First target datasets for the consideration of postural variety in FE HBM analysis of the lumbar spine

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I. INTRODUCTION

Initial spinal posture and position have been found to have an influence on spinal loading and kinematics during frontal crashes [1]. This study describes the identification of a first set of positioning target data to be used with FE Human Body Models (HBMs) in order to have more objective model comparisons.

II. METHODS

Thirteen detailed Magnetic Resonance Imaging (MRI) scans of volunteers were analysed and compared to the 2D X-ray measurements of [2] in terms of LL, SS, TK and TLK angles (see Fig. 1). The focus was set to the LL angle characterising lumbar spine curvature. The MRI scan data were created with seat-back angles between 16 and 20 degrees for upright position, and between 40 and 50 degrees in reclined position.

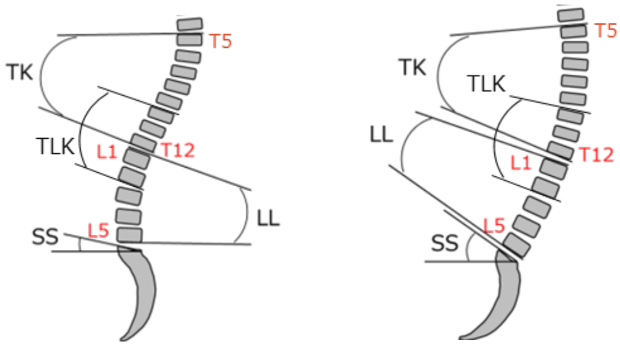

Fig. 1. Measurements of spine angles for S-shaped subjects (left) and kyphotic subjects (right).

Two sets of existing scans in an Upright Open MRI scanner were analysed. For the first one, the volunteer sitting posture was initially measured in the driver's seat of a 2016 Acura TLX in the subjects' preferred driving posture and reclined posture [3]. Thereafter, a representative and non-ferromagnetic seat, mimicking the geometry and properties of the Acura TLX seat, was used. This seat had an adjustable seat-back angle, head restraint height, seat-belt anchor location, and an adjustable vertical and horizontal position of seat back. The volunteers were positioned on the seat in a MR scanner and the postures from the vehicle measurements were reproduced. For the second set, generic seat elements were used to place the volunteers in upright and reclined positions [4]. MRI procedures were optimised for landmark identification and for co-registration. A standardised definition of reference points and coordinate systems, applicable to 3D scan data as well as FE HBM geometries, was applied to the 3D data. The definition of a local vertebral body coordinate system proposed by Draper *et al.* [5] was used to analyse the the curvature of the segmented spine. In this procedure the local vertebral centre forms the origin of a local coordinate system and is the midpoint between two planes fitted to the endplates. The local z-axis is the average of the endplate normals and the local x-axis is defined as the vector from the vertebral canal centre to the origin.

III. INITIAL FINDINGS

According to the findings of [2], two representative spinal postures were identified for the upright position – one with a S-shape and one with a kyphotic lumbar spine, based on the LL angle. These two types of curvature are shown in Fig. 1. For the reclined conditions no separate groups of curvatures could be discerned, the spinal curvature is always lordotic with a positive LL angle. In the reclined position the LL angle is in general larger than in the S-shaped upright position, but there is overlapping data corresponding to variation between individuals.

For both upright position types, representative individuals were selected from the entire pool of available scans, and a representative individual was also selected for the reclined position. These representative individuals were selected based on which individuals were closest to the mean LL values of each subset. A summary of the spine angles for each representative can be found in Table 1.

For all three representative individuals the local coordinate systems of each vertebral body were defined to be used as target postures for HBM spinal positioning. A plot of this target data can be seen in Fig. 2.

	Upright S-Shaped	Upright Kyphotic	Reclined
	Angle in deg.	Angle in deg.	Angle in deg.
TK	-16.8	-10.9	-8.1
TLK	-15.6	-4.5	-9.1
LL	6.6	-5.5	21.7
SS	-8.6	-11.6	-21.9

Table 1. Comparison of angles measured in 2D scan groups and 3D individual datasets. Positive LL angles are in lordosis, negative LL angles are in kyphosis

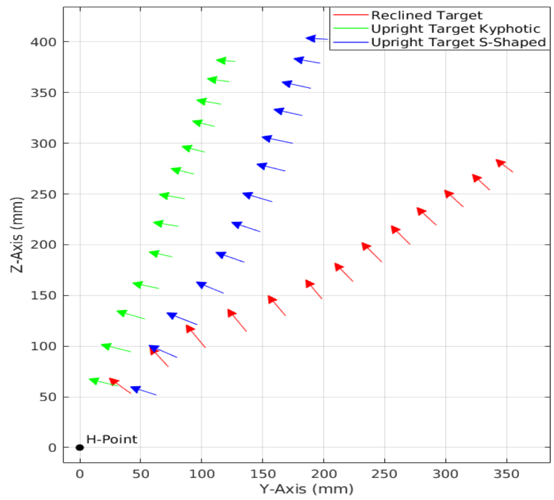

Fig. 2. Sagittal plane view of the target spinal positions for the identified representatives. The positions were aligned to the same H-Point. Each vector represents the local X-Axis of a vertebral body

IV. DISCUSSION

The TK and TLK were similar across all of the data, and this is also reflected in the representative individuals. This suggests that the TK and TLK angles alone have no effect on the LL angle, and that LL alone is a good indicator to what type of spinal posture an individual has. This does not mean that TK and TLK should not be considered when making a full-body HBM position, as thoracic spine position could influence the lumbar positioning.

The finding that in the reclined position there were no discernible differences between S-shaped and kyphotic individuals identified in their respective upright postures [2] suggests that at a certain angle of seatback recline, the individual curvatures might be dominated by the external factors of the seating environment. If this is indeed the case, the target datasets derived here may serve as a first basis for standard HBM postures for load cases where spinal posture plays an important role.

Because these representative postures are derived from individuals, and most likely will not be the same size as a given HBM, using this target data present a challenge. Geometrical or anatomical differences will make it necessary to scale or otherwise align either the target data or the HBMs. In order to have comparable models, and to ensure that they reflect reality, harmonization and standardisation procedures should be developed.

V. REFERENCES

[1] Draper, *et al.*, ESV, 2019.
[2] Izumiyama, *et al.*, IRCOBI, 2022.
[3] Booth, *et al.*, AAAM, 2022.
[4] Rieger, *et al.*, VDI, 2022,
[5] Draper, *et al.*, IRCOBI, 2020.