

# UMSAEP Final Report

## Pediatric Knee Disorder Consortium – A Partnership between South Africa and the University of Missouri

Submitted by Trent Guess, Associate Professor, and Antonis Stylianou, Associate Professor

### **1. Background**

Sports injuries in pediatric and adolescent populations are increasing in western countries and developing countries are following suit. Many pediatric sports injuries occur at the knee. For example, injury to the anterior cruciate ligament (ACL) in youth sports is common with an injury repeat rate higher than in adults. A lack of knowledge of pediatric knee anatomy and biomechanical understanding of pediatric musculoskeletal structure and development at the knee hinders injury prevention, treatment and rehabilitation. With this preface, experts in the areas of joint biomechanics, computational modeling, statistical treatment and medical imaging created a consortium dedicated to producing a framework for identification, evaluation, and verification of pediatric pathologies pertaining to the knee. This consortium partnered researchers at the University of Missouri, Children's Mercy Hospital, the South African Institutions of the University of Cape Town and Stellenbosch University, and the Laboratory for Medical Information Processing (LaTIM) in Brest, France. As an initial step to accomplishing the consortium goals of improving treatment and prevention of pediatric knee injury, the consortium proposed to use an existing medical imaging data set (magnetic resonance imaging (MRI)) of pediatric knees acquired at Children's Mercy Hospital in Kansas City, MO to produce three-dimensional (3D) geometries of knee anatomy for the purpose of characterizing developing knee anatomy and the resulting implications to pediatric knee biomechanics and injury risk.

### **2. Project Goals**

Funding was requested to enhance this existing pediatric knee MRI data set by segmenting and analyzing MRI for downstream analyses, administering surveys to data base participants, recall subjects for repeat medical imaging, travel to Cape Town, South Africa, and pursue external funding.

### **3. Project Work**

Drs. Guess and Stylianou traveled to Cape Town, South Africa, in March 2019. Details of this trip can be found in the Appendix. Our South African hosts were Tinashe Mutsvangwa, PhD, Division of Biomedical Engineering, University of Cape Town, Cape Town, South Africa, and Johan van der Merwe, PhD, Department of Mechanical

and Mechatronic Engineering, Stellenbosch University, Stellenbosch, South Africa. The primary outcome of our meeting were procedures for segmenting knee MRI that met our goals of analyzing and predicting bone growth and analyzing knee biomechanics. We also developed a plan for pursuing external funding and journal articles. Project communication continued through weekly conference calls. These calls continue. Funding was used to hire students to segment knee MRI into 3D geometries using our agreed upon procedures.

#### 4. Outcomes

This project enabled a collaborative framework for processing and analyzing data related to pediatric knee anatomy. This was a necessary step in segmenting knee MRI in a manner that will enable downstream analyses, particularly machine learning models of pediatric knee growth and computation models of knee biomechanics. From this framework, funding was used to generate appropriate 3D knee geometries (Fig 1). These geometries will be used for analyses that create better understanding of pediatric knee anatomy, knee biomechanics, and the implications of bone growth. Funding from this project was also used to hire graduate and undergraduate students that were trained in processing MRI data and creating 3D geometries. Importantly, this project provided necessary pilot data for an R01 proposal to the National Institute of Arthritis and Musculoskeletal and Skin Diseases. A proposal entitled “*Machine learning models of pediatric knee morphology and bone growth: implications for ACL biomechanics, movement and ACL injury treatment*” was submitted to NIH in October 2020.

