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Abstract

Computational models for the personalized analysis of human femurs contain uncertainties in bone material properties and loads, which affect the simulation results. To quantify the influence we developed a probabilistic framework based on polynomial chaos (PC) that propagates stochastic input variables through any computational model. We considered a stochastic E-ρ relationship and a stochastic hip contact force, representing realistic variability of experimental data. Their influence on the prediction of principal strains (ϵ_1 and ϵ_3) was quantified for one human proximal femur, including sensitivity and reliability analysis. Large variabilities in the principal strain predictions were found in the cortical shell of the femoral neck, with coefficients of variation of $\approx 40\%$. Between 60-80% of the variance in ϵ_1 and ϵ_3 are attributable to the uncertainty in the E-ρ relationship, while $\approx 10\%$ are caused by the load magnitude and 5-30% by the load direction. Principal strain directions were unaffected by material and loading uncertainties. The antero-superior and medial inferior sides of the neck exhibited the largest probabilities for tensile and compression failure, however all were very small ($p_f < 0.001$). In summary, uncertainty quantification with PC has been demonstrated to efficiently and accurately describe the influence of very different stochastic inputs, which increases the credibility and explanatory power of personalized analyses of human proximal femurs.

Keywords: femur, personalized medicine, uncertainty quantification, polynomial chaos, finite cell method

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