will total \$5.9M for this research. A clinical trial involving several of The Steadman Clinic's physicians alongside scientists and researchers across SPRI's departments, the RMIP is at the heart of the mission of both organizations. The award is unique, not only because of its substantial size, but also because the NIH does not typically fund human regenerative medicine clinical trials.

Entitled "The Use of Senolytic Agents and Anti-Fibrotic Agents to Improve the Beneficial Effect of Bone Marrow Stem Cells for Osteoarthritis," the RMIP trial builds from CRPM's pioneering therapeutic and biologic research and expands upon the clinical trials currently underway from the DoD.

Therapeutics to Improve Patient Outcomes

The goal of this multi-step, five-year clinical trial is to determine whether senolytic and/or antifibrotic agents will improve the beneficial effect of Bone Marrow Stem Cells (BMSCs) for the treatment of symptomatic knee osteoarthritis (OA). The trial will include four groups, totaling 100 patients, to investigate the team's hypotheses that the use of these agents will improve patient outcomes. These groups include a group treated with both the senolytic and anti-fibrotic agent, a group treated with only the senolytic or the anti-fibrotic agent and a placebo group. The team will analyze patient outcomes to see if the use of the agents was beneficial.

The RMIP is led by Principal Investigators Drs. Johnny Huard, Marc Philippon and Scott Tashman. Dr. Leslie Vidal serves as the Clinical Principal Investigator, and Drs. Thos Evans, Jonathan Godin and Armando Vidal serve as clinical investigators on the trial.

The RMIP Begins Enrollment

The team was awarded an Investigational New Drug Authorization (IND) from the Food and Drug Administration (FDA) and the trial was approved by the Institutional Review Board (IRB). The planning phase of the project has been completed and the trial began patient enrollment in June 2021.

In July 2021, CRPM was awarded an Administrative Supplement to the RMIP Clinical Trial to fund additional research in the lab: "Changes in senescent cells and SASP from bone marrow, synovial fluid and peripheral blood after senolytic treatment." This additional research will analyze additional tissues, adding to the department's comprehensive work with senescence.

HEALTHY AGING AND THE EXPLORATION OF SENESENCE

SINCE ESTABLISHING THE CRPM LAB, SPRI HAS EXPANDED ITS RESEARCH TO INVESTIGATE SCIENCE AT THE CELLULAR AND MOLECULAR LEVEL. THIS INCLUDES EXTENSIVE RESEARCH INTO STEM CELLS, ORTHOBIOLOGICS AND HOW THESE THERAPIES CAN BE HARNESSSED TO ADVANCE HEALING FOLLOWING INJURY, SURGERY OR AS A TREATMENT TO A MUSCULOSKELETAL CONDITION LIKE OSTEOARTHRITIS (OA).

AGING AND SENESENCE

In 2019, CRPM launched the Regenerative Medicine Program on Healthy Aging, which investigates musculoskeletal conditions through the lens of aging—when studying these disorders as age-related conditions, it posits opportunities for preventative and responsive therapies as opposed to reactive treatments after the conditions have significantly progressed. The team is focused on the concept of senescence—the aging and decay of cells—and how it impacts musculoskeletal conditions. Alongside its orthopaedic and musculoskeletal studies, CRPM is investigating senescence as it relates to other diseases like Duchenne Muscular Dystrophy (DMD), fracture repair, cancer and cardiovascular disease.

CRPM suggests that patients with osteoarthritis have senescent cells that damage their cartilage. Often referred to as “zombie cells,” senescent cells are at the root of many conditions because as people age, their senescent cells grow and expand, replacing healthy cells. The team began its research by studying senescent cells in the lab, expanding the research to preclinical trials that centered around an animal model with OA. Through treating the animal model with senolytic supplements, the team discovered that OA could be delayed in the mice. From this initial discovery, SPRI and The Steadman Clinic began federally funded clinical trials in humans with the goal to delay cartilage degeneration. The team is hopeful that the senolytic supplements could even repair existing damaged cartilage, which would be a monumental discovery in the scientific community.

BUILDING A UNIQUE PATIENT DATABASE

Alongside its clinical trials, CRPM has built a database of human patients by collecting blood samples and analyzing them for senescence. Most of the tested patients presented within a normal range, but for individuals with outlying high senescent levels, Dr. Huard recommended the individual complete a full blood panel with their physicians. Most of the outlying patients had chronic health conditions, which the team hypothesizes is the reason for their increased senescence.

The team has now tested over 200 patients for senescence and has observed reduced senescence in individuals who take senolytic supplements. The team will continue to test these individuals at different time periods and compare samples with and without senolytic supplements to determine the potential impact of these supplements on senescence levels over time.

The purpose of reducing senescent cells is distinct based on each individual’s health and goals. In the context of orthopaedic conditions, it could mean the difference between a patient needing a surgical intervention or not. If surgery is inevitable, the patient will likely be in a healthier position to recover. Dr. Huard refers to this approach as optimizing a patient’s surgery before they have it.

NEXT STEPS FOR SENESENCE TESTING

As SPRI continues its clinical trials and building its senescence database, the team looks to expand beyond its orthopaedic research to investigate the impact of senescence on more age-related disorders. SPRI will leverage its strong collaborations with organizations and universities like the Buck Institute, University of Wisconsin, University of California, San Francisco and more to create a robust senescence cellular network with aims to discover treatments, therapies and preventative measures regarding senescence in people.



DEPARTMENT OF BIOMEDICAL ENGINEERING

FACULTY AND STAFF

SCOTT TASHMAN, PHD
DIRECTOR

TRAVIS TURNBULL, PHD
DEPUTY DIRECTOR

ALEX BRADY, MS
SENIOR ROBOTICS ENGINEER

KIMI DAHL, MS
RESEARCH SCIENTIST

SARAH WILSON, MS
RESEARCH ENGINEER

AMANDA VINSON
RESEARCH ASSISTANT

ADAM BRADSHAW
RESEARCH ASSISTANT

AUSTIN CARCIA
RESEARCH ASSISTANT

JUSTIN BROWN
RESEARCH ASSISTANT

ANNA BRYNIARSKI
RESEARCH ASSISTANT

JACQUELINE FOODY
RESEARCH ASSISTANT

CARLIE JONES-HERSHINOW
RESEARCH ASSISTANT

RITESH KASHYAP, MS
RESEARCH ASSISTANT

MITCHELL MESSNER
RESEARCH ASSISTANT

SPRI'S DEPARTMENT OF BIOMEDICAL ENGINEERING (BME) IS A COLLECTION OF MULTIDISCIPLINARY LABORATORIES AND RESEARCHERS THAT APPLY QUANTITATIVE, ANALYTICAL AND INTEGRATIVE METHODS TO THE FIELD OF ORTHOPAEDIC MEDICINE.

BME focuses on the role of mechanics and movement on injury and re-injury prevention as well as assessment of surgical and nonsurgical treatments for restoring musculoskeletal function. The team is dedicated to integrating clinical care, research and education, combining SPRI's engineering expertise with the resources of renowned orthopaedic surgeons from The Steadman Clinic, with the ultimate goal of improving treatment of musculoskeletal diseases and orthopaedic injuries. Biomechanics, motion analysis, biomedical imaging and orthopaedic engineering are at the center of the department's research approach.

Since our last edition of the *Orthopaedic Research Journal* was published, BME has continued its productive physician collaborations, maintaining the imperative clinical lens that keeps its focus on high-impact research. BME's research portfolio has expanded significantly to include an essential role in nearly all of SPRI's clinical trials, providing advanced biomechanical and quantitative imaging assessments to evaluate the effectiveness of regenerative medicine treatments for restoring tissue health and function.

BME includes a state-of-the-art Biomotion Laboratory for assessing human movement and function that includes video-motion analysis, an instrumented treadmill, force plates, a wireless EMG system, IMU sensors, insole pressure sensors and a unique Dynamic Stereo X-ray system, utilizing cutting-edge technology designed by Dr. Scott Tashman, director. Studies of musculoskeletal anatomy and new orthopaedic procedures are conducted in the department's Robotics Laboratory, which is one of the most advanced facilities of its kind in the world. A custom robot and other equipment can recreate physiological joint motion, which are combined with video-motion analysis and 3D laser scanning to capture musculoskeletal geometry and function.

Over the last few years, BME research has become much more tightly integrated with the other SPRI departments. In addition to its contributions to the CRPM regenerative medicine clinical trials, BME engineers work side-by-side with the Imaging Research team to combine structural imaging data with biomotion assessments for advanced understanding of structure-function relationships.

