A reference database of standardised continuous lumbar intervertebral motion analysis for conducting patient-specific comparisons

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Introduction

To understand spinal disorders in terms of their biomechanical effects on symptoms and evaluate treatment effects, biomechanical variables must be repeatable over an acceptable follow-up period in a symptomatically stable population. In previous work using quantitative fluoroscopy (QF), where both the motion task (lumbar flexion) and the analysis were highly standardised, some intervertebral motion sharing characteristics in the lumbar spine were found to be significantly different in NSLBP patients and asymptomatic controls **(1)**. Control measurements were also stable over 6 weeks, making measures suitable for use in outcome and prognostic studies **(2)**.

Previous studies have found it advantageous to study the outward and return paths of lumbar flexion separately in order to appreciate the differences in dynamic loading models during bending and lifting tasks **(3)**. Against such normative data, individual patient studies using the same protocols can be compared. The aim of this study was to establish a database of reference values for key dynamic lumbar motion variables during controlled outward and return bending using standardised QF recording and analysis protocols. These could serve as reference information for both the construction of mathematical models and for comparison with patient-specific kinematics.

Methods

Low dose continuous fluoroscopic image sequences, recorded at 15 fps, were acquired from 131 asymptomatic participants during active, weight-bearing lumbar flexion and return motion. This used a bending protocol guided by an upright motion frame **(Fig 1).** This standardised the bending range and velocity and minimized accessory movements. Continuous intervertebral rotations in the sagittal plane were extracted for each level (L2-S1) in each frame and transformed into contributions proportional to the total L2-S1 angle. Mean and ± 95% confidence intervals across all participants were calculated for each 1% increment of L2–S1 motion. Data were separated to distinguish the flexion and return-to-neutral portions of the bending task. Statistically significant differences between each level's contribution to motion were detected by the absence of overlap in the ±CI95 bands and checked using statistical parametric mapping.

Results

Full data sets were extracted from 127 participants, (48.8% female, mean age 38.6 years, range: 21-70). The proportion of the motion performed by each level at full flexion was similar to previous studies **(4)**. However, there were significant differences in the contributions to bending during motion, both between and within levels, which change as participants progress through the tasks **(Figures 2a and b)**. Across the study population, each intervertebral level also had its own characteristic motion signature, with significant differences ($p<0.05$) between each level's contribution. These were sustained throughout the motion.

In the individual back pain patient example (Fig 2c), L2-3 initially accepted a higher proportion of the outward motion than that of the controls (Fig 2a), and considerably less at L4-5, although both showed return to near-normal sharing levels by completion of the bend. On the return motion (Fig 2d), it is L4-5 that initially accepts a higher proportion in this patient, and L3-4 considerably less, although by the time the upright position has been reached and all but L4-5's share of the motion resemble the normative values (Fig 2b).

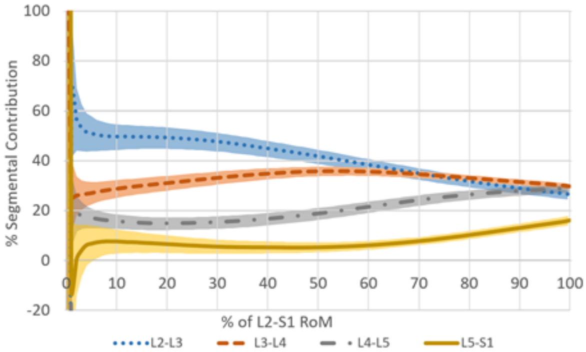
Figure 1. Upright motion controller

Figure 2. Proportional contributions to motion from L2-S1 with 95% CIs in 127 healthy controls in a) flexion, b) return and comparison with a patient with chronic, non-specific low back pain c) and d).

Controls (n=127)

Outward

Return



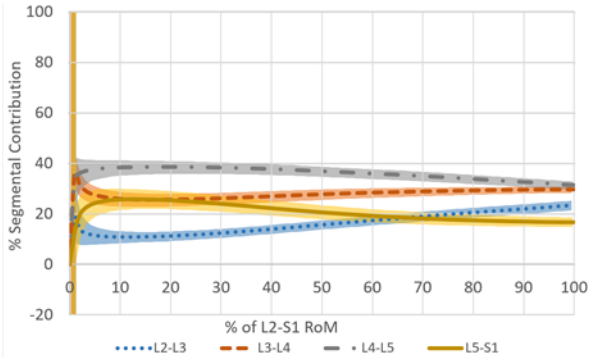
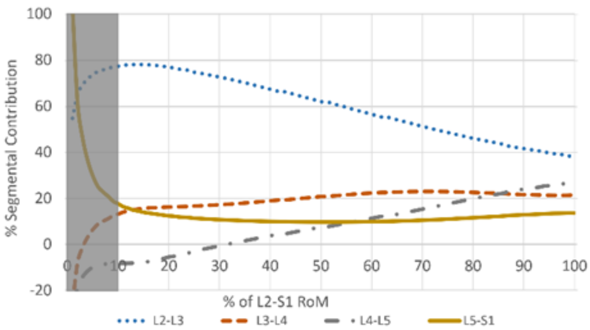


Figure 2a

Figure 2b

Patient (n=1)



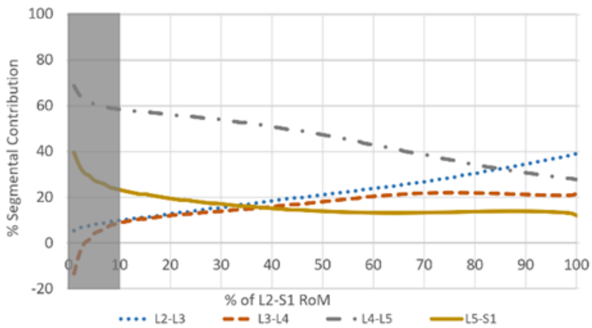


Figure 2c

Figure 2d

Discussion

In the controls (Fig 2a and b), despite differences in gender, BMI, age, anatomy, co-ordination and strength, all levels exhibited consistent motion contributions. This was attributed to the use of the guided motion apparatus (Fig 1) making the database also suitable for comparison with both cross-sectional and longitudinal data from individuals and with groups of patients with low back pain in research and clinical studies. The patient (Fig 2c), exhibits much more initial flexion at L3-4 than the controls during forward bending, while L4-5's motion is initially paradoxical. On return, L4-5 initially accepts much more of the motion and L2-3 much less (Fig 2d). These differences are likely to be related to a combination of loading, motor control and tissue material characteristics. They may also be suitable for modelling dynamic segmental loading in clinical and occupational settings.

References

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