A thoracolumbar multibody model capable of simulating scoliosis deformities

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BACKGROUND

Adolescent **I**diopathic **S**coliosis (AIS) is regarded as a multifactorial disease. Several studies have been conducted to unravel the aetiologies and pathogeneses that underlie AIS [1-3]. However, the aetiopathogenesis behind AIS has remained controversial [2-3].

We hypothesize that musculoskeletal modelling can offer an insight into the matter. A previously developed thoracolumbar spine model [4] is able to reconstruct large spine deformations, albeit with a kinematically indeterminate driver strategy, which makes it difficult to uncover the mechanical mechanisms behind spinal and thoracic deformity. This works presents an improved and kinematically determinate model motivated by the fact that correct kinematic constraints are a condition for subsequent use of the model to investigate the kinetics of scoliosis aetiology.

METHOD

The model was created using the AnyBody Modeling System (AMS, v. 7.2), which is commercial software (AnyBody, Aalborg, Denmark).

Scoliosis deformities and severity can be described by clinical measures and anatomical degrees-of-freedom (DOF), including 3-DOF Vertebral Rotation (VR) forming the Cobb angle, Rib-Vertebral Angle Difference (RVAD), Vertebral Translation (VT), Rib Hump index (RH), Sternum Translation (ST) and Rotation (SR). These variables are calculated from anatomic landmarks at osseous elements on medical imaging data.

A detailed study of clinical data describing ribcage deformation led to decoding of the inherent kinematic constraints in the human thoracolumbar system and implementation of these constraints into the model. Several modifications of joint definitions compared to previous models were performed. Intervertebral joints in the entire spine were defined as spherical joints. Articulation between ribs and vertebrae, costo-vertebral and costo-transverse, were modeled as universal joints (allowing 2-DOF rotation). Articulation between ribs and the sternum, costo-sternal, were defined as spherical joints for all ribs, except the ninth and tenth pairs, which were modeled as 4-DOF joints allowing 3-DOF rotation and 1-DOF anterior-posterior translation. These modifications led to a kinematically determinate model that is drivable by clinically accepted measures. The proposed thoracic model, including T10 to T1 vertebrae, non-floating ribs and sternum, has 17 DOF after implementation of the kinematic constraints.