PUBLICATIONS & ABSTRACTS 2019-2021

29 PEER-REVIEWED JOURNAL PAPERS

- 9 papers published in the *American Journal of Sports Medicine* (the most highly cited orthopaedic journal)
- More than 25 national/international conference abstracts

KEY HIGHLIGHTS

- BME's Biomotion Lab is providing critical assessments, including video-motion analysis, Dynamic Stereo X-Ray imaging, muscle strength testing and functional evaluations, to determine the efficacy of regenerative medicine treatments for SPRI's federally funded clinical trials.
- By continuing to upgrade technologies and methodologies, including new 3D motion assessment tools, laser distance measurements, quantitative ultrasound and 3D printing of fixtures and instruments, BME's Robotics Lab has maintained its status as one of the most advanced facilities of its kind in the world, producing high-impact studies driven by the vision and creativity of The Steadman Clinic orthopaedic surgeons, clinical fellows and the BME engineering team.
- Collaborations between BME and CRPM continue to expand. Beyond the ongoing clinical trials, Drs. Huard and Tashman are Co-Principal Investigators on several multidisciplinary grants submitted to the NIH and other organizations in 2020-2021.



OPTIMIZING RETURN-TO-DUTY PROTOCOLS

One of the four projects from SPRI's first Department of Defense (DoD) contract includes a clinical study focused on optimizing return-to-duty protocols following injury. The Mobile Platform for Optimizing Warfighter Rehabilitation (MPOWR) study is focused on reducing the rate of re-injury after ACL reconstruction, as re-injury rates occur in 10–15% of surgical cases and ACL injuries are common in military personnel. Nearly 40% of military personnel who experience an ACL injury are not able to return to duty or return to their original activity level. Much of this has to do with musculoskeletal training and optimization. However, in order to train well, specific gaps need to be identified.

CLINICAL AND MILITARY LENS IMPORTANT TO STUDY

BME's Director Scott Tashman, PhD serves as Principal Investigator alongside Matthew T. Provencher, MD, MBA, CAPT MC USNR (Ret.) prominent orthopaedic surgeon at The Steadman Clinic. Given the high re-injury rates, the collaborators considered whether or not existing return-to-duty protocols were sufficiently targeted at the unique challenges faced by military personnel with ACL injuries, perhaps leading to return to duty before they were fully healed.

As standard return-to-duty and return-to-sport tests often occur in a controlled, indoor environments, the team created an outdoor obstacle course that would more likely replicate the conditions military personnel would face in the field. As a U.S. Navy Reservist and former orthopaedic surgeon to the U.S. Navy SEALs, Dr. Provencher's background was instrumental to the development of the study.

MPOWR STUDY PROGRESS

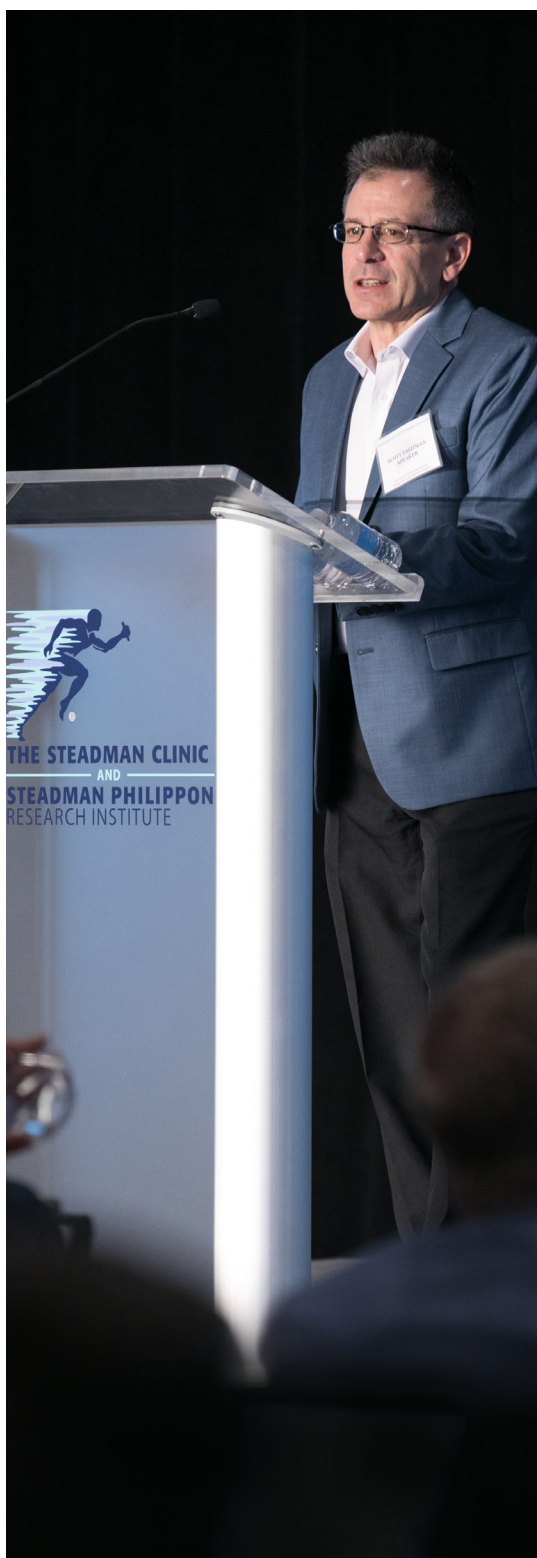
The BME team first evaluated and validated state-of-the-art wearable sensor technologies that enable in-the-field, advanced assessments of movement biomechanics that previously required a dedicated, indoor laboratory. The team then designed an outdoor MPOWR course that recreated physical challenges experienced by military personnel during training and on the battlefield. A study of 50 uninjured subjects was performed to determine the "normal range" of wearable sensor measurements and develop algorithms for identifying abnormal biomechanics that might place individuals at risk for injury/reinjury.

The ongoing phase of the study includes recruiting and evaluating 50 participants who are recovering from an ACL reconstruction. The team is using the validated wearable sensor measurements to assess differences in how these individuals perform on the course compared

to the uninjured subjects, focusing on how the injured/ repaired knee responds to different terrains and activities and identifying any functional deficits following reconstruction. Advanced MRI will also be acquired at the same visit and repeated one year later to evaluate how effectively these biomotion assessments can predict structural status of the healing ACL graft.

POTENTIAL IMPACT FROM MPOWR

While the primary goal of MPOWR is focused on optimizing return-to-duty protocols, there are greater implications to this research in the context of injuries and sport. As most return-to-sport evaluations performed in the clinic do not reflect the true demands of various sports, the findings from MPOWR may lead to the development of other protocols that better replicate real-world conditions. The wearable sensor technology provides an interior view into the ligaments and joints, giving a more objective reading than how a participant feels after a test. These refined protocol programs could help significantly reduce re-injury rates and ensure that more military personnel, athletes and recreationists are able to return to their activities safely.



Department Director Scott Tashman, PhD presents at the 5th Annual Vail Scientific Summit

SPRI BIOMOTION LAB INCORPORATES LEADING-EDGE IMAGING TECHNOLOGY

MAKING AN IMPACT WITH DYNAMIC STEREO-RADIOGRAPHIC IMAGING

One of Dr. Scott Tashman's goals when he moved to SPRI was to set up one of the world's most advanced Biomotion laboratories. A key component of the lab would be the dynamic stereo-radiographic (DSX) imaging technology that he developed, which has become the gold standard for high-accuracy musculoskeletal kinematics. Not satisfied with merely recreating the system he had previously designed—which has now been copied in several labs around the country—Dr. Tashman looked to upgrade the SPRI DSX configuration.

