STIFFENING ROLE OF COMPRESSION ON LUMBAR SPINE RESPONSE IN FLEXION/AXIAL ROTATIONS - APPLICATION OF A NOVEL WRAPPING ELEMENT

Shirazi-Adl, A
École Polytechnique, Montréal, QC

**INTRODUCTION:**

In occupational and recreational activities, the human lumbar spine is subjected to large compression loads (~3-4 kN) combined with varying rotations in different planes. The ligamentous lumbar spine, however, can resist without hyper-mobility only a negligible fraction of this force (<100 N). Accurate consideration of the lumbar spine stiffness in large compression loads is essential in many areas; e.g., investigation of industrial low-back disorders, search for optimal lifting postures, evaluation/development of spinal fixation systems/disc prostheses, verification of spinal stability, and quantification of passive resistance for adequate partitioning of loads in biomechanical models of spine. Analysis of the lumbar spine under compression loads, however, is not possible due to the moment artifacts and stability concerns. The current work aims (a) to develop a novel wrapping element that allows for the stable, with no artifact moment, application of large compression forces and (b) to quantify the effect of large compression forces on the response of the lumbar spine in flexion/axial rotations/moments. It is hypothesized that the segmental rotational stiffness in flexion and in axial torsion is markedly dependent on the compression load.

**METHODS:**

A novel wrapping element is developed that allows the application of large compression loads without any hypermobility (instability) and moment artifacts. The compression is applied through cable elements that are attached to vertebral centers and wrap around pre-defined edges at different end-plates so as to follow the curvature of the lumbar spine remaining nearly normal to disc mid-planes [1] (Fig. 1). The position of contacting edges at end-plates is initially adjusted in order to minimize changes in lumbar lordosis as the compression increases up to 2700N. The detailed response of the model is analyzed under flexion and right axial moments up to 20 N-m in presence of a compression preload; 0N, 900N, 1800N or 2700N. Both loads are applied at the L1 with S1 fixed.

**RESULTS:**

Under compression preloads up to 2700 N, the lumbar spine remains stable with negligible changes in lordosis (<1.1°). The compression preloads substantially stiffen the lumbar spine in sagittal flexion (Fig. 2), an effect more pronounced at smaller flexion moments/rotations. Compression load increases facet forces and maximum disc fiber strains whereas it decreases ligament forces. The maximum disc fiber strains (at innermost annulus layers) decrease slightly at smaller flexion rotations but increase at larger rotations. The disc pressure at all levels increases significantly with compression and slightly with flexion. The compression force substantially stiffens the response in axial torque (Fig. 3), especially at smaller torques. It also increases maximum disc fibre strains, disc pressure and facet forces under axial torque.

**DISCUSSION:**

The conventional, gravity-directed, application of axial compression preload, as expected, generates instability in multi-segmental models as well as artifact moments. In contrast, however, the lumbar spine remained stable in this study with nearly no changes in lordosis as the large compression forces were applied by a wrapping element. Larger compression forces could also have been applied. The nonlinear response of the lumbar spine in pure rotations/moments was further stiffened as the compression preloads increased to 2700N. The stiffening effect was much more pronounced at lower rotations/moments. Similar stiffening effects have been measured in studies on spinal single- [2] and multi- [3] motion segments. Due to the marked alterations in stresses, the mechanical role of various components and the risk of tissue injury are influenced by the coupling between loads and motions.

This study confirmed the applicability of the novel wrapping loading allowing the detailed investigation of the entire lumbar spine under large compression loads and rotations without instability or artifacts. It is, hence, an ideal tool for the testing and evaluation of various fixation devices/disc prostheses. Moreover, the substantial increase in the ligamentous stiffness in flexion caused by large compression preloads should be considered in model studies of occupational and manual material handling tasks while partitioning external moments among passive and active components or examining system stability.

**REFERENCES:**

[1]Shirazi-Adl and Parnianpour, Clin Biomech 15:718-725, 2000.
[2] Janevic et al, J Orthopaedic Research 9:228-236, 1991.
[3] Patwardhan et al, J Orthopaedic Research 21:540-546, 2003.

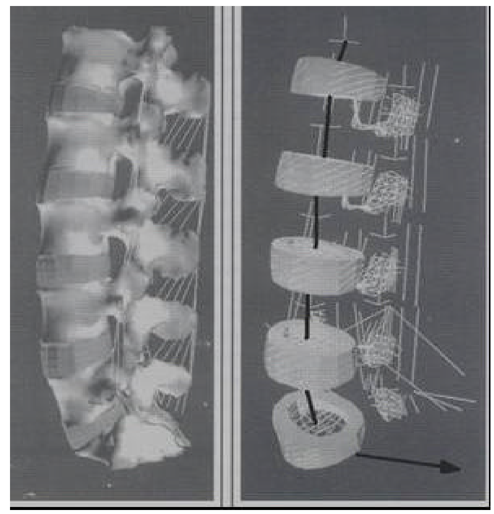

Fig. 1- Views of the FE model showing also the wrapping element.

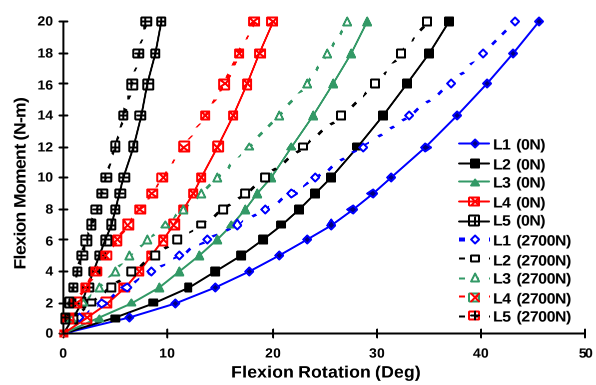


Fig. 2- Lumbar response in flexion ± 2700N compression preload.

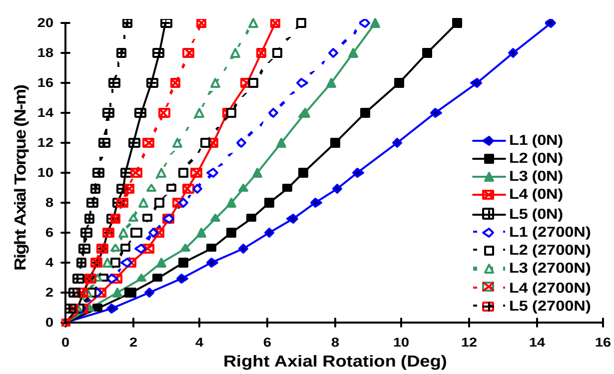


Fig. 3- Lumbar response in torsion ± 2700N compression preload.