INTRODUCTION

Forward bending causes compression, anterior shear, and a flexion moment at the lumbar spine. A combination of posterior muscle and ligament forces must be generated in order to prevent excessive motion and restore upright posture.

It is generally believed that forward bending to 90 degrees while maintaining a straight or extended lumbar spine is biomechanically favorable compared to lifting with a rounded back[1]. However, simple static biomechanical models predict the same spinal loading regardless of lifting technique. Posterior muscle activation with concomitant facet engagement may reduce the compression experienced by the disc.

Therefore, the objective of the current study was to simulate forward bending with a previously validated finite element model of L4-L5 and determine if increasing posterior muscle force results in a reduction in disc pressure. We hypothesized that posterior muscle activation during forward bending would increase facet contact and reduce intradiscal pressure and nucleus extrusion forces thereby minimizing the contribution to progressive disc herniation.

METHODS

A finite element model of a ligamentous L4-L5 motion segment was generated from QCT data of a cadaveric spine. The model was validated using disc pressures, cortical and endplate strains, and kinematic data from peer reviewed literature[2, 3]. Development and validation of the model has been previously described[4, 5].

An additional validation was undertaken for the current study whereby the forces exerted from the nucleus to the surrounding annulus during combined compression and flexion were evaluated. A previously published cadaveric study demonstrated posterolateral disc protrusions when cadaveric specimens were stripped of their posterior elements, hyperflexed, and exposed to compression[6]. Therefore, the current L4-L5 model was stripped of its posterior elements and subjected to progressive increases in flexion of 2 degree increments (0 to 8 degrees) under a 2 kN compressive load.

For the intact model, an anterior shear force of 400 N and a flexion bending moment of 10 N*m was applied to the superior endplate of L4 to simulate forward bending. The inferior endplate of L5 was fixed rigidly in space. The posterior muscles, or erector spinae (ES), were 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, 100, 200, 300, 400, 500, and 600 N were evaluated. Vector plots of nucleus extrusion forces and nucleus pressure was recorded.

RESULTS

Results from the validation study indicated increased posterolateral nucleus extrusion forces during combined compression and hyperflexion (Figure 1). This result is consistent with previously published experimental results[6].

Progressive increase of the ES force resulted in a general decrease in nucleus extrusion forces (Figure 2). Simulated bending with no ES force indicated force maxima in the posterolateral region. The nucleus pressure tended to decrease with increasing ES force for the “intact” model (Figure 3).
Figure 1. Vector plots indicating the force vectors generated by the nucleus (bottom left image indicates spine orientation). Results from the disc protrusion validation study indicated that combined hyperflexion and compression resulted in increased posterolateral nucleus extrusion forces consistent with a previously published study (Adams, 1984).

Results from the current study indicate potential benefits for the disc by maintaining a strong core or keeping a straight back while performing bending lifts. A study on professional weightlifters documented a reduction in lumbar flexion just prior to lifting heavy weights while bent over (dead lift) [7]. The authors suggested several reasons for this including muscle control and geometric advantages, but do not indicate the potential for increased facet engagement. The authors calculated that during these heavy lifts the disc would be exposed to load levels on the order of 17 kN, which is substantially larger than known compressive failure loads [6]. A possible explanation for this discrepancy is the contribution of the facets. Results from the current study suggest that weightlifters are activating their ES in order to engage the facets prior to heavy lifting to offload the discs. Based on the current study, keeping a straight back or increasing the lumbar lordosis while lifting, or rather engaging your erector spinae to promote facet contact, will result in lower disc pressures and nucleus extrusion forces.

REFERENCES