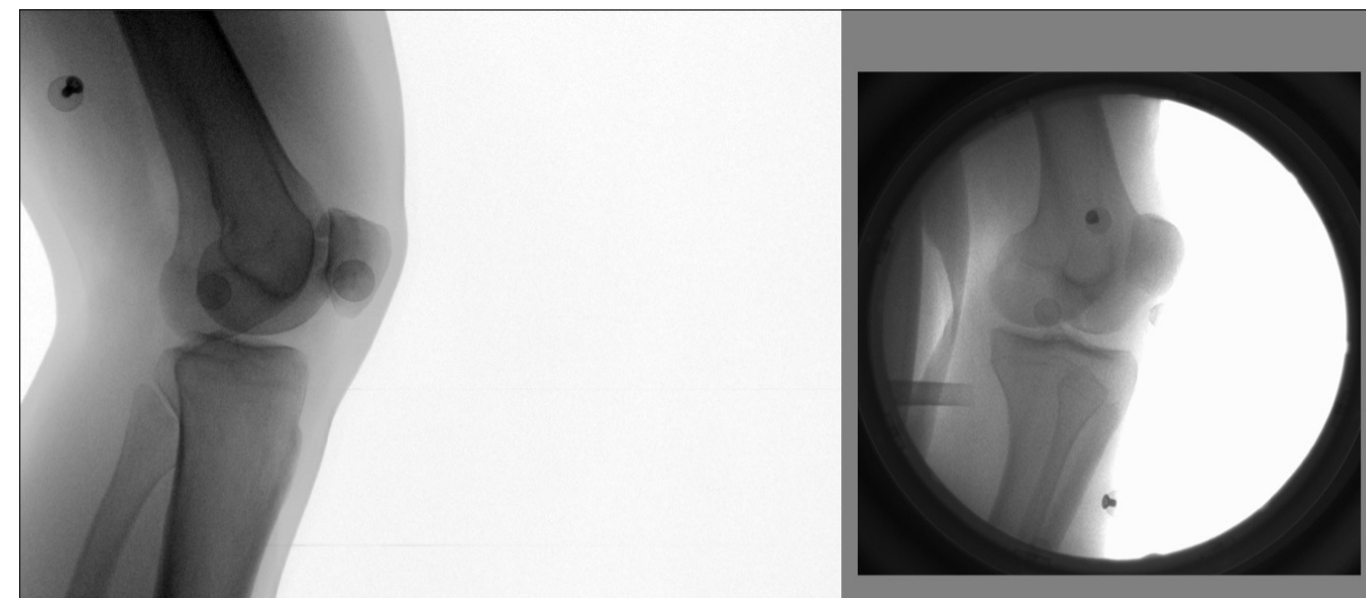
DSX systems use image intensifiers for detecting X-ray images, which are basically giant, round vacuum tubes (similar to old CRT televisions). Most radiographic imaging is now performed using flat-panel detectors (with technology similar to today's LCD TVs), but commercially available flat panel detectors cannot achieve the higher frame rates required for dynamic motion studies. Through extensive investigation, Dr. Tashman identified a company that had developed a new flat panel technology capable of achieving high

frame rates. He traveled to Shanghai to work with the company's engineers and with the support of a generous benefactor, he was able to acquire the first two detectors shipped to the USA. Currently, SPRI owns the only detectors of its kind in the United States. The BME team then designed and fabricated custom, motorized support structures that provide the positioning flexibility necessary for imaging any joint in the body.

The advantage of these new detectors is clearly shown in the image below. The knee X-ray on the left is from SPRI's flat panel detector, while the one on the right is from an image intensifier. Both images were acquired dynamically (during a jump landing) using the same amount of radiation. The benefits of the flat panel include higher resolution, improved contrast and a much larger, rectangular field of view.



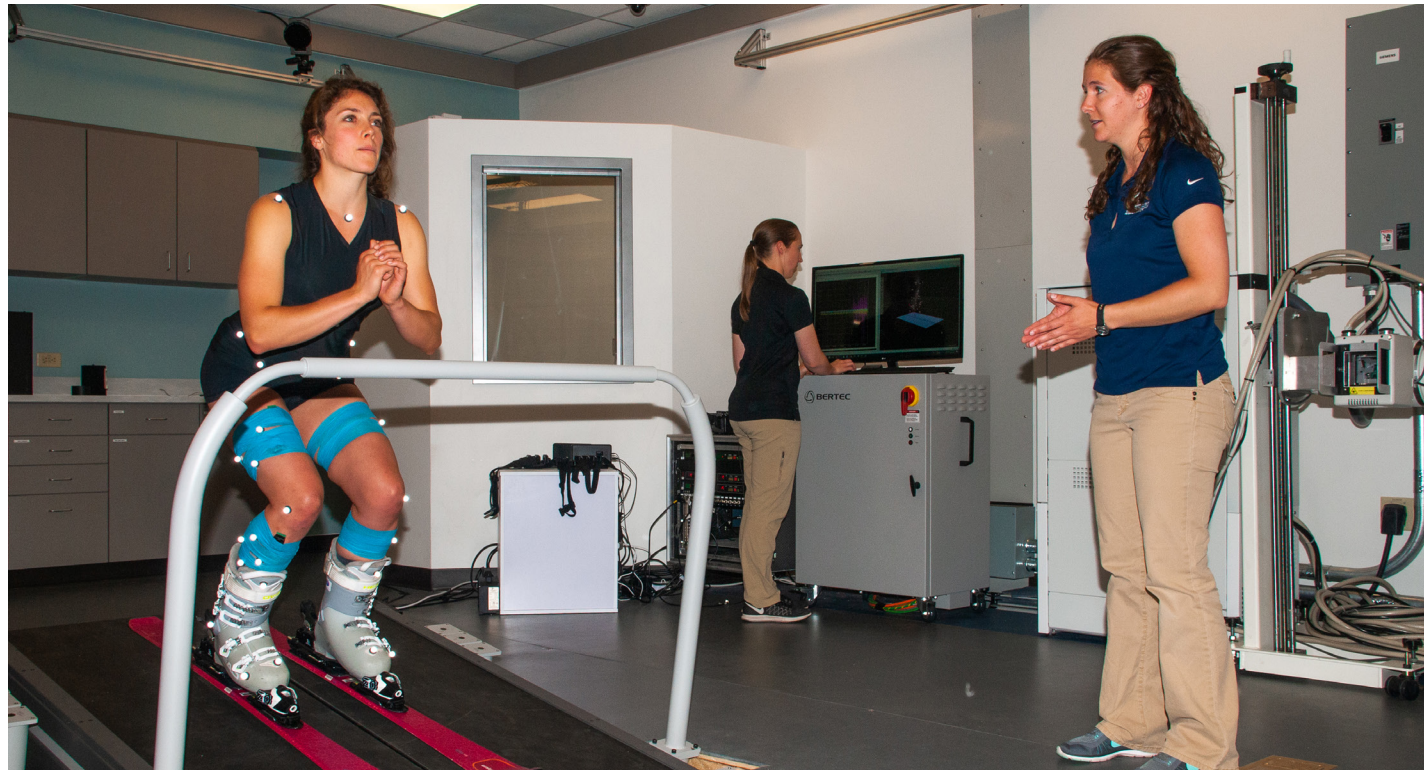
The flat panel DSX system is able to move to image any joint on the body



Imaging Comparison - (LEFT) SPRI's flat panel detector produces a clearer image than the traditional detector (RIGHT)

THE SIGNIFICANCE OF THIS ADVANCED IMAGING TECHNOLOGY

These new flat panel detectors are now used for all of SPRI's DSX studies. Besides improving image and data quality for all of our studies, the larger field of view and extended dynamic range is enabling studies of joints and movements that were traditionally very difficult to image. This provides new opportunities for hip studies with Dr. Philippon, and will soon be employed for studies of the lumbar spine with The Steadman Clinic's spine surgeon, Dr. John Pelosa.



Biomotion researchers test biomechanical function with ski equipment

REDEFINING OUTCOMES ASSESSMENT

As SPRI's regenerative medicine program advances innovative treatments from the bench to the clinic, BME has taken on an increasingly important role for evaluating the efficacy of these new therapies. The ultimate goal of nearly all orthopaedic treatments is restoration of movement, and SPRI's state-of-the-art biomotion lab is ideally suited for assessing function of any part of the body.

For SPRI's osteoarthritis studies, BME utilizes 3D motion analysis and force sensors to determine whether a treatment can effectively restore healthy movement patterns during common activities of daily living. For the ACL injury study, the team is using the upgraded DSX system to directly assess ligament function and joint stability. The combination of these advanced whole-body and tissue-level functional assessments with the assessment of biomarkers, collection of patient-reported outcomes and advanced imaging for assessing ligament and cartilage structure provides the most comprehensive evaluation of treatment efficacy available anywhere in the United States. Besides providing definitive evidence of treatment benefits, this rich dataset also guides development of next-generation therapies.

CREATIVE ENGINEERING TO IMPROVE TREATMENT OF ANKLE FRACTURES

Certain types of ankle fractures can be highly debilitating and difficult to treat. The BME robotics team recently conducted a study to evaluate different treatment options for malleolar fractures, which constitute up to 44% of all ankle fractures and are especially challenging.

The team developed a unique 3D printed guide to accurately and repeatably replicate a malleolar fracture pattern. Thanks to this innovative technique, they were able to biomechanically evaluate multiple treatment methods for this previously unstudied injury pattern, including screw fixation, internal brace, and suture button fixation. Using SPRI's robotic arm driven by customized software that simulates natural ankle loading and motion, it was found that the commonly employed suture button fixation did not provide adequate stability, but a combination of screw fixation and an internal brace greatly improved the quality of fixation. This finding was a meaningful step forward in treating patients with malleolar fractures, as the best method for treating this injury was previously unknown.

