A Parametric Skeleton Model of Human Upper Extremities Accounting for Morphological Variations Among the Diverse Population

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Introduction

- Based on Crash Injury Research Engineering Network (CIREN) data, approximately 25% of motor-vehicle crash injuries are upper extremity-related. Upper extremity injuries are common in vulnerable road users, such as bicyclists and motorcyclists.[1]
- Virtual testing using human body models (HBMs) may provide an opportunity to consider upper extremity injuries in the safety design evaluation process.
- Parametric HBM representing the morphological and biomechanical variations of the population may further enhance safety equity among the diverse population.[2]
- A parametric upper extremity skeleton model is not yet available, limiting the capability of HBMs to evaluate the variations of upper extremity injuries in motor-vehicle crashes.

Objectives

- To develop parametric skeleton models of human upper extremities, including the humerus, clavicle, and scapula.
- To investigate morphological variations, specifically the effects of age, stature, sex, BMI, and bone length on upper extremity skeletal geometries.

Methods

- Computed Tomography (CT) scans of the upper extremities were obtained from the University of Michigan Health System following protocol approved by the University of Michigan Institutional Review Board (HUM00004842).
- The study population consisted of 105 patient CT scans. 55% of the population was female (n=58), and mean age was 40.8 (SD=13.2).
- Statistical models of the humerus (n=89) and clavicle (n=58) were developed.

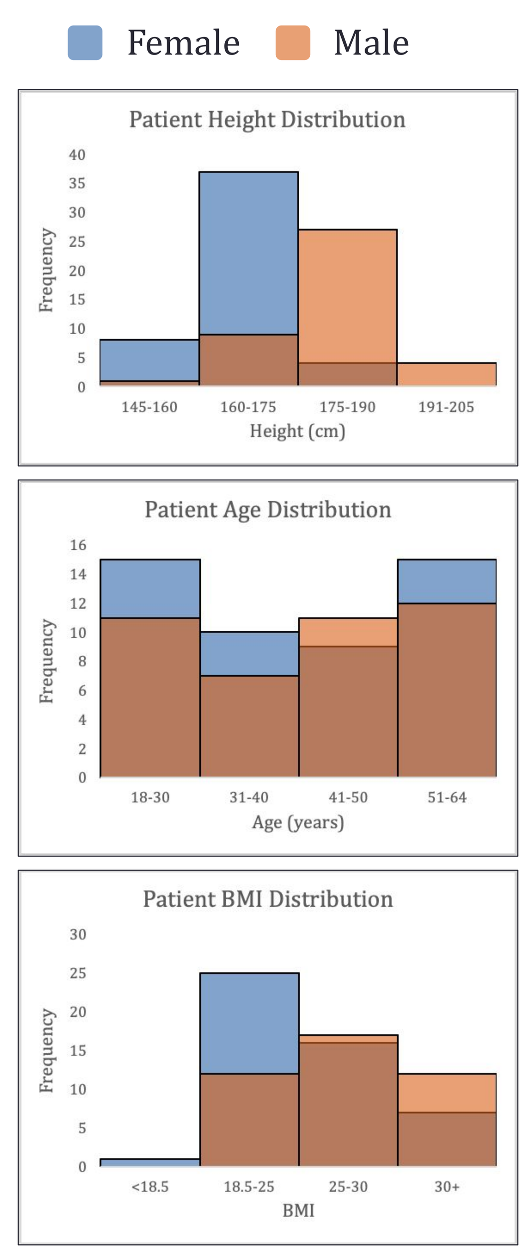

Fig 1. Distribution of humerus study population.

