# Democratization of Modeling & Simulation in Biomechanics

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In biomechanics, computational modeling & simulation (M&S) enables scientific discoveries by establishing a platform for understanding the structure-function relationships in health and disease and the mechanistic foundations of data associations. It facilitates engineering innovations by a-priori evaluation of performance and safety of new interventions. Simulations also support clinical diagnosis, medical training, and individualized medicine. The evolution of the M&S enterprise has been dramatic, providing powerful and accessible computing hardware and software for biomechanics simulations. However, biomechanical models, particularly in the area of organ and tissue level mechanics, have not been widely available. Motivated by this state of affairs, we have started two M&S projects to deliver computational models of the knee [1] and of multi-layer tissues of musculoskeletal extremities [2]. Our intention has been to democratize M&S, at least in the respective areas of joint mechanics and layered-tissue mechanics, and to provide guidance for others, who may want to pursue similar endeavors in their own domain of interest. This document briefly summarizes the properties of M&S that we perceive as important for democratization and then lists our activities in response. Our goals are to achieve specificity, efficiency, accessibility, usability, comprehensibility, and credibility. Specificity is addressed by collecting specimen-specific data on diverse samples; not only to characterize anatomy but organ and tissue level mechanical properties as well. Automation of data analysis and model development stages increases efficiency. Using Python scripting, model parameters can be extracted from raw data and model generation and assembly can be handled in an unsupervised fashion. Data and models are made widely accessible by adopting a web-based open development approach and free and open source dissemination. The use of free and open source software and public delivery of utility scripts enhance accessibility. Usability is founded upon case studies to illustrate the potential utility of data and models. Implementation of cloud computing and data querying interfaces will likely assist users to access and evaluate models and data in an expedited fashion. For comprehension of data and models, specifications for data collection, analysis, modeling and simulation tasks are publicly documented in a detail that cannot necessarily be provided in journal articles. Scholarly publications are developed based on reporting considerations [3]. Credibility is in part ascertained by quality assurance of data, which was conducted through reproducibility tests. Uncertainties in data analysis and model development are quantified, particularly when subjective decision making is not avoidable. Biomechanical validation data collected at organ and tissue levels provide the basis to establish predictive capacity. Version control systems assist tracking of data, models, analysis and model generation scripts. All these activities are inline with guidance from the M&S community in healthcare [4]. There are overlaps in the desirable properties of M&S and the activities to achieve these. Yet accomplishing one does not necessarily warrants the achievement of the other. The framework described in here provides a holistic approach to promote utmost outreach of models in biomechanics, specifically for joint and tissue mechanics of the knee and for muscle-skin-fat layers of the extremities. In addition, the described properties for democratization of M&S are universal and the activities to accomplish these are broadly applicable – irrespective of the model system.

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**References**

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