THE IMPORTANCE OF BIOLOGICAL VARIATION: A META-ANALYSIS OF BIOMECHANICS MODELING PRACTICES

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Introduction

Physical variation in biological systems is intrinsically linked with evolution and adaptation [Darwin, 1859]. Significant levels of variability are present in all aspects of human biomechanics, including dimensions and material properties, stature [Daubes, 1887], function [Tahmoush, 2010], and pathological conditions [Drumm et al, 2012]. However, the treatment of variation in biomechanical modelling has not reflected the levels of variation in nature. The purpose of this study was to characterize the modelling practices currently in use in the biomechanics research community and to encourage more rigorous treatment of this important topic.

Methods

A meta-analysis was performed based on 60 research articles published in Journal of Biomechanics in the year 2011. Each article was reviewed thoroughly and corresponding data were recorded in a database. Data was collected in aspects such as: the number of reported parameters in the modeled system; the statistical distribution of each parameter; the number of parameters varied and held constant; the technique used for varying model parameters; the source(s) of parameter values; the total number of simulations performed; and the type of validation performed.

Results

Both the number of model parameters used in each category (geometry, material, and boundary conditions), and the number of varied parameters were tabulated. Only 28% of studies included more simulations than the median number of model parameters. On a case-by-case basis, 32% of models involved more simulations than model parameters. In other words, 68% of studies involved fewer simulations than the number of model parameters. The median ratio of simulations to total number of model parameters was 36%, indicating that half of all studies were based on an experimental design in which 36% or fewer of model parameters were varied.

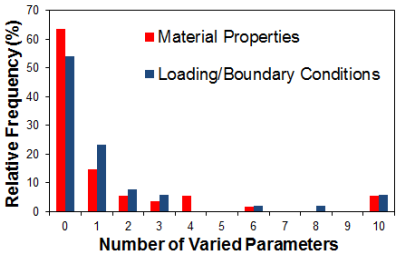

Figure 1: Histograms indicating proportion of model parameters varied within two categories.

Discussion and Conclusion

Biomechanical models typically exhibited variation in one major category (geometry, material, or boundary conditions), but did not include variation in the remaining two. For models based on idealized geometries, the median number of varied and fixed parameters was 3 and 15, respectively. Thus, the median model holds approximately 80% of all model parameters fixed throughout the study. The reasons for fixing certain model parameters were rarely provided. Based on the experience of the authors in performing biomechanical research studies and discussing this issue with colleagues, the reason for holding so many model parameters fixed is due to practical constraints on time and resources: it is usually infeasible to vary all model parameters.

We recommend that the biomechanics community give additional consideration to the issue of biological variation in future studies. The inclusion of biological variability will lead to broader biomechanics studies involving more simulations which will produce more reliable results, thus improving the quality of future research.

References

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