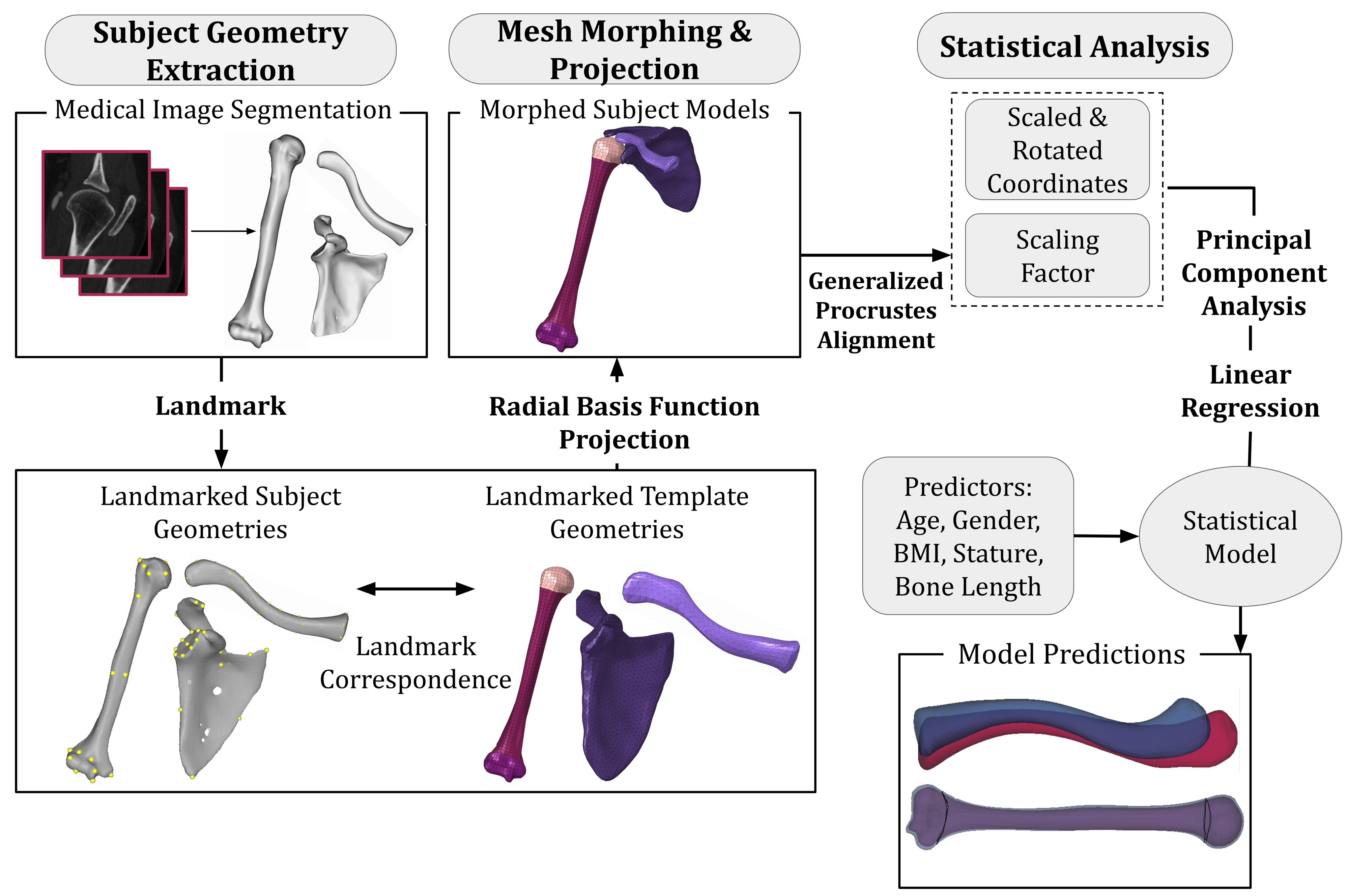

Fig 2. Methodology for generating a statistical shape model of the humerus, clavicle, and scapula.[2]

