Biomechanical Effect of Different Postures and Movements on the Lumbar Spine in Patients with Lumbar Spinal Implants

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INTRODUCTION: The spine is the most central skeletal system supporting the body and consists of the cervical, thoracic, lumbar, coccygeal, and sacral vertebrae, each with 7 cervical vertebrae, 12 thoracic vertebrae, 5 lumbar vertebrae, 5 sacral vertebrae, and 4 coccygeal vertebrae. The overall shape of the spine is S-shaped, with the normal cervical vertebrae curved forward, the thoracic vertebrae curved backward, the lumbar vertebrae curved forward, and the sacral and coccygeal vertebrae curved backward. In this study, we calculated the stresses in different postures when implants were applied to patients with osteoporosis and analyzed the results.

METHODS: In this study, the analysis of a 3D FEM (finite element method) for the vertebral spine was performed. The 3D FEM includes intervertebral discs (including nucleus pulposus and annulus fibrosus), endplates, and facet joints, as well as a lumber spine of L1 to L5 (including cortical bone, cancellous bone, and posterior element). In addition, a sacrum was modeled to apply structural boundary conditions, and thoracic and cervical vertebrae were modeled as a line to reduce FEM computation time. As shown in Figure 1, the FE model was generated according to the posture with a one-level implant. Three types of load modes—flexion, lateral bending, and axial rotation—were applied to the FEM; a load of 300 N was applied to the head; and a moment of 10 N·m was applied along the flexion, lateral bending, and axial rotation movements of the lumbar spine. All structures were connected to each other in bonding contact conditions, and all degrees of freedom for the sacrum were constrained.

RESULTS SECTION: The stresses under flexion loading mode for the four different postures were calculated as shown in Figure 2. Overall, we found that the stresses in flexion mode were greater than the other movements such as lateral bending and axial rotation motion. We also found that the difference in stress values between the different postures is significant. In the case of cortical bone, the stresses in slumped sitting on a chair and sitting on a floor are larger than those in standing and erect sitting on a chair. In the case of annulus fibers and nucleus pulposus, we can see that the stresses in the sitting on a floor and slumped sitting on a chair postures are larger than the stresses in the standing and erect sitting on a chair posture. Finally, for implants, the results for sitting on a floor are significantly higher than the other results.

DISCUSSION: In conclusion, this study highlights the importance of maintaining an upright sitting posture in a chair. Such a posture can effectively reduce von Mises stress on critical anatomical structures such as the annulus fibrosus, nucleus pulposus, and cortical bone. This reduction is comparable to the stress experienced when standing. This finding is particularly relevant to modern people who tend to spend long periods of time sitting. It's also worth noting that the traditional practice of sitting on the floor, common in East Asian cultures, is associated with increased von Mises stresses on the annulus fibrosus, nucleus pulposus, and cortical bone compared to the recommended upright sitting posture on a chair. This particular sitting posture appears to be associated with the development of lumbar degenerative kyphosis, a condition commonly observed in East Asia.

SIGNIFICANCE/CLINICAL RELEVANCE: Incorporating a lifestyle centered around maintaining an upright seated position in a chair and ensuring proper lumbar lordosis will be crucial in the prevention of a range of degenerative disc diseases and spinal deformities.

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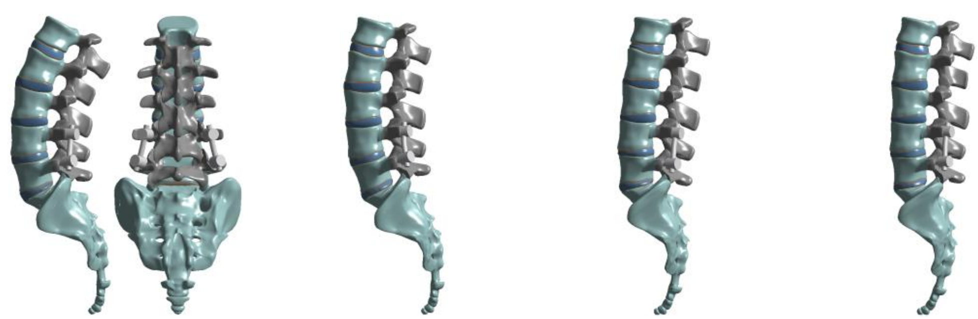
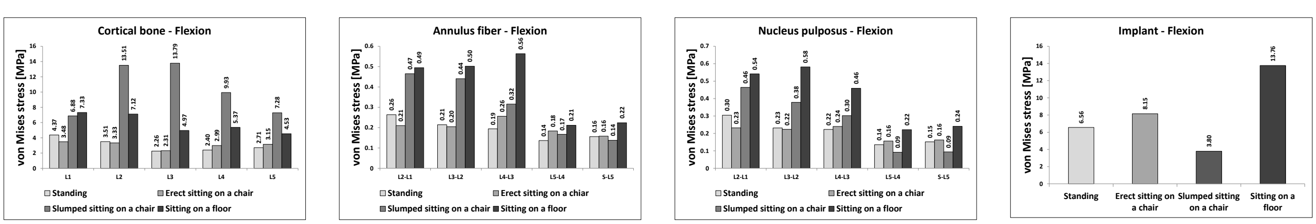


(a) (b) (c) (d)

Figure 1. Vertebral body finite element model by posture: (a) standing, (b) erect sitting on a chair, (c) slumped sitting on a chair, (d) sitting on the floor



(a) (b) (c) (d)

Figure 2. Results of von Mises stress in flexion movement: (a) cortical bone, (b) annulus fiber, (c) nucleus pulposus, (d) Implant