In-vivo Lumbar Vertebrae Kinematics

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Introduction
Quantification of lumbar spine kinematics in normal subjects is critical for investigating the biomechanical factors that cause spinal pathology as well as for further improving surgical techniques designed to restore normal lumbar function. However, due to the limitations of current technology and the complicated anatomy of the spine, a quantitative understanding of in-vivo kinematics under active physiologic weightbearing activities remains elusive.

This paper uses a newly developed combined MR and dual orthogonal fluoroscopic imaging system (DFIS) method [1] to investigate lumbar spine motion in human subjects under weightbearing conditions. The objectives are to quantify the normal lumbar vertebral range of motion (ROM) in-vivo at different lumbar levels.

Methods
Eight asymptomatic subjects with an age ranging from 50 to 60 years were recruited for this study under the authors’ institutional review board approval and examined for the absence of low back pain and other spinal disorders. The lumbar segments of each subject were initially MR scanned in a supine position. Parallel sagittal images of 1.5 mm thickness were obtained to construct 3D models of L2-L5. Following MR scanning, the lumbar spines of the subjects were imaged using the DFIS [1]. The subjects were asked to stand and position their lumbar spines within the view of both fluoroscopes and actively move to different postures in a predetermined sequence: standing, 45° flexion, left-right bend, and left-right twisting (Fig 1a). Two orthogonal images of the targeted spinal segment were taken at each posture simultaneously from two directions. Using 3D and 2D registration, the MR models were matched to the osseous outlines of the fluoroscopic images from the two orthogonal views to quantify spine kinematics at each activity in 3D (Fig 1b).

Results
Mean translations in all three directions ranged between 0.2 and 1.5mm. Translations in the anterior-posterior (0.7-1.4mm) and left-right (0.5-1.5mm) directions were similar and were higher than the cranial-caudal direction (0.2-0.7mm) in general. The corresponding translations were similar for different motions and at different segmental levels.

During flexion-extension motion, the flexion ranges were 5.4°, 4.3° and 1.9° on average for L2-3, L3-4 and L4-5 levels, respectively (Fig 3a). The upper level had a higher ROM and L2-3 and L3-4 had significantly higher flexion ranges than the L4-5 [2] which facilitates flexion. This difference may also be attributed to the lordosis of the lumbar spine. Besides the primary rotations, coupled translations were found to be greater in the left-right and anterior-posterior than proximal-distal directions. Coupled bending and twisting motions were found to have a larger range of motion than coupled flexion.

This data provides baseline information on the normal ROM of the lumbar vertebrae on which there is no consensus at present. Several radiographic diagnostic criteria have been proposed for lumbar spine instability: vertebral translation >3-5 mm or relative endplate orientation >10-20° in the sagittal plane [3]. The normal segmental ROM we measured was within a mean of 2mm and 6°. In the future, we intend to increase the number of subjects tested to increase the statistical power in order to help establish a standard. We also hope to include translational and rotational limits in the coronal plane for this new standard. Furthermore, this method can be used to study and compare patients with low back pain to help improve surgical treatments aimed at restoring normal kinematics.

References