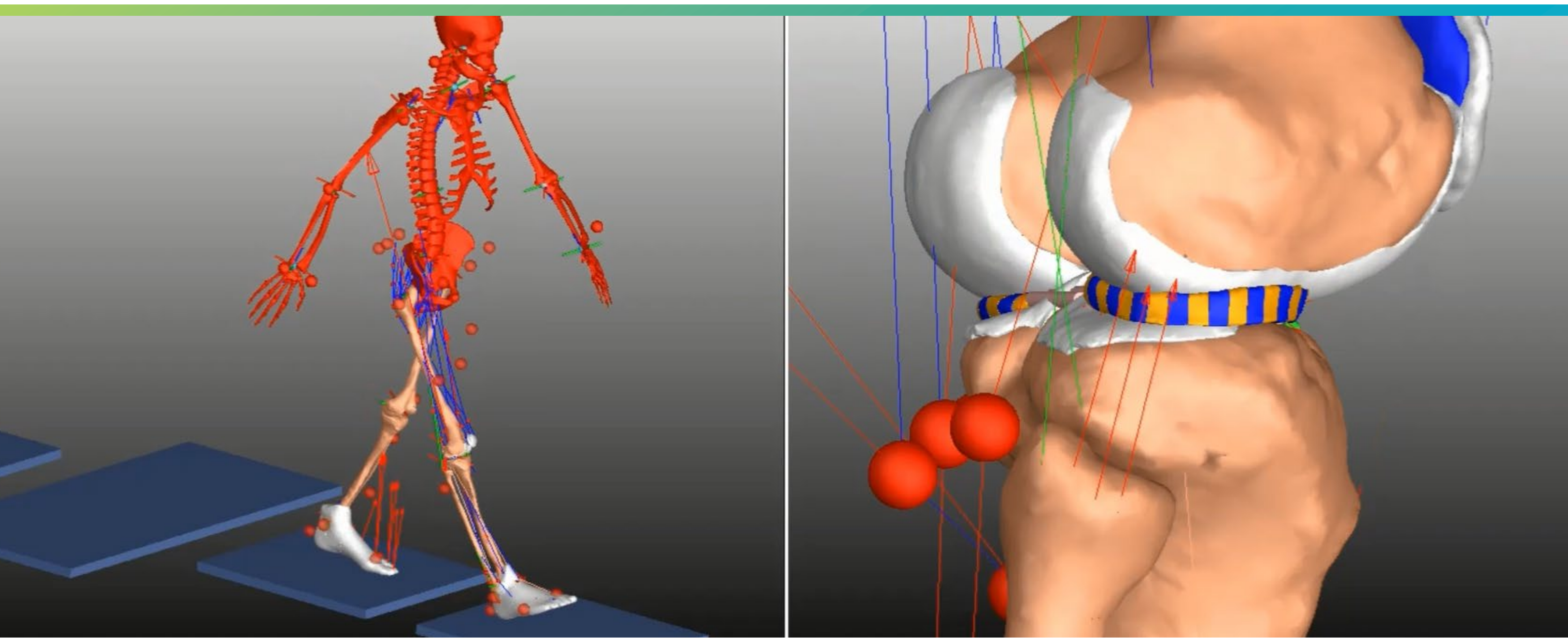
Case study

University of Missouri

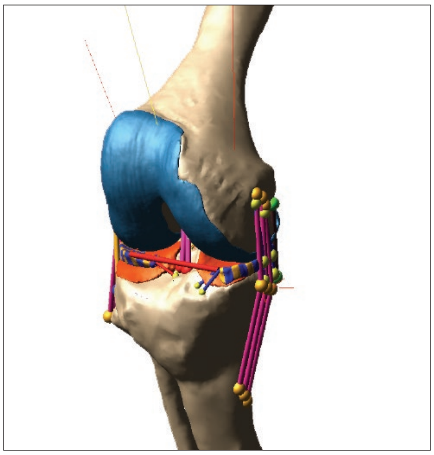
Adams simulations help diagnose knee problems



