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Summary

This work presents an improved spine model with an articulated ribcage capable of simulating scoliosis deformities. In this model, joint constraints were defined based on experimental data. A set of clinically accepted parameters that can be measured from bi-planar radiographs, controls the spine curve and ribcage configuration of the model. The normalized compression and lateral shear forces of the intervertebral joints along the spine were reported for a normal and a scoliotic spine. Future use of the model will include investigation of the pathomechanism behind adolescent idiopathic scoliosis, simulation of brace effects, and optimization of brace treatments.

Introduction

The pathomechanism underlying **A**dolescent **I**diopathic **S**coliosis (AIS) has remained unclear [1], and a better biomechanical understanding of the phenomenon might contribute to uncovering the phenomenon. The linked system of spinal vertebrae, ribs, and sternum is highly constrained with multiple closed loops, and an anatomically valid constraint definition is essential for reliable force transmission through the model. This work presents an improved and kinematically determinate musculoskeletal spine model with an articulated ribcage, capable of simulating various spine deformities.

Methods

A previously presented spine model [2] forms the basis of the new model. The model was developed in the AnyBody Modeling System, and different types of kinematic joints were implemented [3], based on reported clinical data of intact ribs, leading to a kinematically determinate model, which can simulate healthy spines and ribcage kinematics as well as scoliotic deformations without violations of anatomical constraints.

The posture is defined by a set of fifteen clinically accepted measures (such as Cobb angle) and anatomical degrees-of-freedom (DOF) from the patient's bi-planar radiographs. Muscle and joint reaction forces are simulated by an inverse dynamics analysis.

Results and Discussion

The patient's spine curve and rib rotations were constructed from radiographs (Figure 1). The normalized compression (NC) and normalized lateral shear forces (NLS) of the intervertebral joints along the lumbar and thoracic spine were presented for normal and scoliotic spines, and polynomial curves were fitted to them. The lumbar and thoracic apical vertebrae of the scoliosis patient were L3 and T8, respectively. The NLS of the normal spine is zero. However, scoliosis seems to increase the NLS corresponding to the curve shape, indicating that the turning points of the spine curve (L1 and T6) occurred where the NLS polynomial curve hits zero. Besides, the progression of scoliosis appears to increase the NC, especially in the lumbar region.

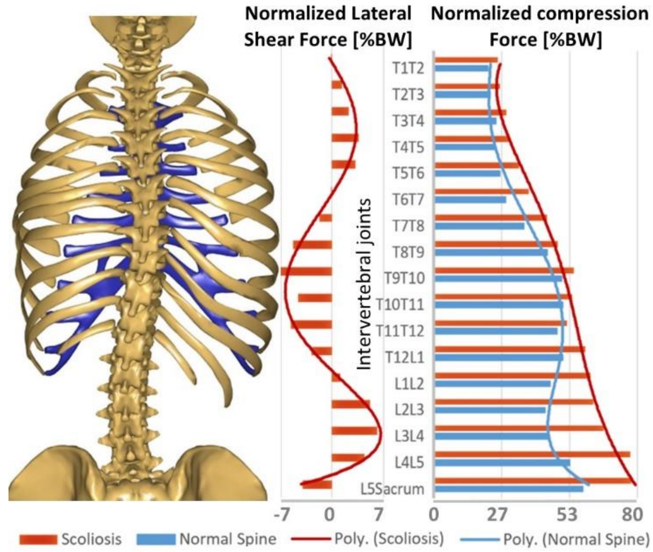

Figure 1: Posterior view of the scoliosis model. Normalized lateral shear and compression forces of the intervertebral joints for the normal and scoliotic spine, and their fitted polynomial curves. All forces are normalized to body weight [BW].

Conclusions

This work presents an improved spine-ribcage model for simulation of scoliosis deformities, suitable for investigating the pathogenesis of AIS by analyzing force trends. In a future perspective, the model can simulate the effect of supportive forces from braces, which can contribute to an optimization of brace interventions.

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