

CAN THE LUMBAR-CALIBRATED PROPERTIES OF THE ANNULUS FIBROSUS BE EXTENDED TO THE THORACIC LEVEL? MATERIAL MODEL COMPARISON

Salvador Moreno-Vegas (1), Alejandro Peña-Trabalon (1), Vicente Blanco-Salgado (1), Belen Estebanez (1), Ana Perez-Blanca (1), Maria Prado-Novoa (1)

1. Clinical Biomechanics Laboratory of Andalusia (BIOCLINA), Malaga, Spain

1. Introduction

Two methodologies are distinguished for modeling the anisotropy of the annulus fibrosus (AF): axial springs simulating collagen fibers (CF) within hyperelastic ground substance (GS) layers [1]; or the HGO material model to simulate CF and GS [2]. Currently, both methodologies coexist but their advantages and disadvantages remain unclear. Lumbar AF properties have been calibrated via FEMs using experimental range of motion (ROM) data of functional spinal units [3,4] and applied to lumbar and thoracic models, but thoracic validation is lacking. This study aims (i) to assess if the lumbar-calibrated material models can be extended to the thoracic segment and (ii) to compare the response of both methodologies with the experimental thoracic ROM.

2. Materials and Methods

A thoracic AF (T7-T8) was modelled from MRI, using 5 concentric rings with 52 sectors of hexahedral and hybrid 8-node elements (C3D8H). Element size followed a geometric progression to represent CF angle variation. For the first methodology, CF were modelled by 6 layers of non-linear crisscross springs (CON3D2) interspersed between rings of elements with a reduced second-order polynomial to model the GS (Figure 1a). Properties were extracted from a lumbar calibrated study carried out by our research group [1]. For the second methodology, the 52 sectors were grouped into 5 regions (Figure 1b), using HGO parameters from a previous lumbar-calibrated study [2]. Eight FEM were built (Abaqus®) for each methodology, replicating the experimental test of reference [3]. The AF underwent flexion, extension, lateral bending and rotation loads at 1 and 2.5 Nm, measuring ROM of the corresponding rotation of the upper surface.

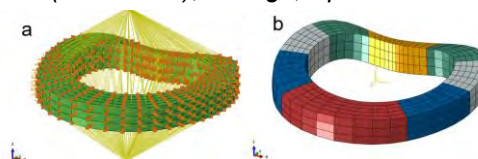


Figure 1: FEM of the T7-T8 AF for the first (a) and second (b) methodology.

3. Results

Table 1 compares ROM obtained with the experimental data [4]. The axial spring model overestimates ROM by 45-197%, while the HGO underestimates it by 3-60%, except in extension at 1Nm.

Experimental ROM (°) (Wilke et al. (2020) [3])				
Load	Flexion	Extension	Lateral bending	Rotation
1 Nm	2.38°	2.50°	3.00°	3.75°
2.5 Nm	3.80°	3.80°	4.70°	5.88°
ROM (°) for the first methodology (axial springs)				
1 Nm	6.00°	7.42°	5.98°	5.75°
2.5 Nm	9.12°	11.05°	8.98°	8.51°
ROM (°) for the second methodology (HGO)				
1 Nm	2.00°	2.76°	1.96°	1.70°
2.5 Nm	2.91°	3.67°	2.99°	2.30°

4. Discussion and Conclusions

Therefore, to study the thoracic ROM, extending AF properties calibrated with lumbar data is inaccurate, requiring thoracic-specific calibration. Furthermore, we found that simulating the AF response with the HGO model has a lower computational cost and is easier to implement and extend to other levels as the geometry of the elements is not dependent on the angle of the CF.

5. References

1. F. Ezquerro et al, Med Eng Phys, 2011
2. L.F. Nicolini et al, Lat Am J Solid and Str, 19:442, 2022.
3. F. Heuer et al, J Biomech., 40(2):271-80, 2007
4. H.J. Wilke et al, Eur Spine J. 29:179-185, 2020.

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