BY JOY P. KU, PhD, DIRECTOR OF DISSEMINATION FOR SIMBIOS

Reaching Under the Hood of a 20-year-old Musculoskeletal Model

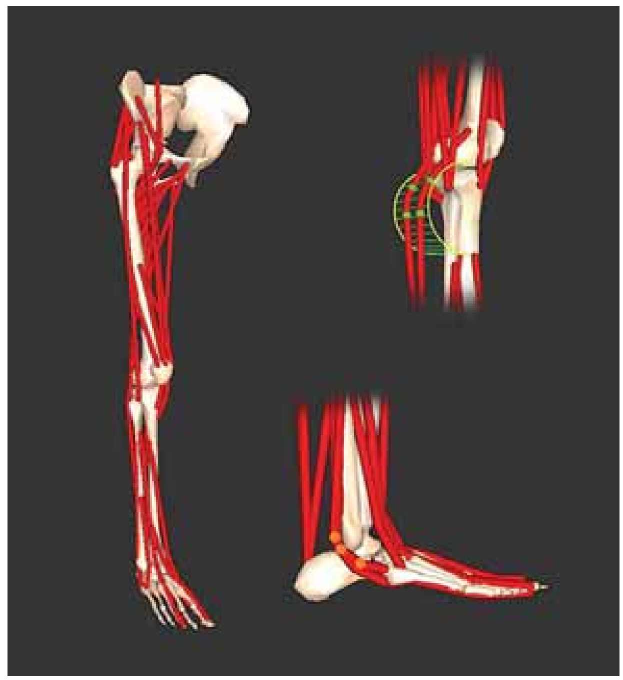
It's often said that all models are wrong, but some are useful. And one model that certainly falls in the "useful" category is the human lower-limb model that Scott Delp published in 1990. It captures the musculoskeletal geometry and muscle arrangements from the hips down to the feet and has been used in numerous simulation studies over the years, providing insights in fields such as sports and medicine. As the saying goes, though, the model is not perfectly accurate. Based on two very small, decades-old studies, the model is limited in how faithfully it can reproduce human movements. Now, with the availability of new experimental data, researchers have updated this lower-limb model, enabling it to address new research problems.

"This is an exciting new tool," says **Edith Arnold**, a mechanical engineering graduate student at Stanford University and the creator of the new model. "It should both correct some of the problems people were having with the old models and allow people to answer new questions."

To gather data for the new model, **Samuel Ward**, **PT**, **PhD**, assistant professor in radiology, and his colleagues at the University of California, San Diego took apart 26 human muscles from each of 21 different cadavers, examining them fiber by fiber to determine both their organization and physiological properties. Using a laser technology that was only just emerging when Delp created the original model, the group measured the length of the sarcomeres, the individual subunits that make up the muscle. This critical piece of information allowed them to normalize their muscle fiber measurements and determine the force-length relationship that characterizes how a muscle performs.

The original model is like a car where no one's opened the hood, says Ward. We know the car performs in a certain way but its parts and how they function together have not been well-studied. "We lifted the hood on the model, looked around, and got a whole bunch of new data to really understand the fundamental properties of the model."

Not only is the data more comprehensive, it is also derived from a much larger number of cadavers than was the original model: 21 versus 2 or 3. The larger sample size provides a better idea of what constitutes normal muscle architecture and behavior.



Having a model based on this number of cadavers is great, says **Jonas Rubenson**, **PhD**, assistant professor in the biomechanics group at the University of Western Australia. "It's a huge leap forward in these models, and now we can be a lot more confident that the muscle parameters are actually representative."

Rubenson is using the model to test some of the assumptions in his experimental study of the force-length properties in the calf muscles. However, Arnold points out that there are a lot of other reasons why people may be interested in the updated model, including a more realistic representation of the knee and changes to bone geometries based on new imaging data.

Creating these models is difficult and time-consuming, says Arnold. "But I like creating these tools that are going to be useful for many people. I'm excited to use this model in my own research and to see what others will do with it." □

DETAILS

The updated lower limb model can be accessed via the neuromuscular models project at http://simtk.org/home/nmblmodels. This Web site is a simtk.org umbrella project, providing links to many other musculoskeletal models that are available for downloading from the simtk.org website. See also, Arnold, E.M., Ward, S.R., Lieber, R. L., and Delp, S.L., A model of the lower limb for analysis of human movement, *Annals of Biomedical Engineering*, 10.1007/s10439-009-9852-5 (2009).

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Simbios (http://simbios.stanford.edu) is the National Center for Physics-Based Simulation of Biological Structures at Stanford.