Results

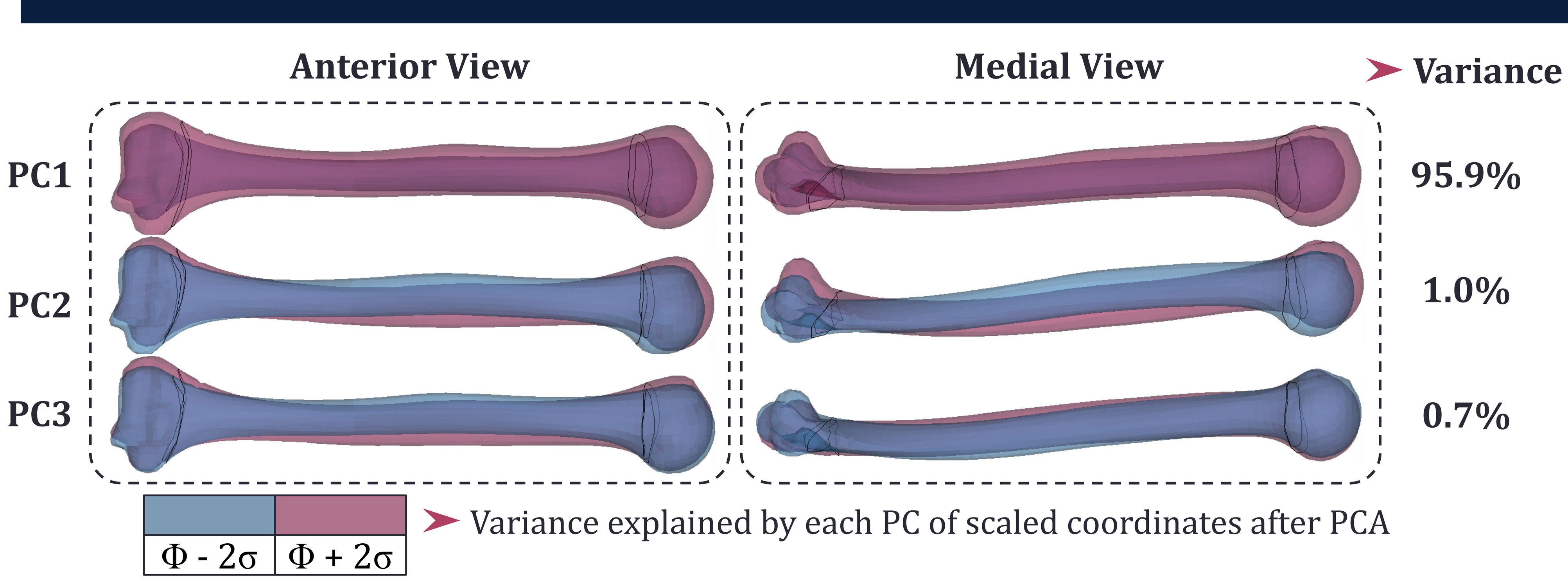

Fig 3. Predicted humeral geometries with varied PC scores.

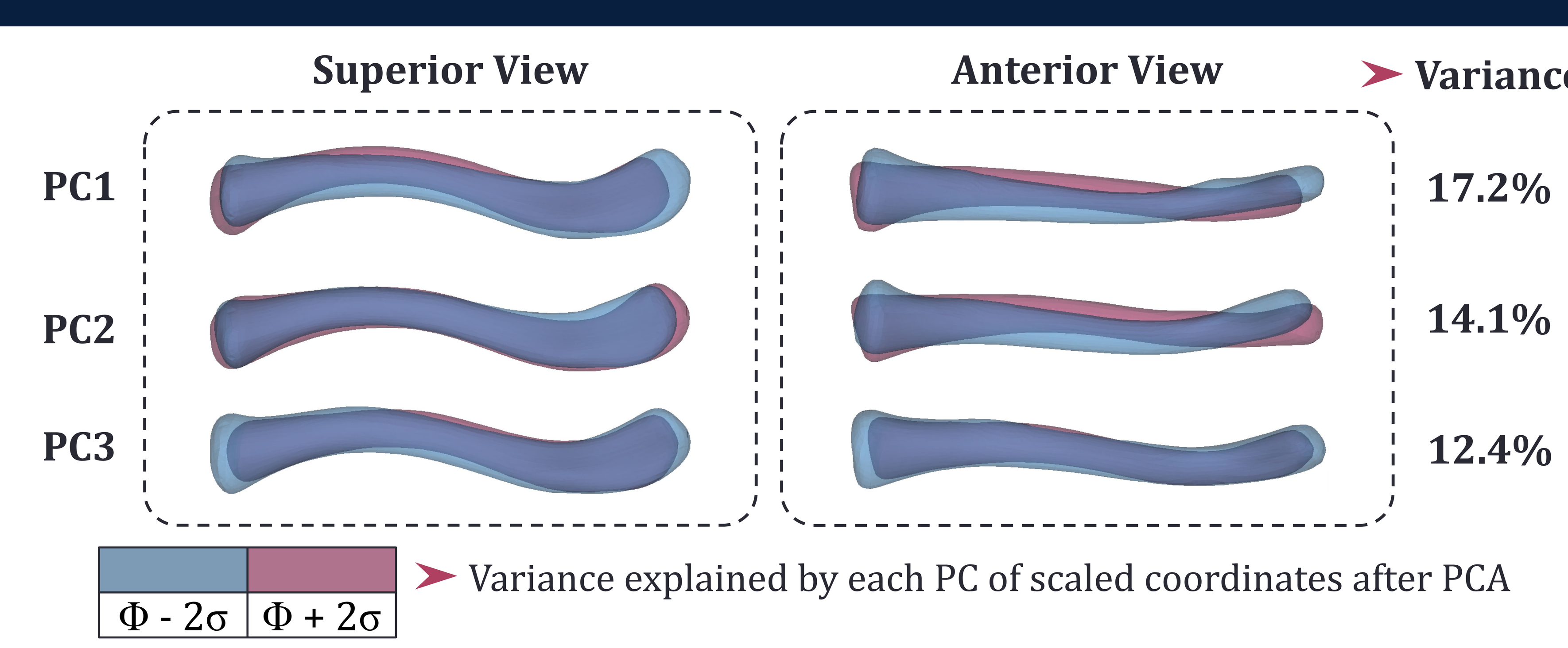

Fig 4. Predicted clavicular geometries with varied PC scores.

