Range of Motion of the Whole Spine: A Data Collection from 30 Years of Experiments

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INTRODUCTION: Spinal motion segments not only exhibit different ranges of motion (RoM) in specific spinal regions but also vary from motion segment to motion segment within these regions. There are numerous papers describing RoM in these different regions but often the numbers can hardly be compared because they originate either from in vitro or in vivo measurements using different methods and loading conditions. Therefore, almost no data is available for the whole spine using the same methodology. Particularly in case of numerical modeling, this is crucial for an appropriate validation. The purpose of this study therefore was to summarize data from a large pool of data from 30 years of in vitro experiments performed under standardized conditions.

METHODS: For this database evaluation, a total of 139 cervical, 129 thoracic, and 612 lumbar human spinal specimens were collected. All specimens have been tested in flexion/extension, lateral bending, and axial rotation under pure moment loads of ±2.5 Nm for the cervical, ±5.0 Nm for the thoracic, and ±7.5 Nm for the lumbar region using the same testing device [1]. All flexibility tests have been performed under same conditions without axial preload, while the five uncontrolled degrees of freedom had been unconstrained and the third loading cycle had been evaluated [2]. Descriptive statistics were performed with diagrams showing medians of RoM and NZ together with minimum and maximum values. Outliers were defined as values being beyond twofold standard deviation. In order to prove data quality, normal distribution was checked using the Shapiro-Wilk test in SPSS 27.

RESULTS SECTION: Parts of the results are presented in Figure 1. While the cervical spine is relatively flexible in all three motion planes, C1-C2 is an exception in axial rotation, moving with 47° as much as the rest of the cervical spine. The thoracic spine is less flexible in flexion/extension but allows relatively large lateral bending and axial rotation. The rib cage has a strong effect on thoracic spine rigidity, especially in axial rotation by a factor of more than two. The lumbar spine is allowing fair motion in flexion/extension and lateral bending but does not allow much RoM in axial rotation.

DISCUSSION: A large data collection is presented that is unique because all data was obtained under same loading conditions in the same testing device. The data were obtained from many different studies for a large variety of biomechanical studies. Therefore, several influencing factors such as specimen length and degeneration may influence the summary shown in Figure 1. However, these influences will be specifically discussed.

SIGNIFICANCE/CLINICAL RELEVANCE: This unique summary will serve as comparative data for future in vitro experiments and for the validation of numerical models for different clinical applications and provide a better idea of the overall spinal flexibility. The impact of potential influencing factors such as the degree of degeneration, segmental length, preload, magnitude of moment, or the rib cage may support clinical discussions.

REFERENCES:

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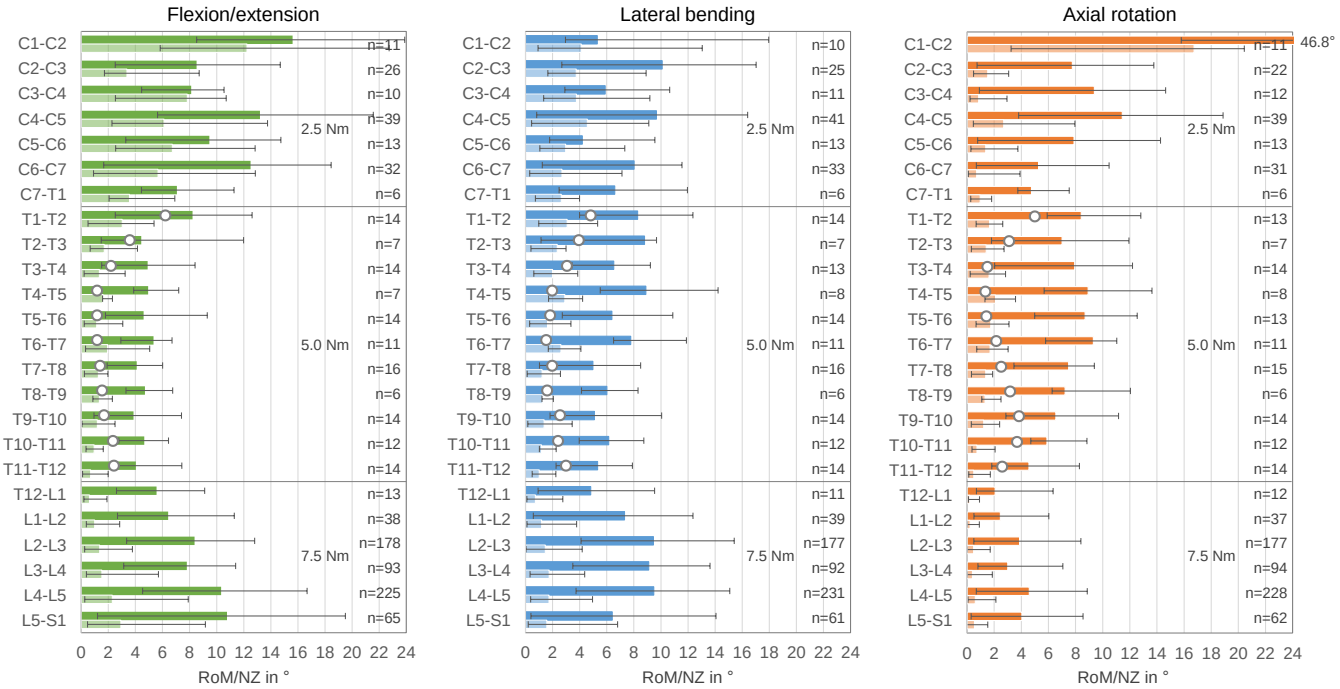

Figure 1. Overview of range of motion (RoM, dark bars) and neutral zone (NZ, bright bars) values of the whole spine. Thoracic RoM data with rib cage is depicted by white circles.