DYNAMIC SAGITTAL SPINAL CURVATURE MEASUREMENT IN LOW BACK PAIN SUFFERERS

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SUMMARY
Continuous sagittal curvature measurement of the spine is complex but may provide important kinematic information regarding movement behaviour. The aim of this study is to determine if a new fibre-optic ribbon of sensors can be used to investigate the curvature and sagittal sequencing behaviour of the spine. Twenty chronic low back pain (LBP) sufferers were requested to complete flexion, extension and lifting. Data were processed in Matlab by fitting Cartesian coordinates, provided by the system, with a spline and calculating curvature through the intersection of two tangents (S1-L1; S1-L3). The Coefficient of Multiple Correlation (CMC) and root mean square error (RMSE) were used to determine reliability and error of measurement and sequencing behaviour was investigated by observing the sagittal profile for each 25% of time. In those subjects whose pain was evoked by flexion and lifting, sagittal sequencing showed a delay in the greatest curvature change (third 25%) as opposed to the second 25% for those without evoked pain. Furthermore the system showed high consistency with CMC values of >0.96 and RMSE <2.7°. The fibre-optic system offers a reliable option for the measurement of curvature through time and can be used to monitor the change in sagittal profile across time.

INTRODUCTION
The ability to observe continuous spinal curvature through time is complex; however this may yield important information about sequencing behaviour of the spine. Recently a fibre-optic sensor ribbon has been shown to be reliable and valid compared to a video system for measuring curvature of the whole and lower lumbar spine [1]. This system houses a series of sensors which measure curvature through modification of light flow throughout its length. This can then be used to reconstruct a sagittal profile which if monitored through time may offer information about sequencing behaviour of the spine.

The aim of this study is to determine if such a system can be used to investigate the sagittal sequencing behaviour of LBP sufferers.

METHODS
Twenty chronic LBP sufferers were recruited from general practitioner referrals to a physiotherapy clinic. Inclusion criteria were movement evoked LBP present on at least 3 days per week, every week for at least 12 months, with pain confined to between the lower ribs and inferior gluteal folds. Exclusion criteria included leg pain, a history of cancer, spinal fracture or surgery. This study was approved by the National Research Ethics Service of the NHS.

A series of 8 paired, fibre-optic sensors attached to a ribbon of sprung steel (‘Shapetape’, Measurand, Canada) were used to measure spinal motion and curvature. The sensors (60mm apart) determine curvature through the degree of modification in transmitted light and position (Cartesian coordinates) data are provided by the system with reference to the base sensor. The base reference sensor was attached securely to the skin overlying S1 and the ribbon fed into a modified elastic bandage housing allowing it to slide during movement. Data were captured using software developed by the company at 100Hz.

Measurements were taken along the spine from S1 to L1 and L3 in standing, extreme flexion, posturing to lift a crate and extreme extension. These measurements were used to locate the L1 and L3 relative to S1 and used as input parameters to determine tangent location. Furthermore these measurements determine the spinal length change associated with the particular movements. Participants stood on designated markers and were requested to bend as far as possible, pause briefly and return to upright. This was repeated on three occasions. Identical instructions were given for backward bending and lifting. The crate was placed on designated markers to ensure consistent positioning.

All data were processed with MatLab (Mathworks, R2008b). Sagittal data (Cartesian coordinates) were fitted with a piecewise cubic hermote interpolating polynomial (Matlab function ‘pchip’). Curvature was defined as the intersection of two tangents, at S1 and L1 (or L3). The curvature-time data were adjusted to compensate for the change in lumbar spinal process location relative to S1 associated with spinal motion. This was achieved by using the magnitude of curvature to map the rate of length change between standing and the extreme posture for each time point across the movement trial. Motion onset and offset was determined using a specific algorithm and data trimmed to remove the stationary part.

Two methods were used to study curvature behaviour of the spine. Firstly, the data were trimmed to include standing to end of range only and sagittal profiles across time were plotted every 10Hz. Data were separated by sectioning the time base into quarters to determine the rate of change in sagittal profile. Secondly, curvature-time curves were time normalized and the correlation of multiple coefficient (CMC) was determined.
along with the 95% confidence interval. Furthermore root mean square errors (RMSE) were used to determine the repeated measurement error, for the whole lumbar spine S1-L1 and lower lumbar spine S1-L3.

RESULTS AND DISCUSSION
Sagittal sequencing shows that evoked pain was common in those whose quartile of greatest change deviated from the second, for the movement of flexion fig 1, which was more evident in the lower lumbar spine. Evoked extension pain was associated with a delay in quartile of greatest change. No such pattern was evident for lifting.

The curvature-time curves were highly consistent for both spinal regions across all movements; 0.96±0.02 and 0.93±0.06 for whole and lower lumbar spine respectively. A single subject’s flexion graph with 95% confidence banding is displayed in fig. 2. The mean RMSE across all movements were 2.6±0.8° and 1.9±0.5° for the whole and lower lumbar spine respectively. These findings show that the fibre-optic system is highly reliable for measuring the movement time behaviour of the lumbar spine.

This study is the first to describe the use of a fibre-optic sensor ribbon for the measurement of lumbar curvature and the observation of curvature change through time. This new motion analysis system can perform reliably for the measurement of curvature during flexion, lifting and extension with small RMSE in LBP sufferers. Furthermore due to the continuous representation of spinal shape provided by the system the observation of shape change across time can be monitored to provide additional information about LBP movement behaviour. The results of this study suggest that LBP sufferers whose pain is evoked by flexion make the greatest curvature change in a quartile other than the second. The third quarter of the forward bending movement is associated with large anterior trunk displacement and therefore high levels of load onto which the subject then completes a large curvature change, adding significant stress to the spine. The first quartile may see early electrical silence in the spinal muscles resulting in an increase in stress to the osteoligamentous spine.

ACKNOWLEDGEMENTS
The authors wish to thank the Private Physiotherapy Education Foundation for funding support along with H-scientific for technical assistance.

REFERENCES
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Figure 1: Sagittal profile of a LBP sufferer with evoked pain during flexion (left) and LBP sufferer without evoked pain (right) every 10Hz. Each line represents a moment in time. Blue is first 25% of movement; green is second 25%; red is third 25% and cyan is fourth 25%.

Figure 2: The mean CMC curve with 95% confidence banding to show the variance in movement trials.

CONCLUSIONS
The fibre-optic system is able to reliably measure spinal shape in LBP sufferers. Moreover it offers the ability to provide visualisation of the entire sagittal shape of the spine which can be used to determine shape behaviour of the spine during functional tasks. Movement evoked LBP may be associated with altered curvature change timing in the lumbar spine.