CENTER FOR OUTCOMES-BASED ORTHOPAEDIC RESEARCH

FACULTY AND STAFF

GRANT DORNAN, MS
DIRECTOR

KAREN BRIGGS, MBA, MPH
DIRECTOR OF HIP RESEARCH

LAUREN PIERPOINT, PHD
HIP RESEARCH MANAGER, 2018–2021

HEATHER GILMAN, PA-C
HIP RESEARCH MANAGER

MARILEE HORAN, MPH
UPPER EXTREMITY RESEARCH COORDINATOR

LAUREN MATHENY, PHDC
FOOT AND ANKLE RESEARCH COORDINATOR

ASHLEY PERRIGAUD
DATA COLLECTION COORDINATOR

SPENCER COMFORT
RESEARCH ASSISTANT

HANNAH DAY
RESEARCH ASSISTANT

BRYANT ELRICK
RESEARCH ASSISTANT

JARED HANSON
RESEARCH ASSISTANT

MAITLAND MARTIN
RESEARCH ASSISTANT

ANNALISE PEEBLES
RESEARCH ASSISTANT

LIAM PEEBLES
RESEARCH ASSISTANT

RICKY POULTON
RESEARCH ASSISTANT

DYLAN RAKOWSKI
RESEARCH ASSISTANT

CHRISTY RUTLEDGE
RESEARCH ASSISTANT

RUI SOARES
RESEARCH ASSISTANT

THOMAS WOOLSON
RESEARCH ASSISTANT

THE CENTER FOR OUTCOMES-BASED ORTHOPAEDIC RESEARCH (COOR) IS SPRI'S LONGEST STANDING DEPARTMENT. THE COOR TEAM HAS BEEN TRACKING AND STUDYING PATIENT OUTCOMES FOR THIRTY YEARS AND IS NOW TRACKING NEARLY 45,000 SURGERIES IN THE COOR DATABASE. THE TEAM HAS COLLECTED OVER 170,000 SUBJECTIVE PATIENT QUESTIONNAIRES AND HAS NEARLY 140,000 UNIQUE PATIENTS INCLUDED IN THE DATABASE.

COOR is the longest standing orthopaedic outcomes database in the world. By tracking patients' outcomes following their treatments, the team is able to validate the efficacy of techniques, therapies and other treatments. Physicians from The Steadman Clinic can use the database to aid in diagnosis and treatment selection, as well as offer patients recovery expectations based in concrete data. A key element of COOR's research is producing long-term outcomes studies, including studies on the pioneering techniques of SPRI's Founder, Dr. J. Richard Steadman and Chairman, Dr. Marc J. Philippon.

Central to the principle of team science, COOR is an important part of all of SPRI's clinical trials and integral in the publication of SPRI's papers. The outcomes data supports The Steadman Clinic's mission of practicing medicine based in research, and physicians from all over the world look to COOR's evidence-based medicine research to inform their clinical decision making.

COOR works closely with SPRI's partner the U.S. Olympic & Paralympic Committee (USOPC) and has been instrumental in organizing the past five Injury Prevention Symposium events. This annual event brings top scientists, researchers and clinicians from all over the world to engage on topics related to injury prevention and protecting athlete health.

44,777
SURGERIES
BEING
TRACKED

174,353
SUBJECTIVE
PATIENT
QUESTIONNAIRES
RECORDED

94,076
OBJECTIVE
CLINICAL
EXAMS
DOCUMENTED

19,510
MRIS
INTERPRETED

139,785
UNIQUE
PATIENTS
INCLUDED
IN DATABASE

PUBLICATIONS

- **112** COOR primary publications since July 2019
- **51** publications utilizing Patient Outcomes Database
- **63%** of SPRI's publications since 2019 included a COOR author
- **86%** of COOR primary publications were performed in conjunction with the Clinical Fellows and/or International Scholars

KEY HIGHLIGHTS

- For the second consecutive year, COOR organized SPRI's virtual Injury Prevention Symposium with partner the U.S. Olympic & Paralympic Committee, hosting the event from the USOPC Headquarters in Colorado Springs
- At the end of 2020, COOR completed its largest database upgrade since 2011, implementing state-of-the-art data science tools and improving the technology that supports data capture and clinical research at SPRI/The Steadman Clinic
- As SPRI has added more clinical trials to its programming, COOR has participated in all trials, offering the support of study design, data collection and statistical analysis
- Coor's legacy of impactful clinical research garnered major honors by the peer-reviewed journal of *Arthroscopy*:

SPRI Chairman Dr. Marc Philippon named author of most influential arthroscopy paper of all time (2020)

SPRI named most prolific publisher among the 100 most-cited articles in the field of arthroscopy (5% of articles) and Dr. Philippon was the most prolific first author (2021)

INTERNATIONAL OLYMPIC COMMITTEE (IOC)-FUNDED RESEARCH:

CRIMP PROGRAM TAKES SPORT CLIMBING TO NEW HEIGHTS

A SPORT WITH GLOBAL ATTENTION

For decades, sport climbing—also referred to as rock climbing—has been a competitive sport governed by the International Federation of Sport Climbing (IFSC). With rapid growth and worldwide exposure, Sport Climbing debuted as an Olympic Sport at the Olympic Games Tokyo 2020, held in 2021 following a COVID-19-related delay.

With sport climbing's popularity and growing interest—there are over 500 sport climbing gyms and more than 5,000 competitive youth climbers across the United States—scientists and researchers at SPRI saw an opportunity to leverage SPRI's outcomes database expertise to intersect with the sport. SPRI launched the Climbing-Related Injury Monitoring and Prevention (CRIMP) program, which began beta testing in February 2021. SPRI was awarded a grant from the International Olympic Committee (IOC) to study the injuries suffered in the sport and ultimately work toward preventing pervasive climbing injuries from occurring.

The Principal Investigator of the grant is Lauren Pierpoint, PhD, a sports injury epidemiologist and hip researcher at SPRI. The study is conducted in partnership with the University of Utah—SPRI and the University of Utah have partnered with the U.S. Olympic & Paralympic Committee (USOPC) as the United States Coalition for the Prevention of Illness and Injury in Sport. Through research and medical advancements, the Coalition aims to protect and preserve the health of athletes. The CRIMP surveillance system is a clear fulfillment of the Coalition's mission.

PUTTING THE SYSTEM IN PLACE

Based in strong epidemiological principles, CRIMP is an extensive injury surveillance system that involves continued planning and collaboration with key stakeholders. A multi-institutional collaboration, CRIMP has several United States-based teams enrolled in the beta testing of the program.

A designated reporter on each team volunteers injury and participation data from their teams, working to build up the database with key metrics that will help SPRI understand denominator data—the volume of training and competition during which opportunity for injuries arise. After capturing the initial months of data, CRIMP will refine its processes and look to a national expansion with its partner USA Climbing.

TOKYO AND BEYOND

The Olympic Games Tokyo 2020 was an important opportunity for CRIMP—the team captured injury information from the games—the first Olympic Games for the sport—as it continued to build out its database. Immediately following the Summer Games, the competitive climbing season began, providing more surveillance needs for athletes. The team will be able to compile a full season of data from elite competitions, capturing all participants and injuries reported from each team. With a year of full competition data, CRIMP will be able to begin extrapolating from the data to develop injury prevention protocols for climbers.

THE FUTURE OF CRIMP

The goal of the CRIMP system is to identify injury problems in sport climbing to develop an injury prevention program based in evidence. In identifying patterns in the way injuries occur, the team can create programs to help prevent many of these injuries from occurring.

The FIFA 11+ program is a warm-up soccer program that has been adopted worldwide to help prevent injuries. It has shown to reduce soccer injuries by 30%, showing that a successful injury prevention program can have meaningful results. In sport climbing, where there is little existing research into injury prevention in the sport, the CRIMP system is a novel approach that can make significant impact in a sport with growing interest and exposure.



ELITE YOUTH SKI RACERS PILOT INJURY PREVENTION PROGRAM WITH SPRI

A NATURAL CONNECTION TO SNOW SPORTS

SPRI and its clinical partner The Steadman Clinic are headquartered in Vail, Colorado—one of the largest and most-visited ski resorts in North America. Both organizations have a longstanding relationship with skiing and snow sports, from treating recreational skiers to members of Team USA. SPRI’s founder Dr. J. Richard Steadman served as Chief Physician for the U.S. Ski Team in the 1970s, and two of The Steadman Clinic’s current physicians—Dr. Randy Viola and Dr. Tom Hackett—serve as head team physicians for the U.S. Ski and Snowboard teams. The organization also has close ties to the U.S. Ski and Snowboard Association, as Dr. Marc Philippon serves on the board and Dr. Peter Millett serves as an ambassador. Many of the clinic’s physicians and sports medicine MD fellows volunteer their time to travel to ski races around the world to provide medical coverage for these athletes, and the clinic’s Dr. David Koppersmith was recently named Head Internal Medicine Physician for the U.S. Ski and Snowboard teams.