Introduction

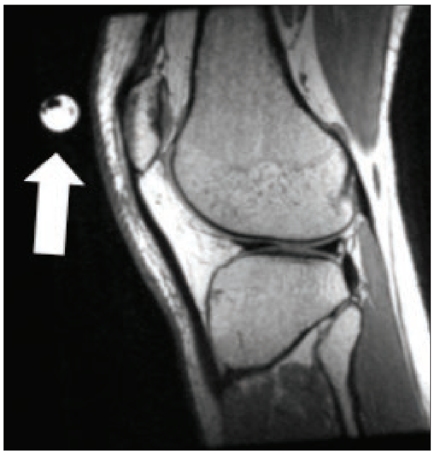
Mankind has explored the galaxies, the depths of the sea, and looked back millions of years into the past. But, there are still some surprisingly large gaps in our understanding of the human body and how it works. For example, the knee joint is at the center of the kinetic chain running from the foot to the pelvis. But the connection between the tibia and femur provides very little geometric constraint. Knee stability is achieved through the operation of a multitude of soft tissue structures.

The details of how these structures work are still largely a mystery. MSC's Adams, a multibody dynamics simulation solution, can provide the right insights to help get a better understanding of the inner workings of the knee.



Bone, Cartilage, and Menisci Adams Model

MRI image of knee and marker (arrow)



MRI image of knee with marker (arrow) visible in MRI and motion capture

Background

Case in point is the role of the menisci. The menisci helps stabilize the knee by creating a cup for the femur to sit in. The menisci also acts as a shock absorber spreading compression forces from the femur over a wider area of the tibia. However there are still many things we still don't understand about the menisci. This is where MSC's Adams come in.

Not long ago, surgeons would routinely remove damaged menisci, but today this is done much less frequently because we know how important they are in maintaining the stability of the knee. However, there are still many things we still don't understand about the menisci. For example, what happens when the ligaments that hold the menisci to the tibia loosen, which often occurs either due to injury or to age? There are a wide range of potential benefits to better understanding of knee biomechanics such as, preventing injury and improving treatment methods.

Researchers at the University of Missouri Mizzou Motion Analysis Center (MAC) recognized that improving our understanding of the menisci would require advancements over traditional analysis methods They needed a multi-body dynamics simulation tool that could replicate muscle driven loading and motion, and had the computing horsepower capacity necessary to model all of the connected components of the knee. Their software tool of choice was Adams.

"Going forward, the potential exists to make substantial advancements in diagnosing knee problems and improving surgical interventions, among other benefits"

Trent Guess,
Associate Professor of Physical Therapy and Orthopedic Surgery, University of Missouri

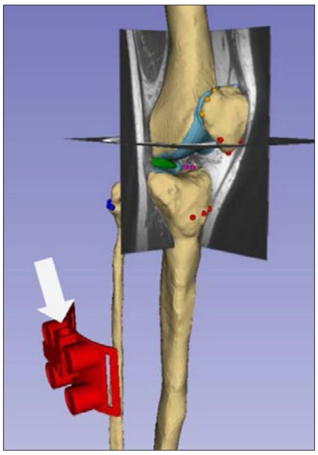
Solution/validation

MAC researchers used Adams multibody dynamics software to develop the most comprehensive and realistic simulation of the knee. They began by outfitting subjects with markers. They used a motion capture system to record the movement of these markers as the subjects walked and moved in the lab. They used Magnetic Resonance Imaging (MRI) to capture images of bone, cartilage, the menisci and ligaments. Force plates were used to measure ground contact forces and EMG measured muscle activation.

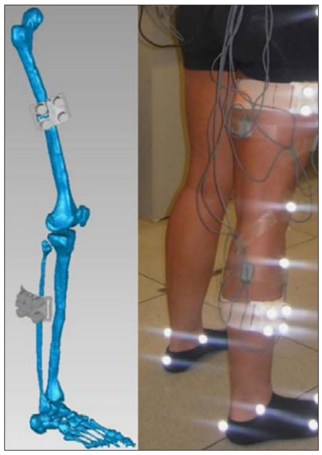
Adams models of each subject's individual internal musculoskeletal system were then created from the data collected. Each model was comprised of 21 rigid body segments, 53 revolute joints and 43 leg muscles. A motion constraint was defined at each marker location and a three axis spring was located between the constraint and the corresponding body segment. This allowed movement of the rigid body bones relative to the motion constraints. The foot-ground interface was modeled by dividing the MRI derived skin geometry into five rigid bodies. Deformable contacts were defined between each of these bodies and the floor.

