# THE NEUTRAL ZONE IN HUMAN LUMBAR SPINE SAGITTAL PLANE MOTION: A COMPARISON OF IN VITRO QUASISTATIC AND DYNAMIC FORCE DISPLACEMENT CURVES

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## INTRODUCTION

The neutral zone (NZ) of a spinal motion segment has been defined as "that part of the range of physiological intervertebral motion, measured from the neutral position, within which the spinal motion is produced with a minimal internal resistance." (1) The size of this region of laxity or high flexibility has been considered an indicator of the stability of a motion segment. The NZ has traditionally been measured in degrees of motion using a quasistatic technique that subjects the segment to pure moments that increase incrementally. The ends of the neutral zone are defined by the positions of the motion segment just before beginning the 3$^{rd}$ cycle in each direction (30 seconds after unloading the 2$^{nd}$ cycle). Thus, the NZ is a measure of residual deformation. Thompson et al suggested that the quasistatic NZ may be an artifact of the testing procedure (2). Using dynamic motion, they proposed a definition of NZ which used derivatives of a 4$^{th}$ order polynomial fitted to both the loading and unloading curves. The region most compatible with the NZ concept was confined by a slope of + or -0.05 Nm/degree. They found an area of laxity around the neutral position in a sheep model only during flexion/extension. *The objective of this study was to compare quasistatic and dynamic force-displacement curves from the same motion segments in regard to ROM and characteristics of the NZ region.*

## METHODS

Three human cadaveric lumbar motion segments (L1-2, L2-3, L4-5) aged 40-82 were harvested and dissected in the standard fashion leaving bone, ligament and disc tissue. Each segment was wrapped in saline moistened toweling to retard drying and mounted in custom fixtures (upper and lower) using dental plaster and K-wires. Motion segments were then placed in a custom testing device. Dynamic flexion and extension motion was induced using a counter-weighted stepper-motor mounted on a low friction bearing platform in the sagittal plane. The motor was controlled by a LabView program. Pure flexion/extension moments were transferred from the motor to the upper vertebra of the motion segment through low friction sliding bearings to allow lateral flexion to occur. Moments were applied at a rate of 1 degree/second up 5 Nm then the motor reversed and applied a moment in the opposite direction. Force data were measured by a 6DOF load cell. Displacement was measured in degrees by CXTA tilt sensors. Four dynamic preconditioning cycles were completed then a 5$^{th}$ cycle was used for analysis (1 degree/second). Immediately after dynamic testing, the upper specimen mounting was attached to pneumatic cylinders via a cable and pulley system and pure moments were applied in 1 Nm increments from 0 load to 5 Nm. Force-displacement points were taken as the position after 30 seconds was allowed for viscoelastic creep after each new load and after removal of the load. The region between the points taken after load removal (representing residual deformation in both flexion and extension) was defined as the quasistatic NZ.

## RESULTS AND DISCUSSION

The ranges of motion attained in both techniques as well as size of neutral zone (degrees) are listed in Table 1. Using 4$^{th}$ order polynomials we found no discrete area with a slope near 0 as did Thompson et al. The region of the dynamic curves prescribed by the quasistatic NZ (centered on 0 load) was isolated and the slopes calculated. Figure 1 shows the two force-displacement curves superimposed for the motion segment with the largest quasistatic NZ (L2-3).

**Table 1.**

| Spec | Q-ROM | D-ROM | Q-NZ | D-slope |
|---|---|---|---|---|
| L1-2 | 10.90 | 11.20 | 0.78 | 0.37 |
| L2-3 | 11.35 | 10.23 | 2.11 | 0.28 |
| L4-5 | 8.20 | 9.90 | 1.43 | 0.38 |

Q=quasistatic, D=dynamic, NZ=neutral zone (degrees), D-slope=slope of curve in dynamic NZ region

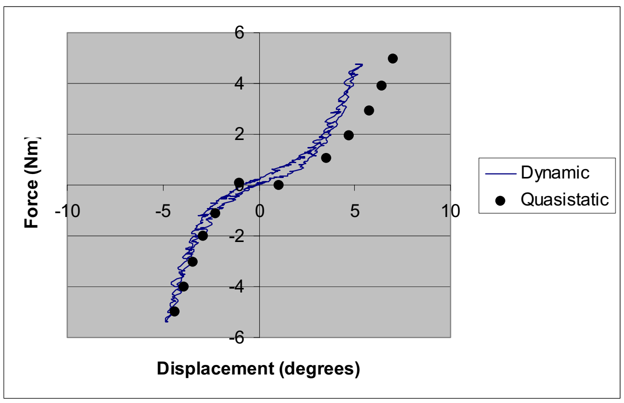


**Figure 1**: Quasistatic and dynamic force-displacement curves of an L2-3 motion segment superimposed.

## CONCLUSIONS

The dynamic force-displacement curves produced by a 1 degree/second moment did not demonstrate an area of laxity about the neutral position as was suggested by the quasistatic curves. This may be due to lack of sufficient relaxation during the dynamic motion despite the low load rate. Alternatively, a true NZ may not exist in these human specimens and the characteristics of motion about the neutral area may be better described by the slope or other functions. Although our results represent only a few specimens, the relevance of the quasistatic NZ, which represents residual deformation after the application of significant load, should be re-examined.

## REFERENCES

1. Panjabi MM. Biomechanical evaluation of spinal fixation devices: I. A conceptual framework. Spine 13(10):1129-34, 1988
2. Thompson RE, Barker TM, Pearcy MJ. Defining the neutral zone of sheep intervertebral joints during dynamic motions: an in vitro study. Clin Biomech 18:89-98, 2003