Relationship Between Pain and Vertebral Motion: A Neural Net Analysis
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Purpose. This study was undertaken to investigate the relationship between low back pain and spinal motion. While numerous studies have demonstrated that individuals with low back pain have impaired spinal motion, few studies have examined the specific relationship between segmental spinal motion and pain. We have applied neural networks to study the relationship between pain and motion parameters, investigating whether the nonlinear and learning features of neural networks are more powerful than linear analyses (discriminate analysis).

Method. Chronic low back pain patients undergoing external spinal skeletal fixation (ESSF) as a clinical test participated in this study. This ESSF test involves placement of intrapedicle screws into the right and left L4 (or L5) and S1 segments, and immobilization with an external fixation frame. The fixator is left in place for approximately eleven days and the patients symptoms are observed as a diagnostic test evaluating whether immobilization relieves their symptoms. The subjects were studied immediately after the ESSF frame was removed at completion of the clinical test. Accordingly, the patients were no longer immobilized, yet they still had the pedicle screws in place. Clusters of four infrared light emitting diodes were mounted on each of the four pedicle screws. The three-dimensional locations of these markers were recorded using a kinematic data acquisition system (Optotrack). Each of the subjects performed a standard battery of spinal motions including bending in all planes and walking. The level of pain experienced during the motion was recorded on a 10-point scale. All movements were unconstrained and performed at a self selected rate and extent. Plane films were used to define local vertebral body coordinate systems with respect to the ired clusters. Intra- and intervertebral motions were calculated, and the time series data was reduced to ranges of motion for each test (thirty-two motion parameters per trial). A three layer neural network with fast back propagation learning algorithm was designed to investigate the relationship between the pain and motion parameters. The input layer had thirty-two neurons corresponding to the thirty-two normalized motion parameters. There were thirty-two neurons in the hidden layer and the normalized pain level was the single output neuron. For comparison, a discriminate analysis was performed to evaluate whether a linear combination of motion parameters can describe the relationship between pain and motion.

Results. There were 245 trials available from nine patients. The neural network was trained using 225 randomly selected trials in a random sequence, reserving twenty trials for model validation. The neural net model showed a strong relationship between observed and predicted pain in the training set (R2=0.098) and validation cases (R2=0.086). The discriminate analysis showed a weak relationship (R2=0.033).

Discussion. Neural networks have been successfully applied to classify low back pain patients, but have not been applied to study the specific relationship between pain and motion. This relationship has been the focus of one study using a multiple regression approach, however the strength of the relationship was weak (R2=0.045 for flexion and R2=0.02 for extension). The current study developed a neural network model relating vertebral motion to pain. This model was trained with a spectrum of trunk motions including bending in all planes (R2=0.098) and was validated with twenty independent trials (R2=0.086). The strength of the relationship justified the value of neural network analysis over discriminate analysis.
This investigation demonstrated a strong relationship between low back pain patients performing a spectrum of trunk motion, and accordingly the strength of the relationship illustrates that universal phenomena related vertebral motion to pain. Although some researchers have found that spinal range of motion measures alone are not sufficient and that velocity and acceleration measures must be included for discriminating between patients, the current analysis describes a strongly predictive model based on range of motion measures alone. Ongoing analysis is evaluating the relative contribution of the various motion parameters within the model.

**Conclusion.** Segmental inter- and intravertebral range of motion parameters were strongly related to the pain experienced during voluntary, unconstrained motions in chronic low back pain patients.