Biomechanical characterization of idiopathic scoliosis based on radiological information

David F. Landinez[1,2], Carlos F. Rodríguez[3], Christian J. Cifuentes[1]
[1]Biomedical Engineering department, Universidad de los Andes, Bogotá, Colombia
[2] I3A, Biomedical Engineering division, Universidad de Zaragoza, Zaragoza, España
[3] Mechanical Engineering department, Universidad de los Andes, Bogotá, Colombia
Email: cc.cifuentes@uniandes.edu.co

Summary

Scoliosis is a three-dimensional spinal deformity that is typically assessed using radiological parameters without considering mechanical effects. This study presents an algorithmic methodology that extracts radiological features from an X-ray and associates them with finite element results through a search process in a database created and validated based on a computational model developed by our group. The algorithm calculates stress and strain distribution in the intervertebral discs while accurately replicating the patient's specific scoliotic curves. The results achieve up to 96% replication accuracy, with biomechanical information effectively presented in a histogram.

Introduction

Idiopathic scoliosis affects 0.5-5.2% of adolescents, with diagnosis primarily based on the Cobb angle [1]. Treatment ranges from orthopedic management to spinal fusion surgery, which carries risks [2]. While computational models have improved scoliosis assessment, current approaches lack generality and validation. This study proposes an algorithm that extracts radiological information from a coronal X-ray of a patient with idiopathic scoliosis and associates it with biomechanical data by searching a database. The study highlights the impact of scoliosis on intervertebral discs.

Methods

A convolutional neural network segments scoliotic curves from 209 patient X-rays, defining a spline interpolation curve to calculate the Cobb angle and identify inflection points. The extracted curve is compared to a database generated by a computational model proposed in [1]. The algorithm receives the scoliotic curve as input, compares it with 3,240 modeled curves, and returns finite element data for the best-matching curve based on mathematical metrics such as Fréchet distance.

Results and Discussion

The algorithm was applied to 209 cases, achieving similarity rates between 84.6% and 94.4%. While it can extract the Cobb angle, variations between 1.2° and 8° indicate that this parameter alone is insufficient to fully characterize scoliosis. Figure 1 shows an example case for a patient. Limitations include the exclusion of sagittal plane effects, the inability to scale anatomical structures, and simplified material properties. However, the generalization using a numerically significant database enhances realism and minimizes computational cost.

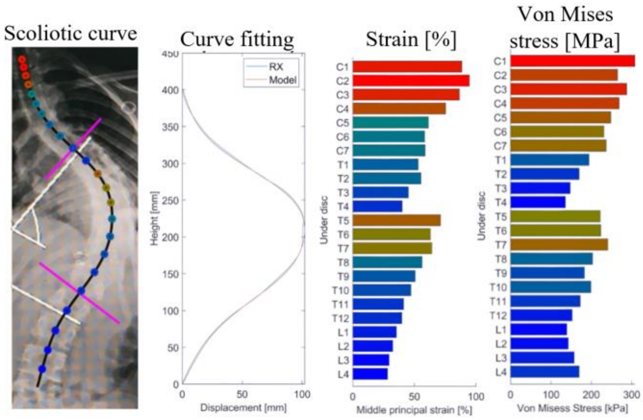

Figure 1. Algorithm results for a patient with 96% similarity. Displayed from left to right: (1) extraction of the scoliotic curve with inflection points, where deformations are color-coded in the discs; (2) the best-matching curve for the patient; (3) maximum equivalent strain results for all discs; and (4) maximum Von Mises stress results.

Conclusions

This algorithm improves scoliosis assessment by accurately replicating patient-specific curves and integrating the biomechanical impact of scoliosis on intervertebral discs. It optimizes diagnosis and treatment planning, offering a more efficient alternative to 3D reconstructions. The study confirms a positive correlation between computational model generalization and result accuracy. Future research will focus on incorporating sagittal information, scaling the model, and expanding the database.

References

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