Musculoskeletal modeling of scoliosis patients with acceptable kinematic accuracy

Shayestehpour, Hamed; Shayestehpour, Mohammad Amin; Koutras, Christos; Tierp-Wong, Christian Nai En; Rasmussen, John

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Shayestehpour, H., Shayestehpour, M. A., Koutras, C., Tierp-Wong, C. N. E., & Rasmussen, J. (2021). *Musculoskeletal modeling of scoliosis patients with acceptable kinematic accuracy*. 4. Abstract from 13th Annual Meeting of the Danish Society of Biomechanics, Kgs. Lyngby, Denmark.

Musculoskeletal modeling of scoliosis patients with acceptable kinematic accuracy

Hamed Shayestehpour[1,*], Mohammad Amin Shayestehpour[3], Christos Koutras[4], Christian Wong[2], and John Rasmussen[1]
[1]Department of Materials and Production, Aalborg University, Aalborg East, Denmark
[2]Department of Orthopedics, University Hospital of Hvidovre, Hvidovre, Denmark
[3]Department of Mechanical Engineering, Sharif University of Technology, Tehran, Iran
[4]Department of Computer Science, Rey Juan Carlos University, Madrid, Spain
Email: hs@mp.aau.dk

Introduction

The aetiology underlying **A**dolescent **I**diopathic **S**coliosis (AIS) has remained unclear [1]. An anatomically valid musculoskeletal model might contribute to uncovering the biomechanical cause. We previously developed and validated a spine model capable of simulating scoliosis deformities, with joint definition compatible with anatomical joint properties [2]. Further, we improved the muscle anatomy of the ribcage and the ribcage-scapula contact model [3].

In this study, we developed a semi-automated process to simulate scoliosis patients using all visible geometrical parameters retrieved from bi-planar radiographs, which improves the kinematics and, thus, the kinetic model.

Methods

In this study, we simulated 14 mild AIS cases with different lumbar, thoracolumbar, and thoracic curves. Firstly, the mannequin was scaled using the patient's height, mass, spine height, ribcage width, and depth. Secondly, we selected four corner nodes of all visible vertebrae in both sagittal and frontal X-rays, subsequently calculating the vertebrae's centers and angles. Further, the rib angles, C7 position relative to the sacrum, and rib humps were measured.

We utilized a least-squares optimization method in AnyBody Modeling System [4], which minimizes the kinematic error between the measured and model parameters. To investigate the accuracy of this method, we calculated the errors of some known clinical parameters, including lumbar and thoracic Cobb angles (CobbL, CobbT), thoracic kyphosis (TK), lumbar lordosis (LL), rib hump from 10th to 5th rib pairs (RH), C7 translation relative to the sacrum in anteroposterior and mediolateral direction (C7T), and all rib angles (RibA). Further, the thoracic and lumbar apical vertebrae of the patients and the model were assessed to be matched as part of spine reconstruction validation.

Results and Discussion

The average and maximum errors for angles were 1.9 and 4.3 degrees, and distances were around 1.3 and 3.7mm. Besides, the apical vertebrae of the model were 100% corresponded to the radiographs. Figure 1 represents the average error of the parameters and the projection of the model to the radiographs of a patient.

Axial rotation of the vertebrae is not measurable from the X-rays directly. However, the model creates relevant axial rotation based on the rib angles and rib hump inputs without violating the costovertebral joint definition.

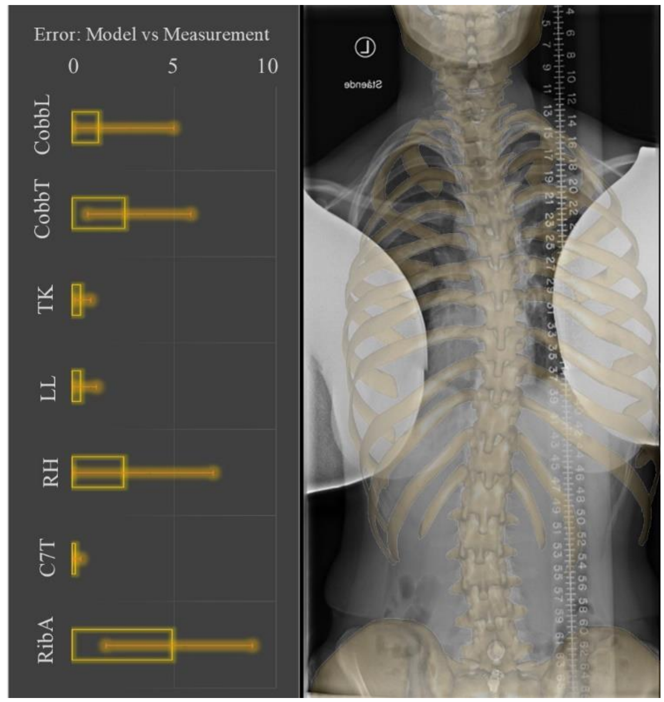

Figure 1: *Left:* The average error of the model together with the error bar of the parameters. The angle and distance errors are in degrees and mm, respectively. *Right:* The projection of the transparent model to the radiograph of a patient.

Conclusions

Since the acceptable measuring errors from radiographs are 5 degrees and 5 mm (or more), the model reconstructs the patients with an acceptable tolerance. Future use of the model will include investigating the pathomechanism behind AIS, simulation of brace effects, and optimization of brace treatments.

Acknowledgments

The project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement NO. [764644].

References

[1] C. Wong, *Scoliosis*, 10-1, 1–5, 2015.
[2] H. Shayestehpour, et al., *Multibody Syst. Dyn.*, 2021.
[3] H. Shayestehpour, et al., *Journal of Biomechanics,*Submitted.
[4] M.S. Andersen, et al., *Computer Methods in Biomechanics and Biomedical Engineering*, 13-2, 171-183, 2010