Capturing this experimental motion data provides kinematic input for a step with the motion constraints moving the model. The model was constrained by the defined joints, as well as by contact and ligament forces at the knee and ground contact forces. To determine muscle forces and knee loading during movment, a forward dynamics simulation was performed that predicted contact forces between the elements of the knee such as the tibia to menisci and tibia to femur as well as forces on knee ligaments, such as the anterior cruciate ligament (ACL). In the forward dynamics simulation, Adams capability of integrating data with Simulink was critical in creating an accurate simulation of the knee. The back and forth communication between Adams and Simulink allowed researchers to gain critical insights that were crucial in the simulation process.

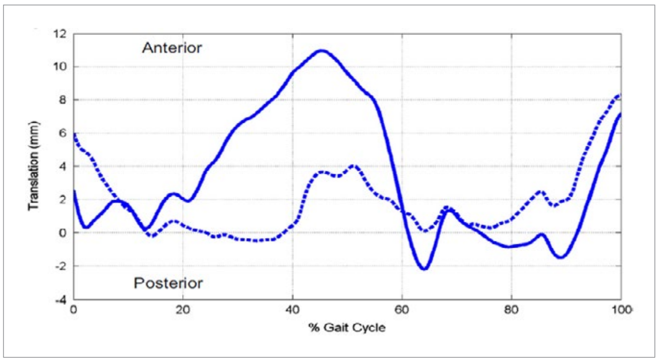
Key highlights:
Product: Adams
Industry: Medical
Benefits:
Predicts ground reaction forces with over 90% correlation to physical results
Accurately predicts internal contact forces
Determines effect of slack in menisci



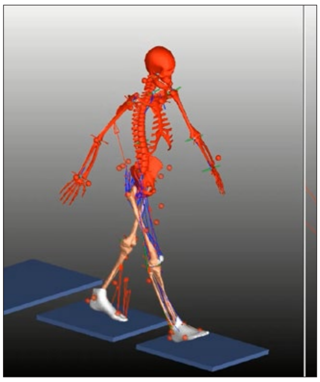
Position of markers recorded by motion capture system

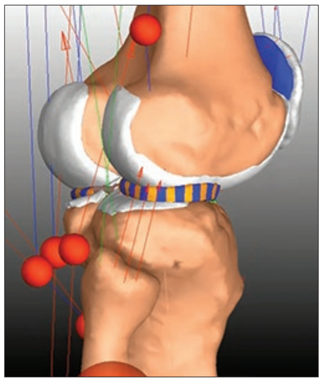


Adams model of menisci created from MRI scan



The biomechanical function of the menisci decreases as the length of meniscal attachments increase





Adams knee simulation: duplicating motion capture system testing (left) and close-up of knee joint (right)

Conclusion

The biomechanical function of the menisci decreases as the length of meniscal attachments increase.

With the use of Adams, MAC researchers have begun to take the steps to grasp the complexity of the menisci function in the knee. They found that increasing the ligament length by about 20% will result in almost a complete loss of force transfer through the menisci during walking. The reduction in the forces absorbed by the menisci increases the forces that were directly transmitted between the tibia and femur, increasing the potential for joint damage and pain. These results will enable researchers and physicians to target and prevent future pain and damage more efficiently than ever before.

“Multibody dynamics has already significantly helped to increase our understanding of knee function,” said Trent Guess, Associate Professor of Physical Therapy and Orthopedic Surgery at the University of Missouri said. “Going forward, the potential exists to make substantial advancements in diagnosing knee problems and improving surgical interventions, among other benefits.”

About University of Missouri

Founded in 1839, the University of Missouri is the largest university in Missouri with over 35,000 students currently enrolled. Located within the department of physical therapy, The Mizzou Motion Analysis Center combines research in biomechanical engineering, orthopedics and physical therapy to generate improvements in measuring and maintaining human motion.

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