SEGMENTAL ANGULAR VELOCITY PROFILE SHOWS DIFFERENT PATTERNS IN NORMAL SUBJECTS AND SUBJECTS WITH L5 ISTHMIC SPONDYLOLISTHESIS (A VIDEOFLUOROSCOPIC STUDY)

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INTRODUCTION
Current definitions of spinal instability are based on a loss of stiffness. Increased range of motion measured on functional radiographs is the most popular parameter to identify clinical spinal instability. There is some agreement that a “giving away”, “slipping out” and “catch” during spinal motion is a sign of instability, but this cannot be defined from static functional radiographs. It is hypothesized that changes in the segmental angular velocity might be a useful parameter in defining clinical instability because all of these signs relate to a sudden change in the segmental motion.

The objectives of this study were to establish in vivo instantaneous velocity and acceleration profiles of L5-S1 segment during forward bending, and to compare the profiles of these non-symptomatic controls with those of mechanical lesion caused by L5 isthmic spondylolisthesis.

MATERIALS AND METHODS
Five patients (3M2F, average age 32.8 [24-41] years old) with L5 isthmic spondylolisthesis were examined. Five healthy male volunteers (average age 36.6 [34-40] years old) with no observable lumbar abnormalities on plain radiographs and without low back pain in the previous 12 months comprised the control group.

With pelvic motion limited by a purpose-built fixator, the subjects were asked to bend forward from full extension to full flexion slowly and smoothly as possible. The L5-S1 sagittal motion was observed by fluoroscopy (Siregraph D2, Siemens, German) and recorded using S-VHS video.

The video data were converted to still images at 25 frames per second (25Hz) on a personal computer. The serial still images were digitized using a purpose-written program with 1 pixel sensitivity. A radio-opaque grid was measured horizontally and vertically to obtain the spatial ratio of the screen for calibration.

The L5-S1 segment was first digitized at 5Hz and its’ angular position profile was plotted to reveal the instantaneous angular range of motion from full extension to full flexion. The maximal angular range of motion was determined from the profile, then the still images from the beginning of the motion to the maximal angular range of motion were further digitized at 25Hz to calculate L5-S1 disc angular velocity and acceleration, as well as the coupled horizontal and vertical translation of L5 to S1 in the same plane.

All the images were digitized by one researcher. The standard deviation of six times remarking and remeasuring of a single disc angle was 0.83°; horizontal translation was 0.78 mm; and vertical translation was 0.50 mm. To remove high frequency noise, the angular and transnational position profiles were smoothed using 3 points moving average method. The obtained velocity and acceleration profiles were also smoothed using the same method.

The experimental protocol was approved by the local university ethics committee, and an informed consent was signed by all the subjects involved in this study.

RESULTS
End Angular ROM versus Maximal Angular ROM
The L5-S1 disc reached its maximum angular displacement before the ends of full extension to flexion motion. The maximum angular ROM at L5-S1 was generally seen between one and two thirds of the full forward bending motion.

Sagittal angular motion.
In a normal subject, change in L5-S1 disc angle from full extension to full flexion showed a gradual acceleration to a single peak velocity. The velocity was slow at the beginning, building to the peak velocity located in the later phase of the profile, with the maximum acceleration just before the peak velocity and the maximum deceleration just after it (Figure 1).

Besides the typical single peak pattern, patterns with more than one peak were also observed in the control subjects.

In L5 isthmic spondylolisthesis, the angular velocity profile typically showed a multiple peak pattern. Disc angle increased very quickly at the beginning, then suddenly slowed down. This cycle repeated several times throughout the complete profile. Compared with the smooth increase in angle in normal subjects, the change in L5-S1 disc angle in subjects with isthmic spondylolisthesis was completed in a jerky, stepwise style (Figure 2).

**REFERENCES**
3. Typical angular velocity profiles in normal subject observed in a normal subject
4. Multiple peak pattern in L5 isthmic spondylolisthesis

DISCUSSION
The maximum angular ROM at L5-S1 was observed before the full forward bending motion was completed. It indicates that the ends of intersegmental motions may show a phase lag phenomenon, i.e., the L5-S1 disc reached its maximum angular displacement while the other segments are still bending forward.

Unlike in vitro experiments, the bending velocity between individuals is highly variable and difficult to control. Therefore, a quantitative expression of the bending velocity may not be suitable in defining spinal impairments. A more qualitative approach, such as the pattern of the angular velocity profile, may be a more ideal parameter in interpreting dynamic information for clinical diagnosis. The subjects with L5 isthmic spondylolisthesis demonstrated different angular motion profiles to those of normal subjects, and these profiles are not affected by the absolute magnitude of the velocity.

Our investigation suggests the hypothesis that unstable spinal segments shows a more jerky intersegmental motion, and therefore the pattern of the segmental angular velocity may be useful in identifying spinal instability.

The coupled horizontal and vertical translation of L5 to S1 were also investigated but not presented here, as the variability of the current translation measurements is too large for any meaningful conclusions to be drawn.

CONCLUSION
1. L5-S1 segmental dynamic motion behavior during forward bending from full extension to full flexion was affected by the presence of isthmic spondylolisthesis.
2. L5-S1 disc angulation reached its maximum before the whole forward bending process finished.
3. Typical angular velocity profiles in normal subjects showed a gradual increase to a single peak velocity, whereas subjects with L5 isthmic spondylolisthesis demonstrated a multiple peak pattern.