With locations in Vail, Frisco, Edwards and Aspen, Colorado, The Steadman Clinic treats many skiing- and snowboarding-related injuries, from acute injuries to chronic conditions.

FILLING IN A SCIENTIFIC EVIDENCE GAP

Alpine ski racing has one of the highest injury rates among winter sports, and tracking this information is relatively new. Prior to the formation of the Fédération Internationale de Ski Injury Surveillance System (FIS ISS) in 2006, there was limited data or literature regarding injuries in the sport. Now studies have shown staggering injury statistics including a 2017 study in *Sports Medicine* that reported an injury incidence of 36.7 injuries per 100 World Cup athletes per season. Of ski racing-related injuries, 68% are lower body injuries, and 35.6% occur in knee ligaments. Most knee injuries impact the anterior cruciate ligament (ACL).

Interest in injury prevention in ski racing has grown, but the majority of studies have focused on World Cup and National Team athletes—there has been little focus on youth alpine skiers. As a result, SPRI researchers saw an opportunity to fill a gap of scientific evidence to focus on preventing injuries in youth alpine racers with the Snow-sport Lower extremity Injury Prevention program (SLIP).



An athletic training resident conducts a physical for a VSSC participant

SPORT-SPECIFIC TRAINING PROTOCOLS

In order to make an effective Injury Prevention Program, SPRI’s team—including Chief Medical Officer and Medical Director of Vail Ski and Snowboard Club (VVSC) Dr. Peter Millett, Director of Athletic Training Brandie Martin and COOR researchers Marilee Horan and Thomas Woolson—partnered with VSSC to conduct injury surveillance in the program’s athletes and develop sport-specific warm-up regimens for the athletes to perform before and during training to reduce and prevent injuries. This includes a pre-training warm-up (about eight minutes long) and two exercises performed prior to each ski run during training. The goal of the program is to not only prevent injuries, but to also specifically reduce injuries caused by overuse, and subsequently reduce the amount of time athletes lose during injury and recovery.

Each winter season, the VVSC trainers implement the SLIP protocols and report any injury data to the SPRI team. The SPRI researchers compile and analyze the injury surveillance data, which the team hypothesizes will show a decrease in injuries and a reduction in the severity of injuries in the skier population.

A LARGER IMPACT

As alpine ski racing is a global sport, a successful injury prevention program in youth ski racers could expand to other ski programs around the world, much like the FIFA 11+ soccer injury prevention program is utilized worldwide. Keeping elite youth athletes healthy and active in their sports also prolongs their competitive careers. Based on the results of the SLIP Program, the SPRI team plans to continue developing sport-specific injury prevention programming.

Outcomes After Arthroscopic Rotator Cuff Repair in Aging Athletes

ROTATOR CUFF INJURY DISPROPORTIONATELY AFFECTS OLDER PATIENTS

Rotator cuff injury is a significant clinical problem that accounts for 30% of all visits to orthopaedic surgeons and is the most common cause of shoulder disability in older patients—40% of individuals over the age of 60 experience rotator cuff injury. Rotator cuff tears can cause severe pain, disability and activity limitations, making their impact significant on the quality of life for these patients.

To investigate further, SPRI investigated mid-term outcomes following arthroscopic rotator cuff repair in recreational athletes over 70 years old—a population that is sparsely reported on in literature. The study evaluated minimum five-year outcomes following the arthroscopic repair of full thickness rotator cuff tears in recreational athletes aged at least 70 years at the time of surgery.

OUTCOMES DEMONSTRATE POSITIVE RESULTS

To conduct the study, data was collected prospectively and retrospectively reviewed: 68 shoulders (64 patients) were included in the study, featuring a mean age of 73.4 years at the time of repair and 80.4 years at the time of follow up. All of the postoperative outcomes measures demonstrated significant improvements when compared to the patients' preoperative baselines.

As recreational athletes were investigated in the study, the COOR team focused on whether or not the patients returned to their pre-injury/pre-repair fitness level. Even though the mean age at follow-up was over 80 years, more than 75% of patients were able to remain physically active with more than half (57%) resuming a higher level of sports activity than before their surgery and 22% returning to an improved, albeit modified, fitness program.

In reviewing the mid-term outcomes following arthroscopic rotator cuff repair in recreational athletes over the age of 70 years, the team determined that the repair was highly effective in reducing pain, improving function and allowing patients to remain active.

OUTCOMES VALIDATE TREATMENT SELECTION

Physicians and researchers study patient outcomes to validate the efficacy of treatments and techniques. With the ultimate goal to help keep people active as they age, SPRI's investigation of surgical outcomes after arthroscopic rotator cuff repair indicates not only that the treatment selection was appropriate and patients reported successful outcomes, but also that conducting retrospective studies is an integral component to practicing evidence-based medicine.



DEPARTMENT OF IMAGING RESEARCH

FACULTY AND STAFF

CHARLES HO, MD, PHD
CO-DIRECTOR

SCOTT TASHMAN, PHD
CO-DIRECTOR

CARLY LOCKARD
SENIOR RESEARCH ENGINEER

MADELEINE DECLERCQ
RESEARCH ASSISTANT

SHANKAR KAUSHAL
RESEARCH ASSISTANT

AMELIA KRUSE
RESEARCH ASSISTANT

SPRI'S DEPARTMENT OF IMAGING RESEARCH DEVELOPS, EVALUATES AND VALIDATES NONINVASIVE IMAGING TECHNIQUES WITH AN EMPHASIS ON MUSCULOSKELETAL HEALTH. IMAGING RESEARCH COMPLEMENTS AND ENHANCES THE CLINICAL RELEVANCE OF RESEARCH CONDUCTED BY THE OTHER SPRI DEPARTMENTS AND PROVIDES CRITICAL NON-INVASIVE OBJECTIVE MEASUREMENTS OF TISSUE HEALTH THAT ARE BEING USED AS PRIMARY AND SECONDARY MEASURES IN SEVERAL ONGOING FEDERALLY FUNDED CLINICAL TRIALS THAT ARE TAKING PLACE AT SPRI.

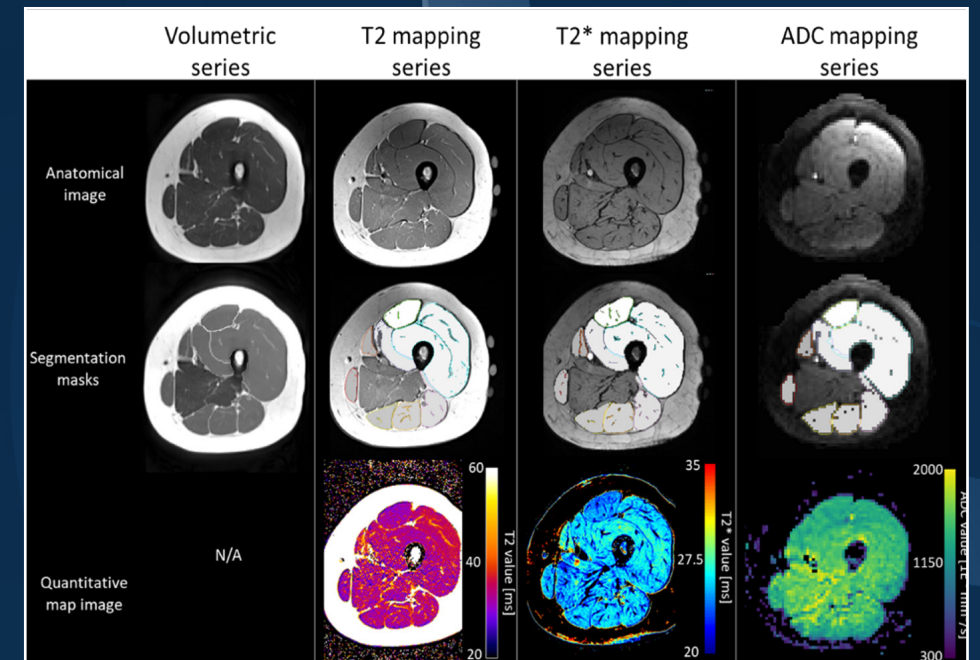
The Imaging Research team is committed to performing leading-edge research with its state-of-the-art Siemens MAGNETOM Skyra and Canon Vantage Galan 3.0 Tesla magnetic resonance imaging (MRI) scanners in Vail and Frisco, Colorado while applying imaging tools to improve patient outcomes. Both 3T MRI scanners provide significantly higher resolution images at a greater speed than with lower field strength scanners, allowing more accurate evaluation of injuries with shorter patient MRI exams.