- Subject covariates account for 81% of the variation in the humeral statistical model.
- Subject covariates account for 83% of the variation in the clavicular statistical model.

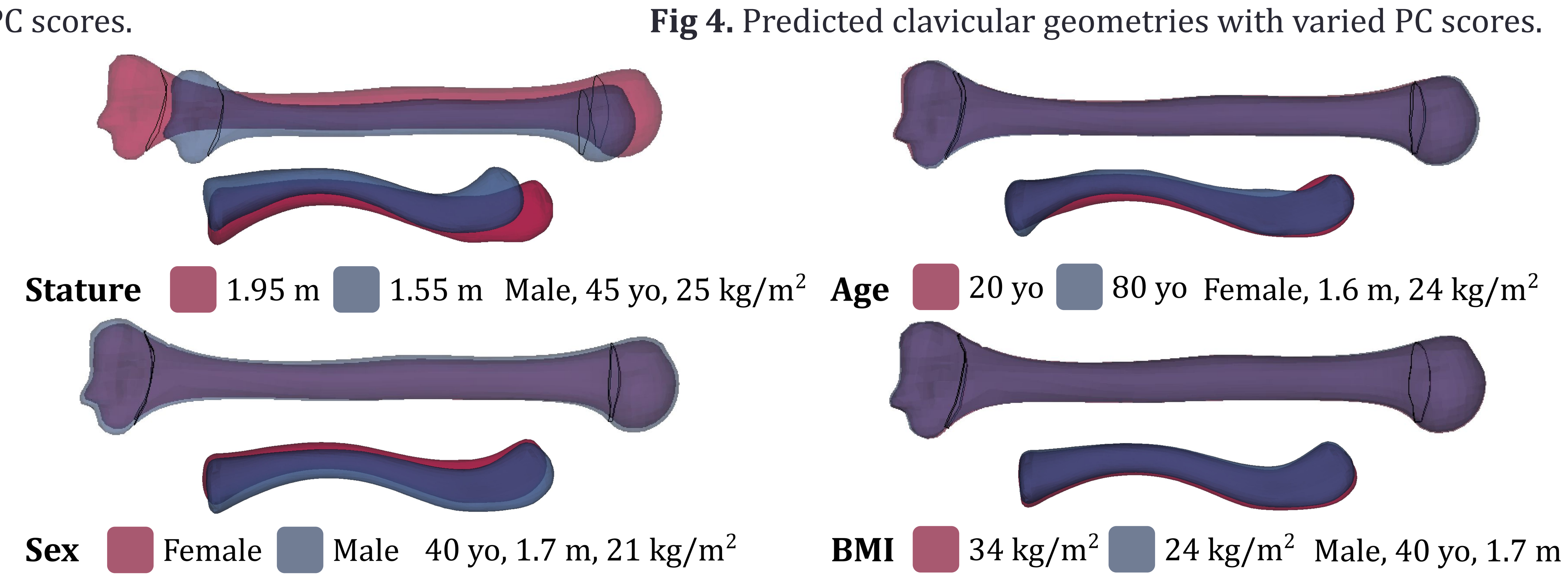

Fig 5. Effects of stature, sex, age, and BMI on humeral and clavicular geometry and curvature.

Discussion & Conclusions

- This study exercised a methodology for creating robust statistical geometry models of the upper extremity skeleton.
- The models developed in this study could serve as a geometrical basis for future development of parametric human body models for upper extremity injury assessment representing a diverse population.
- Future research will focus on improving the accuracy of each model and exploring the effects of interactions between subject covariates and upper extremity bone geometry.

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The completion of this undertaking could not have been possible without the guidance and the instruction from the faculty, alongside the work of the previous Upper Extremity team. The University of Michigan Transportation Research Institute (UMTRI) and the Multidisciplinary Design Program (MDP) have also greatly supported the progress and findings of this research.

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