Purpose of the study: Intervertebral disc degeneration is related to progressive changes in the disc tissue composition and morphology, such as water loss, disc height loss, endplate calcification, osteophytosis. These changes may be present separately or in various combinations, as more commonly observed in the clinical practice, and may have contrasting effects on the biomechanics of the degenerated segment. However, little is known about these effects. In this work, a wide range of clinical scenarios of disc degeneration, in which the most common degenerative changes are present in various combinations, is investigated by means of randomly generated finite element models.

Methods: A poroelastic nonlinear FE model of the L4-L5 human spine segment was employed and randomly scaled to represent 10 spine segments from different individuals. Six different degenerative characteristics (condition of nucleus pulposus, annulus fibrosus and endplate cartilage; height loss; osteophyte formation; diffuse sclerosis) were modeled in 30 randomly generated models, 10 for each overall degree of degeneration (mild, moderate, severe). For each model, a daily loading cycle including 8 hours of 200 N compression representing the night rest and 16 hours of 500 N compression modeling the standing position was considered. Two flexion-extension cycles were also simulated, directly after the application of the 500 N load and directly before its removal.

Findings: A tendency to an increase of stiffness with progressing overall degeneration was observed. Therefore, instability for mild degeneration was not predicted. Nucleus degeneration reduced the daily height change of the disc; annulus degeneration had no influence on this result. However, both parameters were significantly correlated to a decrease in the flexion-extension range of motion. Also osteophytosis, diffuse sclerosis and disc height loss induced a reduction of daily disc height change and spine flexibility. Endplate sclerosis significantly limited the disc rehydration during the rest period.

Conclusions: The present investigation of the biomechanical effect of different combinations of degenerative changes may help to better understand disc degeneration from a biomechanical point of view. These findings might provide a basis for discussion about the choice of appropriate treatments for degenerative disc disease, both conservative or surgical, for specific clinical cases. Since all the considered macroscopic changes were found to be mechanically relevant, they should be taken into account by grading systems for disc degeneration whenever possible.

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