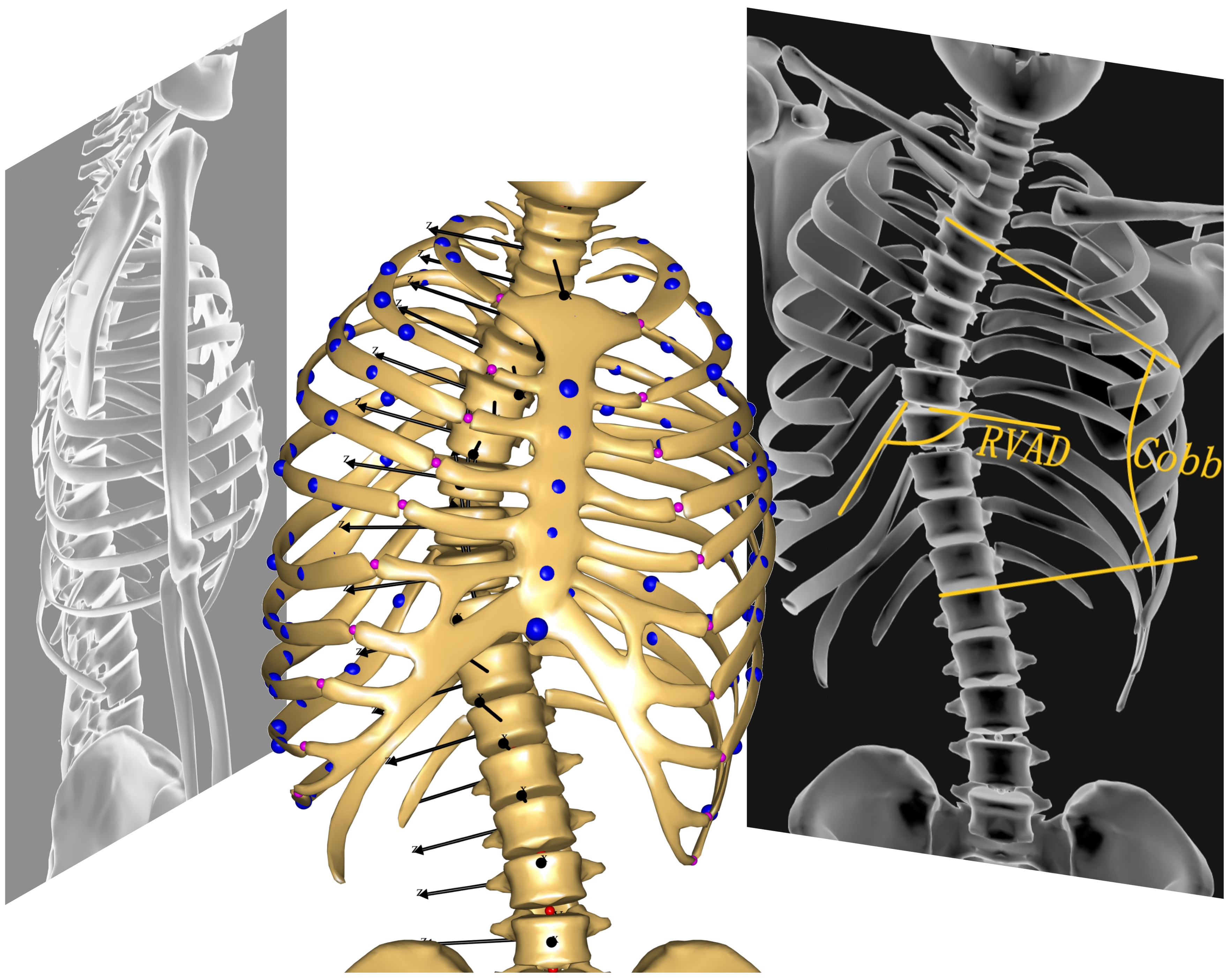
RESULTS

The scoliosis model in the upright standing posture is shown in the figures. The model appears to reproduce VR, RVAD, VT, ST and SR according to typical deformations for scoliosis, thus supporting the constraint assumptions visually. Forthcoming work will attempt quantitative verification of the deformation patterns.

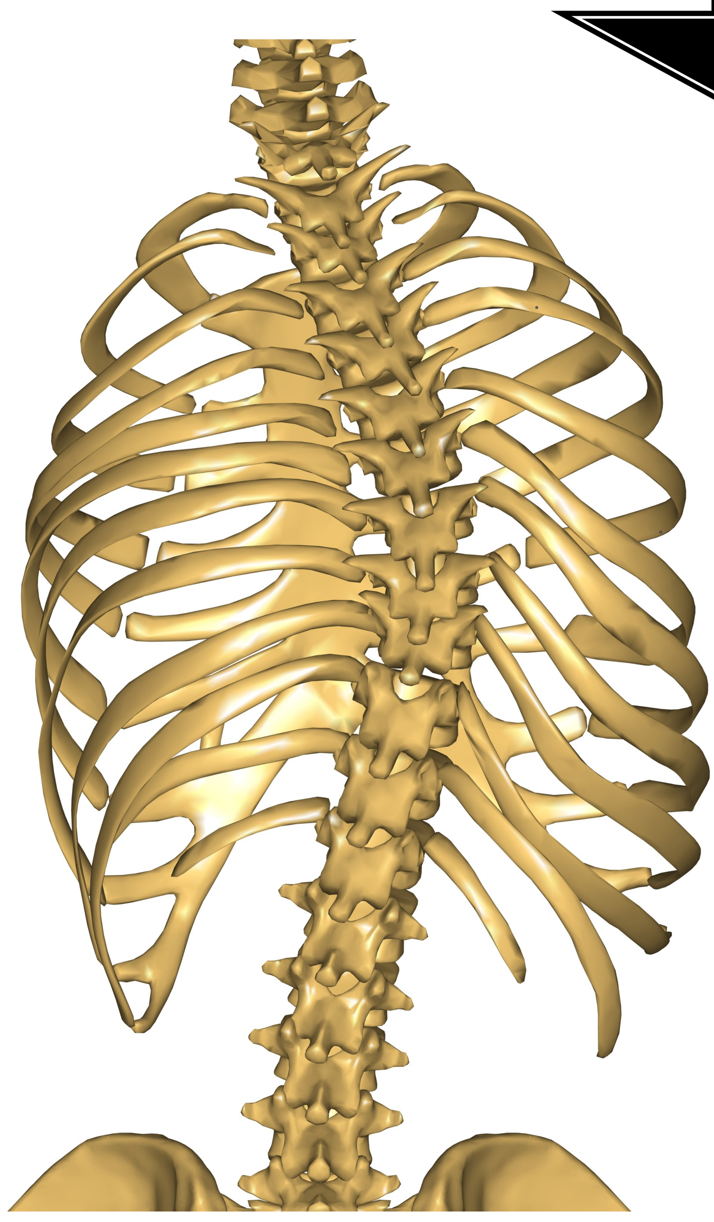
The scoliosis model can cast light on the biomechanics of the costo-vertebral and costo-sternal joints and thoracic cage configuration, while modelling the concavity and convexity of the rib hump. If the model can subsequently be shown to reproduce the kinetics of scoliosis, then it can also be used for *in-silico* design of interventions such as advanced orthotics to manage the condition.

