

In vivo-like long-term compressive loading affects intervertebral disc swelling and flexibility – An ex vivo study

Ann-Kathrin Greiner-Perth (Ulm, Allemagne), Christian Liebsch (Ulm, Allemagne), Hanna Unseld (Ulm, Allemagne), Daniel L. Belavy (Bochum, Allemagne), Gabriele Ambrecht (Berlin, Germany, Allemagne), Kirsten Albracht (Cologne, Allemagne), Helena Brisby (Gothenburg, Sweden, Suède), Deborah Falla (Birmingham, UK, Royaume Uni), Richard Scheuring (Houston, États-Unis), Roope Sovellius (Helsinki, Finlande), Kajsa Rennerfelt (Gothenburg, Suède), Hans-Joachim Wilke (Ulm, Allemagne)

Introduction

The water content of intervertebral discs (IVD) follows a circadian pattern, decreasing under daytime mechanical loading and recovering overnight¹. In the absence of loading, such as in microgravity, more IVD swelling can occur, potentially a reason for increased risk of disc herniation in astronauts². However, specific effects of compressive loading on IVD swelling behaviour and resulting biomechanical properties remain unclear. This study examined how IVD swelling is affected by in vivo-like long-term compressive loading and how this affects intradiscal pressure (IDP), range of motion (ROM), neutral zone (NZ), and IVD height (IDH).

Materials and Methods

To ensure standardized testing of non-degenerated IVDs, 18 ovine lumbar motion segments (6xL1-L2, 6xL3-L4, 6xL5-L6) were hydrated in 0.9%-saline solution for 24h and randomised regarding segmental level to investigate the following loading conditions: 0 N (unloaded), 58 N (*in vivo* recovery load in sheep)³, and 130 N (*in vivo* active load in sheep)³. Flexibility testing was performed using pure moments of 7.5 Nm in a spine tester at five time points: prior to hydration (baseline) and after 2h, 4h, 8h, and 24h of hydration. IDH was determined before and after each hydration interval at 130N using a materials testing machine. IDP was continuously recorded using fiberoptic pressure sensors implanted in the nucleus pulposus. Wilcoxon test and Friedman test with Bonferroni correction were performed ($\alpha=0.05$).

Results

In the unloaded group, median intrinsic IDP increased significantly by +65% after 8h and by +124% after 24h of hydration ($p<0.05$). Median IDH rose significantly at all timepoints ($p<0.05$). During flexibility testing, IDP increased significantly in flexion after 24h and in all other motion directions after 8h and 24h of hydration ($p<0.05$, Fig.1). ROM was significantly reduced in lateral bending after 8h and 24h, while NZ decreased in flexion/extension after 24h ($p<0.05$, Fig.2). In the recovery load group, median IDP increased in extension by +35% after 8h and by +69% after 24h ($p<0.05$), while there were no significant changes in other motion directions, ROM, NZ or IDH ($p>0.05$). No significant changes were observed in any parameter in the active load group ($p>0.05$).

Conclusion

Lumbar ovine IVDs show limited hydration under recovery loads, while active compressive loading suppresses fluid uptake, indicating that sustained compressive load inhibits rehydration. In the absence of external load, IVDs undergo significant osmotic swelling, leading to increased IDP and reduced flexibility. As IDP reflects discal stress, pronounced swelling under unloading conditions may contribute to the elevated herniation risk observed in astronauts. Future studies shall validate these findings in human cadaveric IVDs.

References: [1] Wilke et al. (1999). Spine 24, 755-62; [2] Belavy et al. (2016). Eur Spine J 25,144-154; [3] Reitmaier et al. (2013). PLoS One 8, e69610.

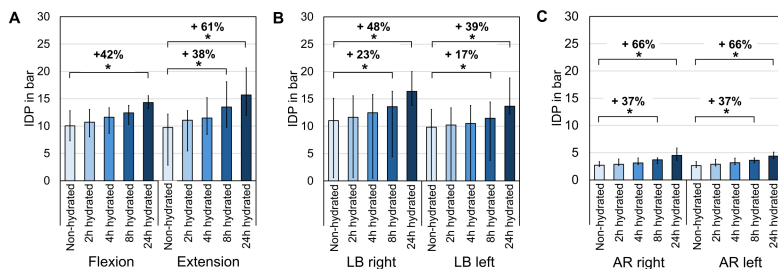


Fig. 1. Intradiscal pressure (IDP) of the unloaded group during flexibility testing at 7.5 Nm: (A) Flexion/Extension, (B): Lateral Bending (LB), (C) Axial Rotation (AR). IDP represented as medians with value ranges (Min, Max).

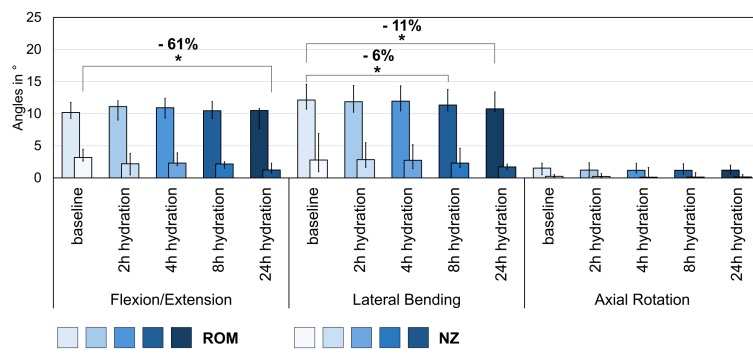


Fig. 2. Range of motion (ROM) and neutral zone (NZ) of the unloaded group during flexibility testing at 7.5 Nm in Flexion/Extension (FE), Lateral Bending (LB) and Axial Rotation (AR). Angles represented as medians with value ranges (Min, Max).