The high-quality imaging provided by these 3T MRI scanners, along with innovative sequences and industry sponsorship collaborations with both Siemens and Canon, allow advanced research work with cutting-edge MRI techniques and optimal research data quality.

Imaging Research is a multifaceted department, assisting SPRI's other research departments and The Steadman Clinic physicians with developing improved non-invasive techniques for diagnosis, treatment planning and monitoring, and patient recovery evaluation. The department's primary goal is to develop imaging-based tools for comprehensive understanding of each specific patient's injuries and tissue health, allowing precise, optimized treatment.

KEY HIGHLIGHTS

- Imaging Research initiated its first of several Canon-sponsored studies in 2019. The results from the first completed Canon-supported study, which looked at a method for using deep-learning artificial intelligence to allow accelerated collection of high-quality images, were presented at the 2021 International Society for Magnetic Resonance in Medicine annual meeting. This advanced image acquisition and processing technique will result in better quality MRI scans for improving diagnosis of complex musculoskeletal conditions while reducing time spent by patients in the MRI magnet.
- Muscle health is critical to day-to-day and athletic function and to recovery from non-operative and operative treatment such as knee surgery. Muscle atrophy and weakness are some of the greatest contributors to impaired function after procedures for age-related disorders such as total joint replacement and rotator cuff repair. Assessing the nature and extent of muscle disorders has, however, been a significant challenge. SPRI has been working with our industry partner Siemens to adapt advanced MRI techniques originally developed for imaging the brain and organs such as the liver for quantitative assessment of muscle health. The first results of this collaboration were presented in February of 2021 at the annual Orthopaedic Research Society meeting. These results and methods will be used in future SPRI research on muscle health changes with injury and other orthopaedic disorders, as well as for assessing the efficacy of rehabilitation and regenerative medicine treatments for improving muscle health.



An example of quantitative imaging scans of thigh musculature, multiple imaging sequences

- Imaging Research contributed to several collaborative studies with SPRI's BME and COOR departments in the areas of foot/ankle, shoulder, hip and spine research, leading to publications in high-impact journals including *Cartilage*, *Foot and Ankle International* and the *American Journal of Sports Medicine*.
- Imaging Research's quantitative MRI methods and expertise have been incorporated into several ongoing multi-year, federally funded clinical trials to allow non-invasive, precise measurement of changes in tissue health within cartilage, ligaments and other tissues in the knee and hip. The ability to obtain precise measurements through non-invasive methods will be instrumental in detecting treatment-related changes and comparing different treatment groups.

AWARDS

The *Journal of Experimental Orthopaedics* Young Researcher Award was awarded to former Imaging Research team member Katherine (Wilson) Carter and coauthors in Spring of 2020, including current SPRI Imaging Research staff, for our 2019 *Journal of Experimental Orthopaedics* paper entitled "Quantitative mapping of acute and chronic PCL pathology with 3T MRI: A prospectively enrolled patient cohort," re-printed in the *JEO* May 2020 Special Issue.

ABSTRACTS AND PUBLICATIONS

7 CONFERENCE ABSTRACTS
4 PUBLICATIONS

DEPARTMENT OF EDUCATION

FACULTY AND STAFF

MARC J. PHILIPPON, MD

CHAIRMAN, STEADMAN PHILIPPON RESEARCH INSTITUTE
CO-DIRECTOR, SPORTS MEDICINE FELLOWSHIP; CO-DIRECTOR,
HIP PRESERVATION & RECONSTRUCTION FELLOWSHIP

MATTHEW T. PROVENCHER, MD, MBA

CO-DIRECTOR, SPORTS MEDICINE FELLOWSHIP

JOEL M. MATTA, MD

CO-DIRECTOR, HIP PRESERVATION &
RECONSTRUCTION FELLOWSHIP

C. THOMAS HAYTMANEK JR, MD

DIRECTOR, FOOT & ANKLE FELLOWSHIP

TOM R. HACKETT, MD

FACULTY, SPORTS MEDICINE FELLOWSHIP

PETER J. MILLETT, MD

FACULTY, SPORTS MEDICINE FELLOWSHIP

ARMANDO F. VIDAL, MD

FACULTY, SPORTS MEDICINE FELLOWSHIP

LESLIE B. VIDAL, MD

FACULTY, SPORTS MEDICINE FELLOWSHIP

JONATHAN A. GODIN, MBA, MD

FACULTY, SPORTS MEDICINE FELLOWSHIP

ERICA LUPIEN

FELLOWSHIP PROGRAM COORDINATOR

FELLOWSHIPS AND SCHOLARSHIPS DEFINE EDUCATIONAL PROGRAMMING AT SPRI

CLINICAL FELLOWSHIPS

SPRI's Department of Education is focused on educating tomorrow's orthopaedic leaders. Each year, SPRI hosts orthopaedic surgeons following their residency programs for a one-year intensive at SPRI and The Steadman Clinic. These programs include the ACGME-accredited Sports Medicine Fellowship, Foot & Ankle Fellowship and Hip Preservation & Reconstruction Fellowship. Over the past two years, SPRI has hosted 16 sports medicine fellows, four foot & ankle fellows and two hip preservation & reconstruction fellows. These physicians work with attending faculty from The Steadman Clinic and each of SPRI's research teams to have a comprehensive clinical fellowship that is based in research and the practice of evidence-based medicine.

The clinical fellowship alumni network now includes over 230 surgeons practicing in communities around the world. These alumni often hold academic positions at leading universities, maintain chief positions at hospitals and work at elite practices. Several of the programs' former fellows have been recruited back to The Steadman Clinic as physicians, including Drs. Randy W. Viola, Peter J. Millett, C. Thomas Haytmanek, Jr, Jonathan A. Godin, Jared T. Lee and Joseph J. Ruzbarsky. Three of these former fellows now serve on the faculty for these clinical fellowships—Drs. Millett, Haytmanek and Godin.

INTERNATIONAL SCHOLARSHIPS

SPRI is proud to host international physicians and scientists each year to participate in research and learn from SPRI's renowned scientists. As practicing surgeons in their native countries, these scholars focus on research while at SPRI and observe The Steadman Clinic's attending physicians. Over the past two years, SPRI has hosted 5 international scholars from Japan, Germany and Norway.

The goal of both the fellowships and scholarships is to provide a comprehensive, immersive education experience for surgeons during their time in Vail. They are able to participate in research in their areas of interest, from biomechanics and biologics to clinical outcomes research. Fellows and scholars work closely with surgeons and scientists, refining their orthopaedic skills in the Surgical Skills Laboratory. They investigate the causes, prevention and cures of degenerative diseases alongside the treatment and prevention of joint injuries. When they complete their time in Vail, these fellows and scholars go on to practice orthopaedic and sports medicine care that is backed in research, ensuring that patients around the world have the opportunity to receive the best evidence-based medical care for their needs.

2019-2020 CLINICAL FELLOWS

SPORTS MEDICINE FELLOWS



Justin Arner, MD
Undergraduate: Shepherd University
Medical School: West Virginia University
Residency: University of Pittsburgh Medical Center



Michael Ciccotti, MD
Undergraduate: Yale University
Medical School: Jefferson Medical College
Residency: Jefferson Medical College/Rothman Institute



Joseph Cooper, MD
Undergraduate: Washington University in St. Louis
Medical School: University of Illinois College of Medicine
Residency: University of Southern California



Daniel Haber, MD
Undergraduate: Brigham Young University
Medical School: Dartmouth Medical School
Residency: Harvard Combined Orthopaedic Residency Program



Adam Johannsen, MD
Undergraduate: University of St. Thomas
Medical School: University of Minnesota
Residency: Stanford Hospital and Clinics



T.J. Ridley, MD
Undergraduate: Gustavus Adolphus College
Medical School: University of Iowa
Residency: University of Minnesota



Joseph Ruzbarsky, MD
Undergraduate: University of Pennsylvania
Medical School: University of Pennsylvania
Residency: Hospital for Special Surgery



Max Seiter, MD
Undergraduate: University of Texas at Austin
Medical School: University of Texas Southwestern Medical Center
Residency: University of Miami/Jackson Memorial Hospital

FOOT & ANKLE FELLOWS



Marissa Jamieson, MD
Undergraduate: Rice University
Medical School: University of Texas Southwestern Medical Center
Residency: The Ohio State University



