On the Application of Statistical Shape Modeling for Improving Infant Musculoskeletal Models

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INTRODUCTION: Musculoskeletal (MSK) models are valuable tools that can help researchers better understand the mechanisms contributing to human movement and can serve as potential diagnostic tools for identifying pathologies and disorders, such as developmental dysplasia of the hip. However, most MSK models are developed for adult subjects, with only a few studies focusing on infant populations despite the greatest growth rate being in early infancy. Researchers typically scale adult models or use medical imaging data (CT or MRI scans) to develop pediatric MSK models. However, scaling adult models does not account for subject-specific MSK geometry, and obtaining medical imaging data of infants can be challenging. There are concerns with radiation exposure, subjecting the infants to uncomfortable conditions for MRIs (which often require anesthesia), the expense, and the time commitment [1]. Linear scaling of generic adult models is commonly used despite being error-prone because it does not require medical imaging data. Therefore, a combination of linear scaling and statistical shape modeling will be used in this study. This study aims to determine whether statistical shape modeling can be used to improve our infant MSK model.

METHODS: A statistical shape model (SSM) of a partial sample of the Ortolani collection (University of Padua, Italy) [2] was built and used to find the mean shape of the femurs in the Ortolani collection. The femur SSM was coupled with a previously developed infant MSK model [3], as shown in Figure 1. Inverse kinematics and inverse dynamics will be used to estimate hip joint angles and hip joint external moments. The results of the SSM-derived MSK model will be evaluated to determine how incorporating the SSM affects the kinematics and dynamics results.

RESULTS: When comparing the results from the SSM-derived MSK model to linearly scaling generic adult models, we hypothesize that incorporating the shape model will improve the kinematic errors resulting from the regression-estimated hip joint center (HJC) location errors.

DISCUSSION: When developing MSK models for pediatric populations, it is essential to consider the scaling method carefully, especially when linearly scaling generic models based on adult cadaveric data. In previous work, we have found that slight changes in the scaling process may lead to large changes in the kinematics results and minimal changes in the dynamics results [4]. This insight is especially a concern when studying pediatric populations or those with hip disorders since researchers are looking to use MSK modeling to assist in clinical decision-making [5]. We hypothesize that incorporating the SSM will have some effect on the kinematics and dynamics results because SSMs have been shown to improve HJC location estimates compared to scaling methods using regression or functional-based approaches [6], [7]. SSMs have also been shown to combat the disadvantages of experimental marker-based scaling of MSK models by reducing errors due to soft tissue artifacts [8] and increasing the scaling process's repeatability [9]. The limitations of this study include the sample size and the difference in subjects. The experimental data used to build the MSK model was from a living subject, while the imaging data used to build the shape model was from cadaveric specimens. These limitations highlight the challenges of collecting imaging data of infants under one year. Future work of the study is to investigate feasible approaches for collecting more data to improve our shape model and develop a generic infant MSK model.

SIGNIFICANCE/CLINICAL RELEVANCE: This research has the potential to extend the tools and techniques physicians have available to them by coupling statistical shape modeling and MSK modeling to better understand the three-dimensional growth changes in infant populations.

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IMAGES:

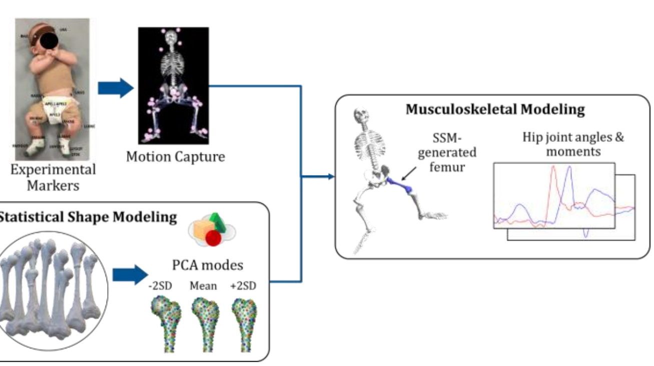

Figure 1. Workflow for coupling statistical shape modeling with musculoskeletal modeling.