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The Role of Facet Contact in Reducing Intervertebral Shear during Simulated Standing

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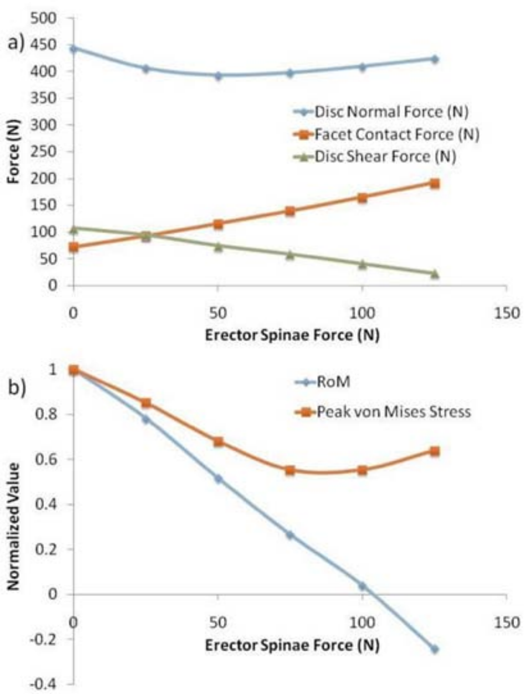
Introduction: During normal standing, compressive and anterior shear forces applied to the lumbar spine due to upper body weight will result in the loss of sagittal balance unless there is muscle contribution. A compressive follower load will not restore sagittal balance or balance anterior shear. Force generated by the erector spinae (ES) has the ability to restore sagittal balance, and may encourage greater facet engagement to offload the shear forces on the disc. The objective of the current study was to apply various magnitudes of ES muscle force to a single lumbar motion segment exposed to a compressive and shear force characteristic of upper body weight. We hypothesized that force generated by the ES would restore sagittal balance, increase facet joint contact forces, and reduce shear force experienced by the intervertebral disc.

Methodology: A previously developed FEM of L4-L5 was used for this study. A compressive load of 400 N and an anterior shear of 140 N were applied to the superior endplate of L4 to simulate standing. The inferior endplate of L5 was fixed rigidly in space. A penalty-based contact algorithm was defined between the facets. The ES was simulated by attaching a force element between the spinous processes approximately 5.5 cm posterior of the joint center and perpendicular to the shear plane of the disc. ES forces of 0, 25, 50, 75, 100, and 125 N were evaluated. The rotational range of motion, von Mises stress in the annulus fibrosus, normal and shearing forces across the disc, and facet reaction forces were recorded.

Results: An ES force of 100 N resulted in the least RoM and restored sagittal balance. Progressive increase of the ES force resulted in a progressive decrease in the shear force experienced by the disc and increased reaction force at the facets (Fig1a). Qualitatively, increasing the ES force resulted in a reduction in the von Mises stress maxima at the axial midplane of the annulus fibrosus. Additionally, the peak von Mises stress value decreased with increasing ES force up to approximately 100 N and then began increasing. This switch corresponded with the switch between flexion (+) and extension (-) (Fig1b).



[Figure 1]

Discussion: Results from the current study supported the hypothesis that forces generated in the ES resulted in a reduction in the shear forces experienced by the disc and an increase in facet contact force. These data demonstrate that a combination of active ES muscle force and passive facet contact force can restore sagittal balance and minimize shear forces acting on the disc. It also indicates that the facets may be in constant contact during normal standing. These data are particularly important when designing spinal implants that alter the relative facet orientation. Excessive disc height distraction during total disc replacement could prevent facet contact and result in high shear forces experienced by the implant.