Katie Bartush, MD
Undergraduate: Southern Methodist University
Medical School: University of Texas Health Science Center San Antonio
Residency: University of Texas Health Science Center San Antonio
Fellowship: Andrews Sports Medicine Fellowship Program

HIP PRESERVATION & RECONSTRUCTION FELLOW



Timothy Beals, DO
Undergraduate: University of Illinois Urbana-Champaign
Medical School: Midwestern University Chicago College of Osteopathic Medicine
Internship: Good Samaritan Regional Medical Center
Residency: University of Texas Health Science Center San Antonio

SPORTS MEDICINE FELLOWS



Aaron Casp, MD
Undergraduate: Princeton University
Medical School: University of North Carolina
Residency: University of Virginia



Justin Ernat, MD, MS, FAAOS
Undergraduate: Illinois Wesleyan University
Medical School: The Chicago Medical School at Rosalind Franklin University
Residency: Tripler Army Medical Center



Jordan Gruskay, MD
Undergraduate: Amherst College
Research Fellowship: Rothman Orthopaedic Institute
Medical School: Yale University School of Medicine
Residency: Hospital for Special Surgery



Donovan W. Johnson, MD
Undergraduate: Eastern Illinois University
Medical School: Georgetown University
Residency: Tulane University



Simon Lee, MD, MPH
Undergraduate: University of Illinois Urbana-Champaign
Graduate: Columbia University
Medical School: University of Illinois at Chicago
Residency: University of Michigan



Ravi Patel, MD
Undergraduate: University of Michigan
Medical School: Rush University
Residency: Henry Ford Health System



Stephanie Pearce, MD
Undergraduate: University of Florida
Medical School: University of South Alabama
Residency: University of South Alabama
Pediatric Orthopaedic Fellowship: Children's Hospital Colorado



Robert Waltz, MD
Undergraduate: United States Naval Academy
Medical School: Uniformed Services University
Surgical Internship: Naval Medical Center San Diego
Residency: Naval Medical Center San Diego

FOOT & ANKLE FELLOWS



Courtney Quinn, MD
Undergraduate: University of Southern California
Medical School: Georgetown University
Residency: Temple University
Sports Medicine Fellowship: University of Virginia Health System



Michael Perrone, MPH, MD
Undergraduate: University of Florida
Graduate: University of Florida
Medical School: University of South Florida
Residency: University of Chicago
Sports Medicine Fellowship: Kerlan-Jobe

HIP PRESERVATION & RECONSTRUCTION FELLOW



Joseph Ruzbarsky, MD
Undergraduate: University of Pennsylvania
Medical School: University of Pennsylvania
Residency: Hospital for Special Surgery
Sports Medicine Fellowship: Steadman Philippon Research Institute



Naomasa Fukase, MD, PhD
Medical School: Kobe University Graduate School of Medicine
Internship: Kobe University Hospital
Post-Graduate: Kobe University Graduate School of Medicine
Japan



Kathrin K ppler, MD
Medical School: Charit  – University Berlin
Residency: Orthopaedic Surgery & Traumatology, University of Heidelberg
Germany



Kaare Midtgaard, LTC, MD
Medical School: University of Bergen
Residency: Namsos Community Hospital/Oslo University Hospital
Post-Graduate: University of Oslo
Norway



Philip-Christian Nolte, MD, MA
Medical School: Johannes-Gutenberg University
Graduate: SRH University Riedlingen
Residency: Bad Duerkheim Hospital
Germany



Yoichi Murata, MD, PhD
Medical School: University of Occupational and Environmental Health, School of Medicine
Internship: Saiseikai Yahata General Hospital
Post-Graduate: University of Occupational and Environmental Health, School of Medicine
Japan



Ingrid Kvello Stake, MD
Medical School: University of Oslo
Residency:  stfold Hospital
Norway



Anna Tross, MD
Medical School: Johannes-Gutenberg University
Residency: German Joint Center, ATOS Clinic Heidelberg
Germany



Dr. Armando Vidal oversees Fellow Dr. Justin Arner in the Surgical Skills Lab



A New Opportunity for Graduate Students

With collaborator Colorado State University (CSU), SPRI has piloted a unique experience for graduate students. Under CSU's School of Biomedical Engineering (SBME)—a top-ranked BME program—SPRI is hosting Anna Laura Nelson, PhD student, providing her with exposure to the world-class surgeons from The Steadman Clinic, the opportunity to participate in clinical trials research and earn her PhD while on the forefront of translational medicine.

Partnering with CSU—which also has a healthy aging program and the top-ranked veterinary school in the nation—provides SPRI faculty access to core facilities and preclinical laboratories. SPRI's CRPM team has a lab close to the CSU campus, providing additional collaborative opportunities for the institutions.

The new graduate opportunity is a pioneering translational medicine experience. Sponsored by philanthropy, Anna Laura's project centers around promoting fracture healing in an elderly population, using an mRNA therapy—similar to the technology used in the COVID-19 vaccine. As part of the CSU and SPRI pilot opportunity, Anna Laura has mentors from both organizations—SPRI's Dr. Chelsea Bahney and CSU's Dr. Nicole Ehrhart. Dr. Johnny Huard, SPRI Chief Scientific Officer, chairs her thesis committee. Anna Laura will publish her findings jointly with SPRI and CSU.

Introducing the SPRI Golf Sports Medicine Program

IN JUNE 2021, SPRI ADDED A CUTTING-EDGE SPORT-SPECIFIC PROGRAM TO ITS OFFERINGS—THE SPRI GOLF SPORTS MEDICINE PROGRAM. HOUSED IN THE STATE-OF-THE-ART BIOMOTION LAB, THE PROGRAM IS SUPPORTED BY SOME OF THE MOST ADVANCED MOTION ASSESSMENT TECHNOLOGY IN THE WORLD.

SPRI's Biomotion scientists and researchers utilize the lab's technology to assess motion before, during and after an injury or surgical repair, providing a unique biomechanical profile for each individual. In partnership with the U.S. Olympic & Paralympic Committee (USOPC), SPRI is dedicated to injury prevention research to help protect athletes from injury, while also refining return-to-sport protocols to help athletes return to their sports following injury or surgery.

The advanced technology in the laboratory and deep skillset of the Biomotion and Biomechanical Engineering scientists, engineers and researchers has enabled the department to develop the unique golf sports medicine program, which is focused on understanding and optimizing an individual's biomechanics while they play. The team outfits participants in small reflective markers on all major body segments to assess movement of the entire body (wrist, elbow, shoulder, trunk, hip, knee, ankle) and uses a leading-edge software platform to analyze the internal biomechanical analysis of the swing. With the addition of a cutting-edge golf simulator in the Biomotion Laboratory and the support of PGA Master Professional Steve Atherton (director of the program), the SPRI Golf Sports Medicine Program provides individuals with the unique opportunity to not only analyze their swing on the outside, but also understand how internal movements contribute to their health and sports performance.

THE TECHNOLOGY: BIOMOTION

SPRI's Biomotion Laboratory is equipped with some of the world's most advanced technology, including a 20-camera, 12-megapixel 1100 frames video motion analysis system, force-sensing platforms (embedded in the floor) and wireless electromyographic sensors for analyzing muscle function. This equipment provides detailed measurement of the kinematics (motion) and kinetics (forces) that generate movement. Combined with the lab's advanced analysis software, the lab can comprehensively assess an individual's biomechanical profile for nearly any activity or sport.

In addition to general assessments of movement quality, the lab software can provide detailed, sport-specific analyses including a specialized module for assessing the biomechanics of the golf swing. This software provides an in-depth view into how an individual's movement may impact their golf swing, providing detailed metrics on swing components such as the kinematic chain, weight transfers and club motion. Applications for these technologies go well beyond simply helping the average golfer improve his or her game. The unique, multidisciplinary team (combining orthopaedic biomechanics experts in the Biomotion lab, the leading orthopaedic surgeons and athletic trainers of The Steadman Clinic, the rehabilitation specialists from Howard Head Sports Medicine at Vail Health and a PGA Master Professional) can use this comprehensive data to guide those recovering from injury or with an underlying orthopaedic condition to improve their physical function and optimize their performance.

THE TECHNOLOGY: GOLF SIMULATOR

The Biomotion technology is complemented by a cutting-edge golf simulator from Foresight Sports. This simulator includes the most advanced and precise launch monitor (the GC Quad), which utilizes infrared object tracking and high-speed, high-resolution camera-based technology to precisely measure every aspect of club head and ball launch performance. By capturing thousands of images per second, building a virtual 3D model and then analyzing a multitude of data components, the technology creates the most accurate and complete picture of ball and club head performance, delivered in nearly real time.

