In Vivo Deformation Of L4-5 And L5-S1 Discs During A Weight-lifting Extension

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Introduction: Degenerative disc diseases (DDD), such as degenerative spondylolisthesis and disc herniation, were usually found at distal lumbar levels (L4/5 and L5/S1). However, the etiology of lumbar DDD is still unclear. Lumbar DDD is thought to be related to the abnormal kinematics and biomechanics of the discs [1]. Knowledge of in vivo deformation of the lumbar discs is critical for understanding the lumbar function and for improving surgical treatments of lumbar pathology.

Methods: Eight subjects were MRI scanned in supine positions (4 males and 4 females, aged between 40 and 60 years). 3D models of the L4- S1 vertebrae were constructed using their 3D MRI images in a solid modeling software (Rhinoceros®, WA). The lumbar spine of each subject during a dynamic weight-lifting activity, extension from a flexion position (~45°) to the maximal extension position, was imaged using a dual fluoroscopic imaging system (DFIS). The captured fluoroscopic images and the 3D vertebral models were input into the Rhinoceros software to create a virtual DFIS. Each 3D vertebral model was independently translated and rotated in the virtual DFIS until its projections to match the osseous outlines captured on the two fluoroscopic images (Fig. 1a). For each vertebral segment, the coordinate system of the lower disc surface was selected to be the reference coordinate system. The overall deformations of the disc were calculated using the relative positions of the corresponding disc surfaces [2]. The disc status obtained during the non-weightbearing MRI scanning was used as a zero deformation condition for calculation of the disc deformations. In this study, we determined the overall deformation of the discs at the anterior edge, center and posterior edge of the discs in the middle sagittal plane (Fig. 1b).

Results: The maximum tensile, compressive and shear strains were located on the edges of discs during the extension motion (Fig. 2). The compressive deformation at the anterior and center points of both L4/5 and L5/S1 gradually decreased with extension of the body (Figs. 2a and b). At the posterior point, the L5/S1 was compressive at around 6% during the extension motion, but the L4/5 experienced an increased compression with extension of the body (12.5% at late stage extension). Anterior-Posterior (AP) shear deformation of the L4/5 changed from anterior to posterior directions during the extension motion, whereas the L5/S1 experienced an anterior shear deformation along the path (Figs. 2d, e and f). At the posterior point, the L4/5 experienced a range of shear deformation of 34%, while the L5/S1 was almost under a posteriorly constant shear deformation of 22% during the entire extension motion.

Discussion: This study analyzed the overall disc deformation of lumbar L4/5 and L5/S1 segments during dynamic motion. The two lumbar discs experienced different overall deformation during the extension motion of the body. Recent epidemiology studies showed high incidence of degenerative
spondylolisthesis in L4/5, but more disc herniation at L5/S1 [3-4]. The different disc deformation patterns experienced in daily activities may help explain the different disc pathologies observed in clinic. **Significance:** L4/5 and L5/S1 experienced different disc deformations during the extension motion of the body. The data may provide insights into the understanding of disease development mechanisms of the lower lumbar segments and developing segment-dependent surgical techniques.

Figure 1. (a) Reproduction of the dual fluoroscopic system and the vertebral positions; (b) A, C and P represented the points at anterior edge, center and posterior edge of the discs.
Figure 2. The average tensile (+)/compressive (-) deformation and anterior(-)/posterior(+) (AP) shear deformation during the extension activity at the anterior (a & d), center (b & e) and posterior (c & f) locations of the discs. The A, C and P represented the points at the anterior edge, center and posterior edge of the disc in sagittal plane. Error bars represented the standard deviations.