

# In Vivo Quantification of Disc Mechanics in an Asymptomatic Aging Population using MRI

Harrah R. Newman<sup>1</sup>, John M. Peloquin<sup>1</sup>, Kyle D. Meadows<sup>1</sup>, Edward J. Vresilovic<sup>1</sup>, Dawn M. Elliott<sup>1</sup>  
<sup>1</sup>University of Delaware, Newark DE  
 harrah@udel.edu

**Disclosures:** HRN (N), JMP (N), KDM (N), EJV (4,8,9 Camber Spine Technologies), DME (9, ORS)

**INTRODUCTION:** The intervertebral disc in a healthy spine enables load transfer, mobility, stability, and regular daily activities. With aging, the disc undergoes structural and compositional degeneration. Disc degeneration often progresses independent of any pain or symptoms. Despite its prevalence in asymptomatic populations, disc degeneration is often implicated as a potential cause of low back pain (LBP). LBP impacts up to 85% of people, with many diagnoses of nonspecific, mechanical LBP [1]; the *mechanical* distinction is because pain is often minimized or exacerbated by different motions or positions. Despite the involvement of disc mechanics in LBP, standard clinical imaging evaluates spine structure, but not mechanics. We and others have recently quantified disc mechanics with repeated magnetic resonance imaging (MRI) in different loading states; though these prior studies have been in mostly young subjects [2], [3]. The purpose of the present study was to quantify the lumbar discs' mechanical response to flexion/extension in a balanced age population to elucidate the changes that arise in disc mechanics with aging, which will be critical in future work to decouple the role of the disc in aging and degeneration from mechanical LBP.

**METHODS:** With IRB approval and informed consent, 84 subjects with no LBP were evaluated. The subjects were evenly distributed to include 7 subjects of each sex (M/F) per age decade (18-29, 30-39, 40-49, 50-59, 60-69, 70-83 years old). Each subject arrived at the MRI facility early in the morning then lay supine for 45 min to unload the spine. Subjects were first scanned in a supine position (*Supine*) with a pillow supporting the head and a bolster supporting their legs. Scanning was then repeated, first with bolsters under the lumbar spine to induce *Extension*, and then with bolsters under the pelvis to induce *Flexion*. In each position, a series of sagittal T1w FLASH images were collected to evaluate geometry, see [2] for full scanning protocol. Sagittal Cobb angle measurements from superior L1 to inferior S1, confirmed flexion ( $+9.8^\circ \pm 4.3^\circ$ ) and extension ( $-9.5^\circ \pm 5.8^\circ$ ) were achieved. Disc deformations were evaluated as the differences between the reference Supine images ("reference state") and Flexion or Extension images ("loading states"). The changes in disc height, width, area, volume, wedge angle, and anterior-posterior (AP) shear displacement were evaluated in accordance with our prior work [2], [4]. Disc registration methods were used to calculate the axial strain between the reference state and loading states; the disc was subdivided into 4 regions (anterior, central, lateral, posterior) [2]. All outcome measures were compared by age group (N=28 subjects/group), young (18-39 years old), middle (40-59 years old), and old (60-83 years old), and by disc level, L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1. Differences between the reference and loading states were evaluated with paired t-tests. All analysis was done in JMP 17 statistical software with significance set at  $p < 0.05$ .

**RESULTS: Flexion (Fig 1A-C):** Disc wedge angle changes were both age- and level-dependent. In the young subject group, there was a significant difference between disc levels, such that the lower levels had progressively greater changes in wedge angle. The middle and old age groups did not have level dependencies. Only the L5-S1 level had greater wedge in the young group compared to other age groups. Disc AP shear displacement was level-dependent but not age-dependent. The discs in the upper lumbar levels had anterior shear, and the discs in the lower levels had posterior shear. Strain measures confirmed flexion at all levels, where the disc anterior side was compressed (Fig 1C, blue) and posterior side was extended (Fig 1C, orange). For young subjects, the greatest strain magnitudes were in the lower levels, while in the old subject group, the greatest strain magnitudes were in the central levels (Fig 1C). From Cobb angle measurements, young subjects had greater Flexion than older subjects. Across all age groups and disc levels, flexion caused a decrease in disc height, increase in disc width, decrease in disc area, and no significant change in disc volume.

**Extension (Fig 1D,E):** Extension induced changes opposite from Flexion. Change in wedge angle and AP shear displacement were level-dependent (Fig 1D,E), but not age-dependent. Upper levels had greater wedge angle change and posterior shear, while the lower levels had less wedge angle change and anterior shear (Fig 1E). Similarly, the greatest strain magnitudes were in the upper levels, and strain magnitude was not significantly different across age groups. Disc height increased and disc width decreased for all age groups and disc levels. There was no significant change in disc area or volume.

**DISCUSSION:** Flexion and extension were successfully induced within the confines of a conventional MRI and lumbar disc mechanics were quantified in an asymptomatic population of all ages, quantifying normative disc mechanics as a function of subject age and disc level. In future work, deviations from these loading trends in LBP subjects could indicate disc levels of potential pathological significance. Interestingly, Extension responses were not age-dependent; all age groups exhibited the same level-dependent trends. The greatest extension wedging was at L2-L3; this may be due to a contribution of the facet joints in the extension load distribution. Because there was no age dependency, extension loading could be a consistent assessment tool in future work.

**SIGNIFICANCE/ CLINICAL RELEVANCE:** Clinical imaging can identify structural abnormalities, but the importance of disc mechanics in normal spine physiology and in LBP suggest non-invasive mechanical assessments of the lumbar spine are needed. Repeated imaging with controlled loading states as quantified in this study can provide mechanical quantification of disc function.

**REFERENCES:** [1] Smith+, *Dis Mod and Mech*, 4(1), 2011. [2] Meadows+, *JOR Spine*, 6(1), 2022. [3] Martin+, *J Biomech*, 71, 2018. [4] Newman+, *Eur Spine J*, 34, 2025.