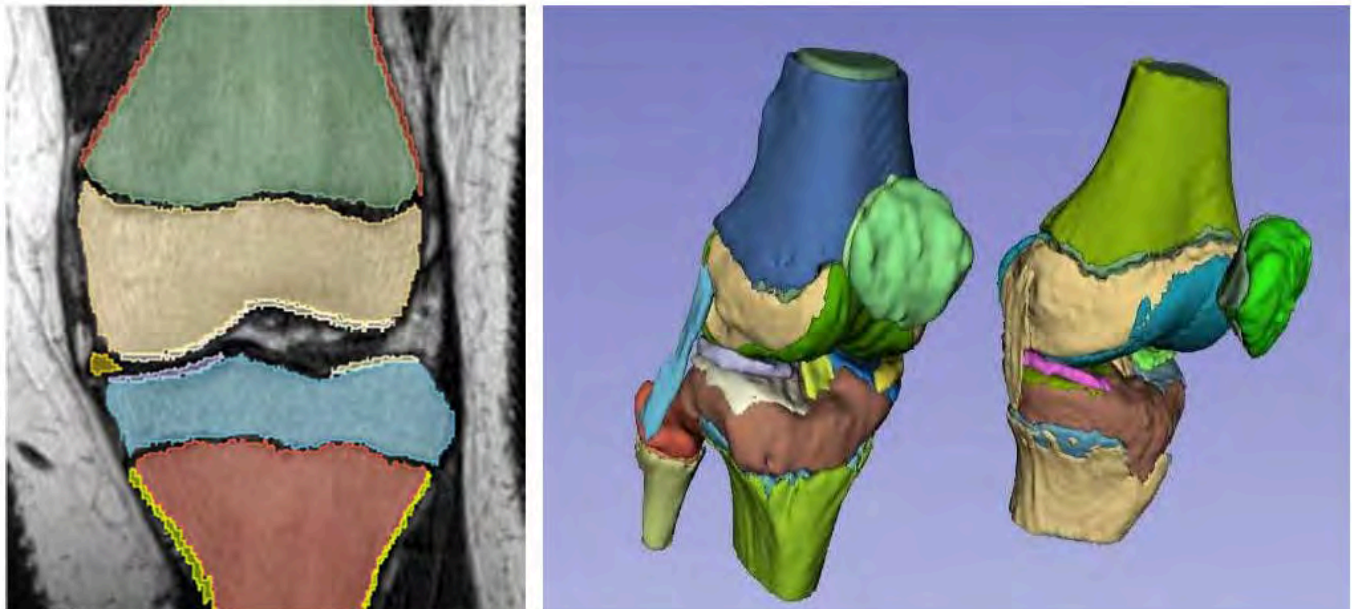


Figure 1: 3D knee geometries created from existing pediatric knee MRI using the developed framework.

The projective narrative of our submitted R01 proposal follows.

Management of anterior cruciate ligament (ACL) injuries in children and adolescents is complicated by skeletal immaturity and treatment is often associated with poor outcomes and high re-injury rates. This proposal will produce individualized information on knee anatomy, predict future bone growth, and relate knee anatomy to ACL biomechanics and motion. The outcomes of this project will enhance the ability of surgeons, trainers, and therapists to provide individualized surgery and rehabilitation strategies that will improve the treatment of pediatric knee injuries.

**Other external funding proposals:**

“A Global Network to Generate Advanced and Cost-Effective Medical Imaging Solutions, Medical Devices, Clinical and Computational Tools for the Treatment of Muscle and Bone Injuries and Diseases” was submitted on April 4<sup>th</sup>, 2019 in response to call H2020-MSCA-RISE-2019. Status: Not funded despite a merit score of 76.4% against the threshold of 70%, due to lack of budgetary resources at our project rank.

“An Integrated Machine Learning and Computational Modeling Framework to Diagnose, Classify, and Evaluate Knee Joint Biomechanics for the Treatment of Pediatric Knee Disorders” was submitted on March 5<sup>th</sup>, 2109 to the FACE Foundation (Thomas Jefferson Fund). Status: Not funded.

**Journal Articles:**

“Knee Morphology in the Adolescent Female.” In process. In this work, we characterize 12 morphological measures of the tibia and femur associated with ACL injury risk using two raters and repeated measures. Measurements were conducted on MRI of 34 females aged 13 – 18 years. A comprehensive examination of knee morphologies associated with ACL injury for early adolescent and adolescent populations would increase knowledge of their prevalence, aiding efforts in injury prevention, ligament reconstruction and rehabilitation for this population.

**Appendix**

Visit to Cape Town and Stellenbosch, South Africa, March 2 -10, 2019 by Trent Guess, Associate Professor, and Antonis Stylianou, Assistant Professor

Hosts: Tinashe Mutsvangwa, PhD, Division of Biomedical Engineering, University of Cape Town, Cape Town, South Africa, and Johan van der Merwe, PhD, Department of Mechanical and Mechatronic Engineering, Stellenbosch University, Stellenbosch, South Africa

The purpose of the meeting was to discuss details for model generation from MRI, to finalize how the segmentation will be performed and what geometries will be extracted, to develop a framework for an external grant proposal, discuss other matters related to the Pediatric Knee Disorder Consortium (PKDC), and to finalize details for submission of a related grant proposal entitled “A Global Network to Generate Advanced and Cost-Effective Medical Imaging Solutions, Medical Devices, Clinical and Computational Tools for the Treatment of Muscle and Bone Injuries and Diseases” in response to call H2020-MSCA-RISE-2019.

March 2 -3

Drs Guess and Stylianou travelled to Cape Town arriving on Sunday March 3<sup>rd</sup>.

