In-vivo Kinematics of Lumbar Facet Joints

Kozanek, M; Wang, S; Xia, Q; Wood, KB; Li,G
Bioengineering Laboratory, Massachusetts General Hospital and Harvard Medical School, Boston, MA
Senior author: gli1@partners.org

INTRODUCTION: Alterations in motion of the facet (zygoapophyseal) joints have been thought to be associated with various types of lumbar spine pathology including disc degeneration, facet degeneration and neural impingement. However, determination of normal in-vivo motion of the lumbar facet joints remains elusive despite numerous in-vitro studies,[1] animal models[2] or finite element simulations [3]. In this study we applied a new imaging technique combined with advanced computer modeling to non-invasively investigate the kinematics of lumbar facet joints in vivo.

MATERIAL AND METHODS: Eleven healthy subjects were first MR imaged in supine position to obtain three-dimensional (3D) models of the lumbar vertebrae from L2 to L5 by segmentation. Next, each patient was scanned using the dual-fluoroscopic imaging system (DFIS) while positioning the upper body in different postures [4]: maximal forward-backward and side-to-side bending, and maximal left-right torsion. The DFIS setup was then re-created in a virtual environment of solid modeling software where positions of the vertebrae were reproduced at each studied posture by matching the 3D MR-based models to the contours of lumbar vertebrae on the fluoroscopic images. Following this, the facet joint kinematics was measured using a Cartesian coordinate system placed in the center of each facet (**Fig. 1**). The standing position was compared to the reference MR (supine) position and the ranges of motion from the end-points of bending and torsion of trunk were also determined.

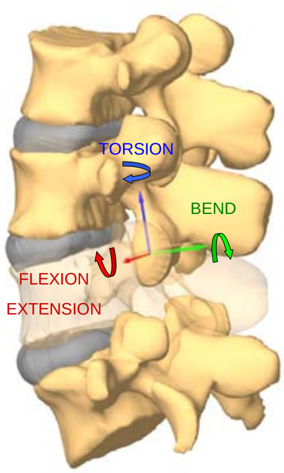

Fig. 1 3D MR-based model of lumbar spine (L2-L5). Cartesian coordinate system was constructed at the center of each superior and inferior articular facet. Motion was measured as motion of the proximal coordinate system (inferior facet of cranial vertebra) with respect to the distal one (superior facet of caudal vertebra).

RESULTS: From supine to standing position the facet joints rotated around the medio-lateral axis (<5°) and translated mainly in the proximal-distal direction (<3 mm, **Fig. 2A**). Likewise, during flexion-extension of the trunk, the predominant motions were rotation along the medio-lateral axis (<7°) and proximal-distal translation (<4 mm) (**Fig. 2B**). Concurrently, the range of motion was observed to be greater in the upper segments (*p*<0.05). During side-to-side bending of the trunk, the motion of the facet joints was also noted to be a coupling of rotations (<6°) (**Fig. 2C**). The primary rotation during this motion was along the antero-posterior axis and its magnitude was greater in the caudal segments i.e. L2-3 < L3-4 < L4-5 (*p*<0.05). Torsion of the trunk was achieved by coupled rotations about the superior-inferior (twist) and antero-posterior axis (bend) (**Fig. 2D**). While the magnitude of the bending component decreased from cephalad to caudad (*p*<0.05), the magnitude of the twisting component increased (*p*<0.05). Translations measured during bending and torsion of the trunk had no predominant direction and their magnitudes were less than 2.5 mm. In addition, slight asymmetry was observed in the translational motion of the facet joints between the left and right side.

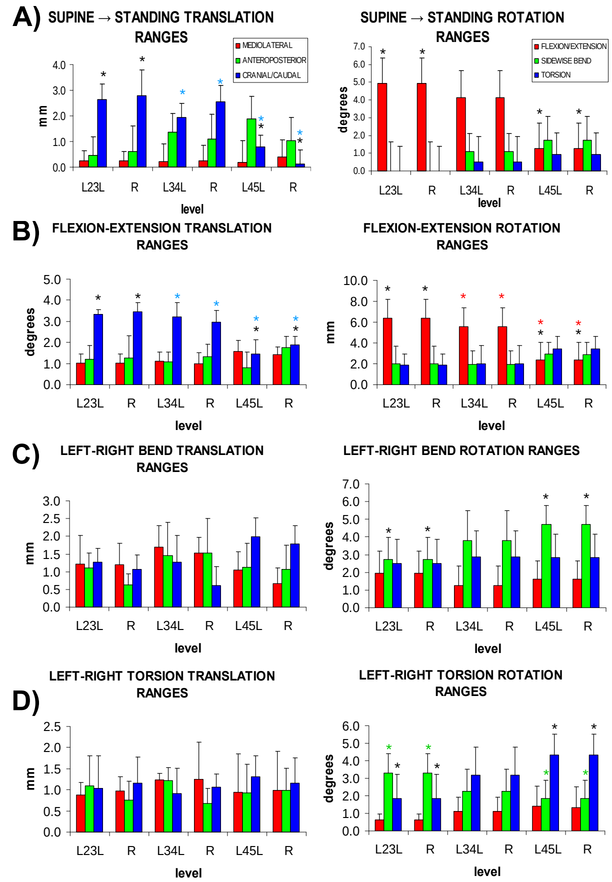

Fig. 2 Ranges of rotations and translations measured in the lumbar facet joints of L2-3, L3-4 and L4-5 levels. Asterisk denotes statistically significant difference at *p*<0.05.

DISCUSSION: This study is the first in-vivo report on the 6DOF kinematics of the lumbar facet joints. We noted that for such a small joint the ranges of motion were of considerable magnitudes (up to 4 mm in translations and up to 8° in rotations). Further, during flexion-extension of the trunk, the facet joints were demonstrated to rotate primarily along the medio-lateral axis and shift in the proximal-distal direction. During the other studied activities of sidewise bend and torsion, the facet joints did not move in one predominant direction of rotation or translation. Instead, the resulting motion was a kinematic coupling of rotations and translations in different directions. This may be related to the different orientation of the facet joints at cranial and caudal levels. Additionally, we observed that the translations were not perfectly symmetrical between the left and right side of the same level. This can be explained by the inherent asymmetry in lumbar facet orientation that has been documented in anatomical studies.[5]

In an era of emerging interest in dynamic fusions, posterior element replacement and total facet arthroplasty systems, this data provides important information that can guide designers with regards to the motion that the implants should accommodate. Based on previous biomechanical studies it can be assumed that implants significantly limiting motion at the instrumented segments might put the adjacent segments at risk of developing degenerative changes and conversely, excessive motion may abnormally stress the intervertebral disc.

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