The biomotion measurements can be performed within the golf simulator, providing a unique linkage between the whole-body motion assessment and the resulting ball trajectory. The participant can immediately see the real-world results of changes in swing biomechanics, in terms of both distance and accuracy. This unique combination of technologies ensures that individuals get the full picture of their golf performance, from inside out.

PARTICIPANTS OF THE
SPRI GOLF SPORTS
MEDICINE PROGRAM
ENJOY A
ONE-OF-A-KIND
EXPERIENCE, SUPPORTED
BY CUTTING-EDGE
TECHNOLOGY BACKED BY
A LEGACY OF RESEARCH.



Add the unparalleled graphic technology and simulation experience to the most advanced biomechanical assessments available, and participants of the SPRI Golf Sports Medicine Program enjoy a one-of-a-kind experience, supported by cutting-edge technology backed by a legacy of research.

and learn ways to modify their movement to not only improve performance, but also improve the care of their joints, ligaments and muscles. Participants are surrounded by cutting-edge scientific equipment and work closely with scientists while they participate in this one-of-a-kind experience.

STEVE ATHERTON, PGA



Joining SPRI as Director of the SPRI Golf Sports Medicine Program, Steve Atherton is a PGA Master Professional—one of only 216 nationally. Twice named the Colorado PGA Teacher of the Year (2008, 2019), Steve is an engaging golf teacher with extensive experience in the mechanics of the golf swing. From 2009–2016, Steve was on *Golf Digest's* list of Best Young Teachers in America, and he has published several articles in golf publications including *Golf Digest* and *GOLF Magazine*.

As director, Steve coaches participants of the program, working with their unique biomechanical profile to optimize their swing. Steve will also participate in groundbreaking research on the golf swing, including the effects of injury and surgery on golf performance.

A DISTINCTIVE EXPERIENCE

Participants in the SPRI Golf Sports Medicine Program have the opportunity to optimize their golf performance, whether they are recovering from an injury or intending to maintain their active lifestyle. Backed by science, this program allows individuals to not only see how they move on the outside, but also on the inside,

Performance in any sport or physical activity is fundamentally linked to overall health and wellness. Consistent with The Steadman Clinic and SPRI's mission to keep people active, participants in the golf program will also have the opportunity to participate in SPRI's Healthy Aging program, run by the Linda & Mitch Hart Center for Regenerative and Personalized Medicine (CRPM). This highly innovative program will assess biomarkers related to health status and provide recommendations for improving wellness and extending "healthspan," helping athletes at all levels to stay active with the sports they love.

RESEARCH

Building on SPRI's research legacy with the Center for Outcomes-Based Orthopaedic Research (COOR), The SPRI Golf Sports Medicine Program is developing its own database. Every participant in the program has the opportunity to anonymously submit his or her data to this research database, allowing scientists, engineers and researchers to analyze the biomechanical data from a large pool of individuals. The database can demonstrate the impact of optimization of biomechanics in golf, which could lead to new coaching techniques and strategies for the sport. Combining golf biomechanics data with injury and treatment history data from SPRI's clinical database will provide unique insights into the optimal levels of function that each patient can expect to achieve after injury or surgery, as well as scientifically designed strategies for each individual to return the highest possible level of function.



Dr. Philippon welcomes guests to the 5th Annual Scientific Summit in 2019

THE SUMMIT AND SYMPOSIUM SPARK COLLABORATION

SPRI'S COMMITMENT TO COLLABORATION EXTENDS BEYOND THE TEAM SCIENCE PERFORMED AT THE INSTITUTE—FROM ESTABLISHING RESEARCH NETWORKS TO HOSTING AND CO-HOSTING MAJOR ACADEMIC MEETINGS, SPRI IS DEDICATED TO PARTICIPATING IN IMPORTANT CONVERSATIONS IN ORTHOPAEDIC AND SPORTS MEDICINE SCIENCE AND RESEARCH. THESE EVENTS WELCOME CLINICIANS, SCIENTISTS AND RESEARCHERS FROM ALL OVER THE WORLD TO JOIN IN KEY DISCUSSIONS AROUND TOPICS LIKE REGENERATIVE MEDICINE, THERAPEUTICS, INJURY PREVENTION AND MORE.

Vail Scientific Summit

The 5th Annual Vail Scientific Summit was held August 24–27, 2019 at the Vail Marriott Mountain Resort. The theme of the meeting was “Advances in Regenerative Medicine,” and the presenting sponsor of the event was Canon Medical.

The conference included a keynote on Healthy Aging by Dr. John Cooke of Houston Methodist Research Institute and Dr. James Kirkland of Mayo Clinic, hosted by SPRI's Dr. Johnny Huard. The four-day event included sessions ranging “Sports and Military Performance,” hosted by SPRI Chairman and Managing Partner of The Steadman Clinic Dr. Marc Philippon; bone and muscle regeneration; cartilage, ligament and tendon research; innovative treatments for injuries and more.

As in past years, the summit included presentations from world-renowned physicians, scientists and researchers. Some of these presenters included Dr. Troy Flanagan, Director of Performance for the Milwaukee Bucks, Dr. Mark Markel of University of Wisconsin, Dr. Regis O’Keefe of Washington University in St. Louis, Dr. Scott Bruder of Bruder Consulting, Venture Group and many others. The conference also included presentations from several of The Steadman Clinic’s physicians—Drs. Philippon, Corenman, Evans, Kim and Matta—and SPRI’s scientists—Drs. Huard, Bahney, Ravuri, Lu and Tashman.

The 5th Annual Vail Scientific Summit also included representatives from the National Institutes of Health (NIH), Orthopaedic Research Society (ORS), Naval Medical Research Center and speakers discussing relevant Food and Drug Administration (FDA) regulations.

Due to COVID-19, the 2020 Vail Scientific Summit was postponed, and SPRI looks forward to hosting the return of the summit August 19–22, 2021, presented by Avanos.

INJURY PREVENTION SYMPOSIUM

The 4th and 5th Annual Injury Prevention Symposiums were presented via live webinar due to COVID-19. But despite the virtual format, both the 2020 and 2021 event were enormously successful in their participation. Hosted by SPRI and its partner the U.S. Olympic & Paralympic Committee (USOPC), the Injury Prevention Symposiums were broadcast from the USOPC Headquarters in Colorado Springs.

4th Annual Injury Prevention Symposium

SPRI and the USOPC hosted the 4th Annual Injury Prevention Symposium via webinar on April 29, 2020. SPRI's team included members of the Media and Production Department and the Center for Outcomes-Based Orthopaedic Research (COOR), who collaborated with the USOPC team in Colorado Springs.

Initially hoping for 500 registrants for the web conference, 5,700 people registered for the event, with 4,880 participants tuning into the all-day conference—a more than 85% participation rate. Participants joined the conference from six continents, 36 nations and all 50 United States.

The success of this event demonstrated that despite the impact of COVID-19, scientists, researchers and clinicians were ready to participate in discussions surrounding Injury Prevention.

5th Annual Injury Prevention Symposium

After the success of the year prior, SPRI and the USOPC decided to host the 5th Annual Injury Prevention Symposium virtually, allowing for participants to avoid traveling with COVID-19 restrictions still in place throughout much of the world. This year, the team opted for a two-day virtual web conference, which was held April 28–29, 2021. Twenty-five presenters offered presentations surrounding the current landscape of injury prevention research, including a keynote address from University of Calgary’s Dr. Carolyn Emery.

Topics in the event included return to sport during COVID-19, translating data for injury prevention, clinical perspectives in injury prevention, concussion research, athlete mental health, injury prevention program implementation as well as presentations from Team USA athletes.

More than 400 participants joined the web conference, including 28 international participants from eight countries.

PUBLICATIONS

JULY 2019–JUNE 2021

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2 of 31 labeled trajectories not tracked
RTOE
LTQE

RTOE	100.0%	1-800
LTQE	100.0%	1-800
RWER	100.0%	1-800
RFT	100.0%	1-800
RBAR	100.0%	1-800
RSBH	100.0%	1-800
RONE	100.0%	1-800
RASI	100.0%	1-800
RPHI	100.0%	1-800
RPSI	100.0%	1-800
RPS	100.0%	1-800
RTHI	100.0%	1-800
RPHI	100.0%	1-800
RSPH	100.0%	1-800
RASK	100.0%	1-800
LAKE	100.0%	1-800
LFT	100.0%	1-800
STRN	100.0%	1-800
CLAP	100.0%	1-800
LRNG	100.0%	1-800
RSBH	100.0%	1-800

STEADMAN PHILIPPON RESEARCH INSTITUTE

181 West Meadow Drive, Suite 1000
Vail, Colorado, 81657
970-479-9797, www.sprivail.org

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