THE EFFECT OF PROGRESSIVE HERNIATION ON LUMBAR INTERVERTEBRAL DISC SIX DEGREE OF FREEDOM MECHANICS

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Introduction

Irreversible changes in disc structure caused by compressive overload towards progressive herniation can alter six degree of freedom (6DOF) mechanics. These changes alter how the disc withstands loads and may leave the disc more suspectable to herniation or other injuries. Studies have shown that disc injuries can alter the disc's mechanical response and may also be a predictor of herniation [1-2]. However, there are no studies on the progressive mechanical changes in the disc leading up to herniation. This study aimed to compare changes in disc mechanics leading up to and after herniation under combined flexion and axial rotation, followed by compressive overload.

Methods

Initial 6DOF mechanics from intact sheep lumbar segments (L2-L3, n=9) were measured in a hexapod robot using an established standardised testing protocol [3]. Specimens were then randomly assigned into one of three compressive overload displacement groups: 1, 2, or 3 mm. Prior to overload, specimens were postured at 13° flexion and 2° left axial rotation with no initial compressive displacement applied. After posturing, each group of specimens were loaded to their respective compressive displacements at 400 mm/min. Finally, the same 6DOF testing protocol was repeated. Differences in 6DOF stiffness and phase (a measure of energy absorption), before and after loading, within each group were assessed using repeated-measures ANOVA with a statistical significance of $p<0.05$, with marginal significance defined as $0.05<p<0.07$. The presence of disc herniation was determined visually.

Results and Discussion

Disc failure occurred with increasing compressive displacement (Figure 1). Herniation was confirmed in two-thirds of specimens in the 2- and 3-mm groups. For the 1 mm group, stiffness in anterior shear and flexion significantly decreased and marginally decreased in left lateral shear and right axial rotation (Table 1). Phase for the 1 mm group increased in flexion, and right/left lateral bending. Specimens in the 2 mm group had decreased stiffness in flexion and right axial rotation, and increased phase in flexion, left lateral bending and right axial rotation. In the 3 mm group, stiffness decreased in posterior shear, flexion, left/right axial rotation. For the 3 mm group, phase increased in all DOFs except for anterior shear and right lateral bending, and marginally increased in posterior shear.

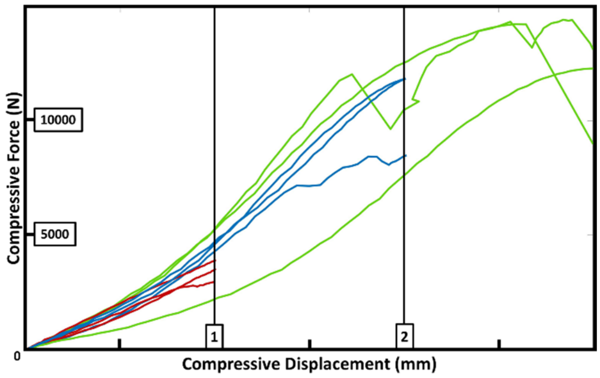

Figure 1: Failure curves of specimens loaded to 1 mm (red), 2 mm (blue), or 3 mm (green).

		Shear						Bending			Rotation	
		Right Lateral	Left Lateral	Anterior	Posterior	Compression	Extension	Flexion	Right Lateral	Left Lateral	Left Axial	Right Axial
Stiffness	1 mm	0.54	0.06	0.03	0.43	0.18	0.99	0.00	0.65	0.14	0.44	0.06
	2 mm	0.88	0.10	0.17	0.85	0.18	0.20	0.00	0.24	0.16	0.14	0.02
	3 mm	0.17	0.10	0.17	0.02	0.15	0.62	0.01	0.75	0.10	0.03	0.01
Phase	1 mm	0.61	0.34	0.99	0.84	0.84	0.19	0.02	0.01	0.04	0.89	0.41
	2 mm	0.44	1.00	0.53	0.70	0.18	0.13	0.03	0.72	0.02	0.26	0.03
	3 mm	0.02	0.05	0.22	0.07	0.01	0.05	0.01	0.08	0.04	0.01	0.00

Table 1: Stiffness and phase p-values from before vs after loading data. Green: significant difference; yellow: marginal significance; red: no significance.

Compressive overload influenced disc mechanics in all groups where either stiffness or phase, or both, were significantly affected. It is possible that although observable macroscopic changes may not be present, particularly in the 1 mm group, microstructural changes altered the macro mechanics of the disc.

Conclusion

This research is ongoing, and although the present sample size was small and visible herniation did not occur in all specimens, significant disc mechanical changes occurred. These findings may be used as mechanical indicators of early-stage herniation in future studies.

References

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