Monday, March 4<sup>th</sup>,

We first met with our University of Cape Town (UCT) host Dr. Tinashe Mutsvangwa at UCT and were provided with access badges and office space. We then travelled to the Sports Science Institute of South Africa in Cape Town. The institute is affiliated with the UCT’s Division of Exercise Science and Sports Medicine. We were provided a tour of the facilities, including a tour of their sports oriented gait lab and other research facilities. Our visit included discussions with researchers at the institute including Dr. Alison September who conducts research in the genetic risk factors underlying soft tissue injuries, such injury to the anterior cruciate ligament. Following this tour, we returned to UCT and were given a tour of UCT’s Division of Biomedical Engineering followed by a discussion of the PKDC including consortium member Bhushan Borotikar from the Laboratory for Medical Information Processing , Brest, France, who participated via skype .

Tuesday, March 3<sup>rd</sup>

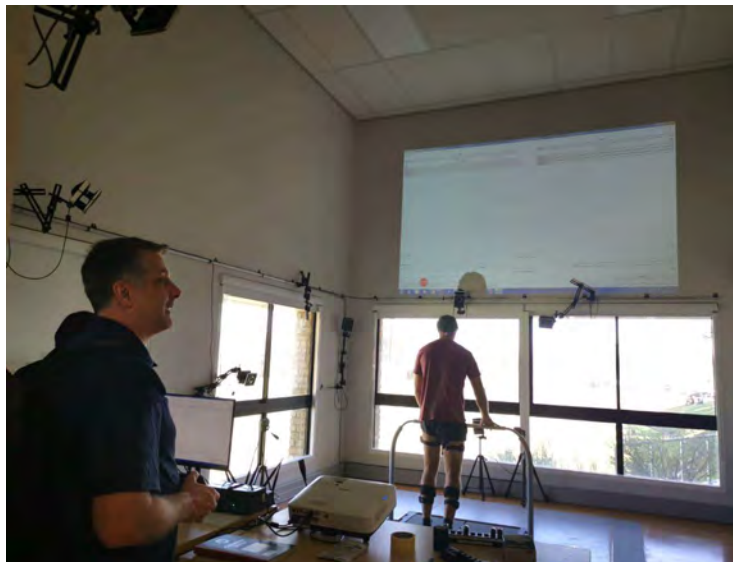
Presentations to UCT’s Division of Biomedical Engineering’s Seminar Series. Dr. Guess’ presentation was titled “Anterior Cruciate Ligament: Injury Risks Factors, Mechanisms, and Prvention. Dr. Stylianous’ presentation was titled “Multibody Models of the Elbow Joint and Orthopaedic Applications”. Following the seminar Drs, Guess, Stylianou, Mutsvangwa, Borotikar, and Merwe discussed the PKDC, and two other grant proposals. These proposals include submission to the Thomas Jefferson Fund titled “An Integrated Machine Learning and Computational Modeling Framework to Diagnose, Classify, and Evaluate Knee Joint Biomechanics for the

Treatment of Pediatric Knee Disorders” submitted on March 5<sup>th</sup>, 2019, and proposal entitled “A Global Network to Generate Advanced and Cost-Effective Medical Imaging Solutions, Medical Devices, Clinical and Computational Tools for the Treatment of Muscle and Bone Injuries and Diseases” submitted to H2020-MSCA-RISE-2019 submitted on April 2<sup>nd</sup> 2019.

Wednesday, March 4<sup>th</sup>

We visited the Neuromechanics lab at Stellenbosch University and received a tour of their facilities including a gait analysis demonstration.

Following the demonstration at the Neuromechanics Lab our Stellenbosch host, Johan van der Merwe, gave us a tour of the Department of Mechanical and Mechatronic Engineering at Stellenbosch University. We then saw student demonstrations for research related to the PKDC. For example, one student was working on a testing machine that simulates loading in cadaver and total knee prosthetics, another student was working on computational knee models. We then drove back to Cape Town to visit the Advanced Orthopaedic Training Centre at Tygerberg Hospital. Following a tour of the facility, we discussed imaging and possible collaborations with orthopaedic surgeons at Tygerberg.



Gait analysis demonstration at the Neuromechanics lab in Stellenbosch South Africa.

Thursday, March 5<sup>th</sup>

We participated in a Student Research Seminar hosted by the Division of Biomedical Engineering and the research lab of Dr. Tinashe Mutsvangwa. Graduate and post-doctoral researchers presented their research work followed by a discussion. The afternoon included another meeting regarding the PKDC and grant proposals.

Friday March 6<sup>th</sup>

On Friday we went on a “team building” hike with our hosts in Jonkershoek Nature Reserve near Stellenbosch.



Hike in Jonkershoek Nature Reserve with Drs. van der Merwe, Mutsvangwa, Stylianou, and Guess.

Friday March 6<sup>th</sup>

Return to Missouri