Novel in vivo motion analysis of the healthy lower lumbar spine during standardized movements and complex daily activities

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INTRODUCTION The purpose of this in vivo study was to evaluate the relation between posture or external moments and segmental motion for the lower spine L3-L4-L5 during standardized movements.

METHOD The study was performed on five normal healthy men (age 26 to 48). Once written informed consent was obtained, indwelling pins of 2.5 mm diameter were inserted into the spinous processes of L3, L4 and L5 (Fig. 1). Three sensors of the motion tracking system FASTRAK were attached to these pins. A fourth sensor was placed on the skin over the spinous process of C7 to measure spine movements. Kinematic data of the segmental motion of L3-4 and L4-5 were recorded at 30 Hz in 6 degrees of freedom. Segmental motion was computed by a modified method described by Steffen [1]. Simultaneously, a video based motion analysis system was used (VICON) sampling kinematic data at 50 Hz. External body markers were attached to the skin over the spinous processes of C7, T4, T9, L1, the shoulders, the pelvis and 15 extra points of the body (Fig.2). Three additional markers were placed on the pins in two planes connected with the sensors of FASTRAK to enable the spatial co-ordination between VICON and FASTRAK. Ground reaction forces were measured at 50 Hz by KISTLER force plates. Unconstrained standardized movements (flexion / extension, lateral bending, axial rotation) were studied.

RESULTS In vivo segmental motion and range of motion for the segments L3-4 and L4-5 was computed for the sequence of events with an accuracy of 0.2 mm and 0.1° respectively. The range of segmental motion was similar to the results reported earlier by Steffen [1] and Pearcy [2]. We identified coupled motion as reported by Steffen [1]. The motion of the segments in relation to posture (Fig.4) was demonstrated in animated sequences (Fig.3). The position of the approximated instantaneous axis of rotation (IAR) was determined with an accuracy of 3 mm (sd) for flexion/extension (Fig. 5) and lateral bending. For flexion/extension IARs were mainly located in a restricted area slightly below the superior end-plate of the lower vertebra (Fig. 5, 3D-illustration). This result is comparable with the results of Pearcy [3]. In some cases we have noticed a shift of the axis towards the zygapophysial joints (Fig.5, cloud of dots) when moving from flexed to the upright position. During lateral bending (Fig. 6) for all subjects the IAR moved from one side to the other with an inclination of 15 degrees to the lower endplate, similar to the inclination of the upper endplate (Fig.6, 3D-illustration)).

DISCUSSION Unique to our study is the fact that we measured time synchronized lumbar spine motion in combination with posture (3D-body motion) and ground reaction forces. This allowed us to compare different trials and different subjects with each other and potentially provides data for an inverse dynamic approach. Resolution and accuracy was comparable to stereo radiography and in vitro studies. Our approach allows in vivo measurements during different tasks of daily living and special load cases.

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REFERENCES

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Fig. 1: Light reflecting markers of VICON on skin and pins inserted into spinous processes of L3, L4 and L5 with attached sensors of FASTRAK.

Fig. 2: Position of 30 external body markers of VICON to determine whole-body posture and spine movements.

Fig. 3: Time series of grid figures showing a lateral flexion to the right and left as seen from behind.

Fig. 4: Lateral flexion in five subjects in segment L4-5 (measured using FASTRAK) versus lateral flexion of the trunk (measured using VICON).
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Fig. 5: Position of IARs and translation of three selected points on L3 for flexion in sagittal view and in 3D-illustration.

Fig. 6: Position of IARs for lateral bending in ap-view and in 3D-illustration.