CONCLUSIONS

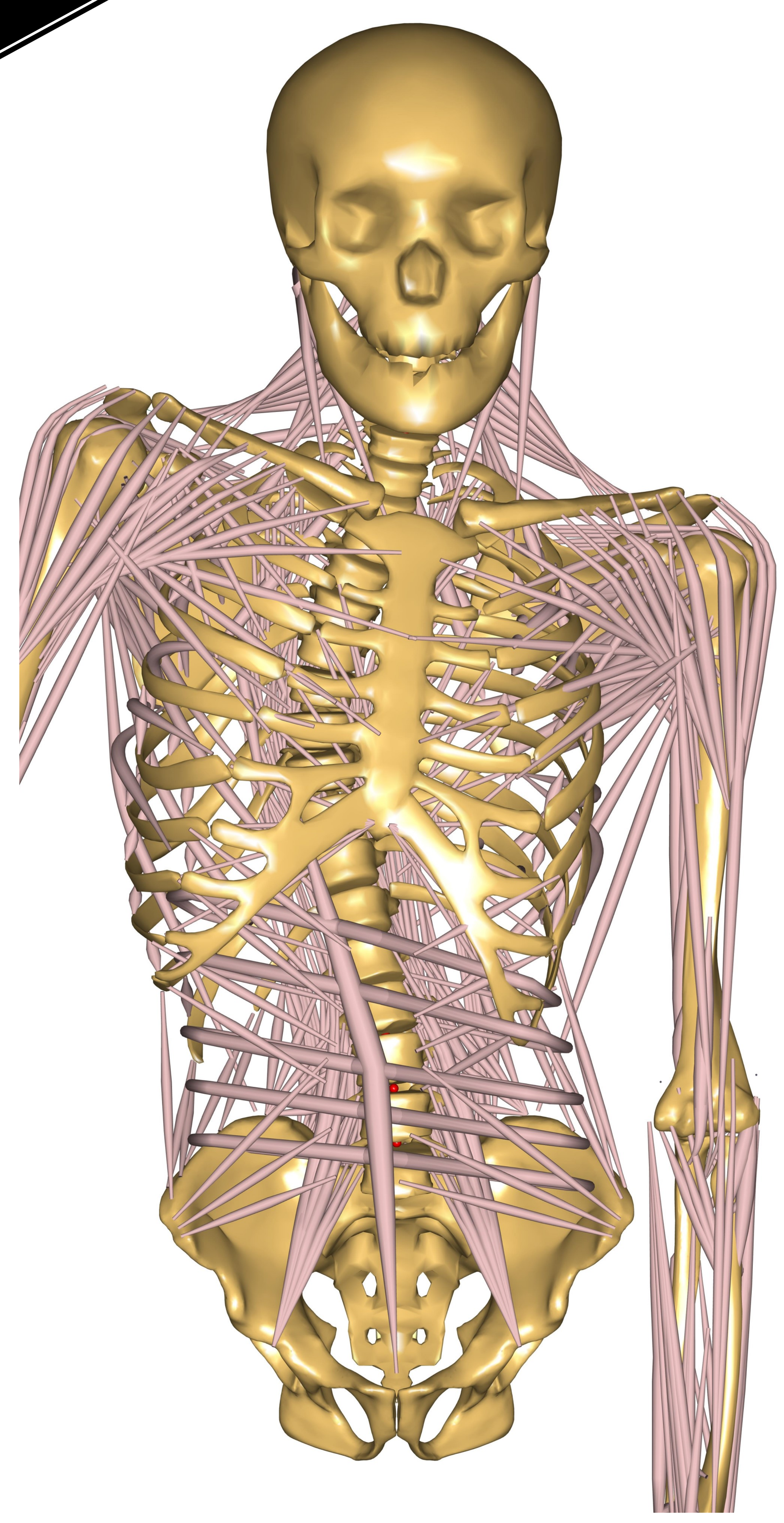
The proposed thoracolumbar model is able to simulate scoliosis deformities and enhance state-of-the-art on scoliosis aetiology as well as biomechanics of the torso.



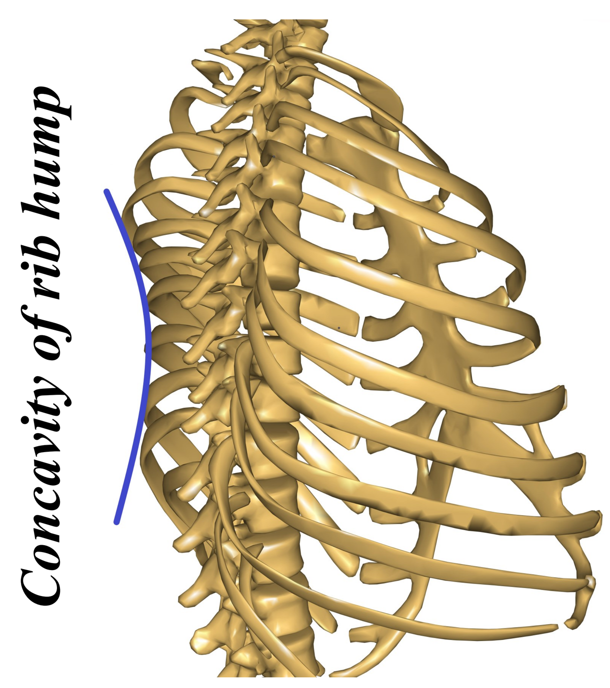
Drive the model using clinical measures from parameterized 3D reconstruction or bi-planar radiographic images



Posterior view of the scoliosis skeletal model



Anterior view of the scoliosis musculoskeletal model in the up-right standing posture



ANYBODY
RESEARCH PROJECT

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