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Three-Dimensional Motion of the Human Lumbar Spine

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Short Communication

Lumbar spine pathology accounts for billions of dollars in societal costs each year. Although the symptomatology of these conditions is relatively well understood, the mechanical changes in the spine are not. Previous direct measurements of lumbar spine mechanics have mostly been performed on cadavers. The methods for *in vivo* studies have included imaging, electro goniometry, and motion capture. Few studies have directly measured *in vivo* lumbar spine kinematics with in-dwelling bone pins. This study tracked the invivo three-dimensional motion of the entire lumbar spine (L5 to S1) in 10 healthy, young-adult subjects. Two 1.55 mm (0.062 inches) diameter Kirshner wires were inserted into each vertebra's spinous process under anesthesia. Motion capture cameras were used to track a triad of passive markers attached to the wires. Offsets between anatomical landmarks and tracking markers were established with a CT scan for each individual vertebra.

Subjects were asked to perform various exercises including walking and voluntary range of motion. Subjects were able to complete all of the exercises. All subjects reported being adequately informed of all of the procedures and there were no neurological or orthopaedic complications. The range of the average inter-segmental range of motion was 4.268 to 4.388 in the sagittal plane, 2.618 to 4.008 in the coronal plane and 4.118 to 5.248 in the transverse plane. Using a direct (pin-based) *in vivo* measurement method, the motion of the human lumbar spine during gait was found to be triaxial. This appears to be the first three-dimensional motion analysis of the entire lumbar spine using indwelling pins. The results were similar to previously published data derived from a variety of experimental methods. Adult degenerative spine disease is a significant problem, accounting for an estimated societal cost of 25 to 100 billion dollars in medical expenses, disability, and lost work time. As the spine degenerates, it is assumed that the mechanical properties change, and while the symptomatology of these conditions is relatively well understood, the mechanical changes in the spine are not.

Most of our understanding of the motion of the lumbar spine is based upon cadaveric models or *in vivo* models using clinical goniometric measurements, radiographic imaging or surface optical markers. Cadaveric models allow invasive, rigid fixation of bone pins and optical markers, but eliminate the effect of normal muscle contraction and limit the ability to measure motion during activities of daily living. Videofluoroscopic imaging has been used to measure flexion and extension, as well as lateral bending during common activities, but this technique is limited in its ability to detect translational and rotational movements about the lumbar spine. Electrogoniometers have also been used to describe three-dimensional motion of the spine. Several studies have reported on the intra- and interobserver variability of these techniques with reassuring results. However, most devices, such as the commonly used OSI CA 6000, are limited in their ability to discern segmental motion, and only measure global lumbar movements. Surface optical markers have been utilized in many series, but movements in the transverse plane have not been possible to measure due to the inherent error of motion at the bone-subcutaneous tissue/skin interface.

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