# NONLINEAR DYNAMIC BEHAVIOUR OF THE HUMAN INTERVERTEBRAL DISC

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## Introduction

The quasi-static response of the intervertebral disc has been reported by numerous studies to be nonlinear and asymmetric [Yamada, 1970; Wang, 2012]. In particular, the quasi-static response resembles the mechanics of *stiffening* systems, where the stiffness increases with the deformation. The dynamic response of these systems shows also peculiar nonlinearities [Schmidt, 1986]. However, the few studies which have investigated the disc dynamics [Kasra, 1992; Izambert, 2003] did not report any asymmetric, nonlinear dynamic behaviour, even though it is evident in quasi-static testing. The aim of this experimental study was therefore to investigate the nonlinear dynamic response of human intervertebral discs, taking different pre-loads and displacements into account.

## Methods

For this study, one lumbar (L4-L5) and two cervical (C2-C3) motion segments were tested. Superior and inferior vertebra were left for embedding, whereas all the bony processes, muscles and ligaments were removed. A test rig was designed to apply a cyclic displacement at the bottom of the disc by a servo-hydraulic testing machine. The axial preload of the disc was applied by several death weights attached to the top embedding pot. For each preload, tests were performed with different displacement amplitudes, since dynamics of nonlinear systems is shown to be dependent from the amplitude of the stimulus. The displacement was driven by a sinusoidal sweep function. The frequency was set to increase linearly from a low frequency to a high frequency boundary and back down. Accelerometers recorded the acceleration of the disc and the frame. Further, a camera system tracked the displacement of markers on the disc and on the frame. Before and after testing, a quasi-static test was performed to precondition the specimen and obtain the nonlinear quasi-static response.

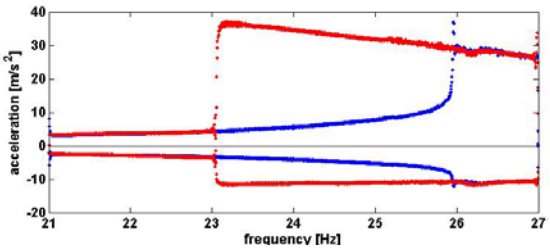


*Figure 1: Peaks of the disc acceleration vs. frequency for the test L4-L5 with 40 kg preload and amplitude of the forced displacement of 0.1 mm. The plot distinguishes between upwards (blue) and downwards (red) step (typical curves)*

## Result

In general the dynamic response showed nonlinear asymmetric characteristics, i.e. larger acceleration amplitude were observed in elongation than in compression. Furthermore, for each test, the eigenfrequency of oscillation was different when the frequency of the forced displacement was increasing compared to when it was decreasing (Figure 1). Increasing the preload reduced the upwards and downwards resonant frequency.

## Discussion

This study has demonstrated the nonlinear asymmetric dynamic behaviour of the intervertebral disc. The disc showed a dynamic response which is typical of the dynamics of nonlinear softening systems. Further studies will investigate the influence of disc degeneration on the dynamic response.

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## References

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