Influence of spine morphology on intervertebral disc loads and stresses in asymptomatic adults: implications for the ideal spine

Background context

Sagittal profiles of the spine have been hypothesized to influence spinal coupling and loads on spinal tissues.

Purpose

To assess the relationship between thoracolumbar spine sagittal morphology and intervertebral disc loads and stresses.

Study design

A cross-sectional study evaluating sagittal X-ray geometry and postural loading in asymptomatic men and women.

Patient sample

Sixty-seven young and asymptomatic subjects (chiropractic students) formed the study group.

Outcome measures

Morphological data derived from radiographs (anatomic angles and sagittal balance parameters) and biomechanical parameters (intervertebral disc

loads and stresses) derived from a postural loading model.

Methods

An anatomically accurate, sagittal plane, upright posture, quadrilateral element model of the anterior spinal column (C2-S1) was created by digitizing lateral full-spine X-rays of 67 human subjects (51 males, 16 females). Morphological measurements of sagittal curvature and balance were compared with intervertebral disc loads and stresses obtained using a quadrilateral element postural loading model.

Results

In this young (mean 26.7, SD 4.8 years), asymptomatic male and female population, the neutral posture spine was characterized by an average thoracic angle (T1-T12)=+43.7° (SD 11.4°), lumbar angle (T12-S1)=−63.2° (SD 10.0°), and pelvic angle=+49.4° (SD 9.9°). Sagittal curvatures exhibited relatively broad frequency distributions, with the pelvic angle showing the least variance and the thoracic angle showing the greatest variance. Sagittal balance parameters, C7-S1 and T1-T12, showed the best average vertical alignment (5.3 mm and −0.04 mm, respectively). Anterior and posterior disc postural loads were balanced at T8-T9 and showed the greatest difference at L5-S1. Disc compressive stresses were greatest in the mid-thoracic region of the spine, whereas shear stresses were highest at L5-S1. Significant linear correlations ($p<.001$) were found between a number of biomechanical and morphological parameters. Notably, thoracic shear stresses and compressive stresses were correlated to T1-T12 and T4-hip axis (HA) sagittal balance, respectively, but not to sagittal angles. Lumbar shear stresses and body weight (BW) normalized shear loads were correlated with T12-S1 balance, lumbar angle, and sacral angle. BW normalized lumbar compressive loads were correlated with T12-S1 balance

and sacral angle. BW normalized lumbar disc shear (compressive) loads increased (decreased) significantly with decreasing lumbar lordosis. Cervical compressive stresses and loads were correlated with all sagittal balance parameters except S1-HA and T12-S1. A neutral spine sagittal model was constructed from the 67 subjects.

Conclusions

The analyses suggest that sagittal spine balance and curvature are important parameters for postural load balance in healthy male and female subjects. Morphological predictors of altered disc load outcomes were sagittal balance parameters in the thoracic spine and anatomic angles in the lumbar spine.