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I. INTRODUCTION

Finite element (FE) models require discretization of volumes into discrete elements (mesh), and the shape of these elements can affect the numerical accuracy of the model. Therefore, the FE mesh often has shape requirements (mesh quality requirements) such as aspect ratio and angles, amongst others. Mesh quality in FE models has an effect on the response of the model, as demonstrated on metals models [1] and bone tissue models [2]. Human Body Models (HBMs) follow industry-guided mesh quality requirements and undergo a hierarchical multilevel validation [3]. HBMs are commonly modified geometrically to study, for example, various postures and anthropometric groups [4]. The morphing process will modify the mesh and potentially change the mesh quality to an extent, depending on the nature of the morphing. However, the effect of mesh quality on soft tissues has not been quantified in the context of the validation of morphed HBMs. This study will aim to quantify the effect of mesh quality of a previously morphed model [5] in the context of the segment level validation subset [3].

II. METHODS

Previously, an aged posture neck model was developed by reposturing the GHBMC M50-O v5.1 neck ($M50_{26}$) using PIPER to represent the posture of an average 75-year-old mid-stature male ($M50_{75}$), with comparable mesh quality to the $M50_{26}$ model [5]. In this study, a C45 segment was extracted from the $M50_{75}$ model with the mesh not fully fixed ($M50_{75}$-C45-P) at the intervertebral disc (IVD) and another C45 segment was extracted from a fully fixed mesh model ($M50_{75}$-C45-G). The IVD of the $M50_{75}$-C45-P model had 2% of the elements outside of the minimum 50° warpage angle and 13% of the IVD elements with a poor aspect ratio (Fig. 1).

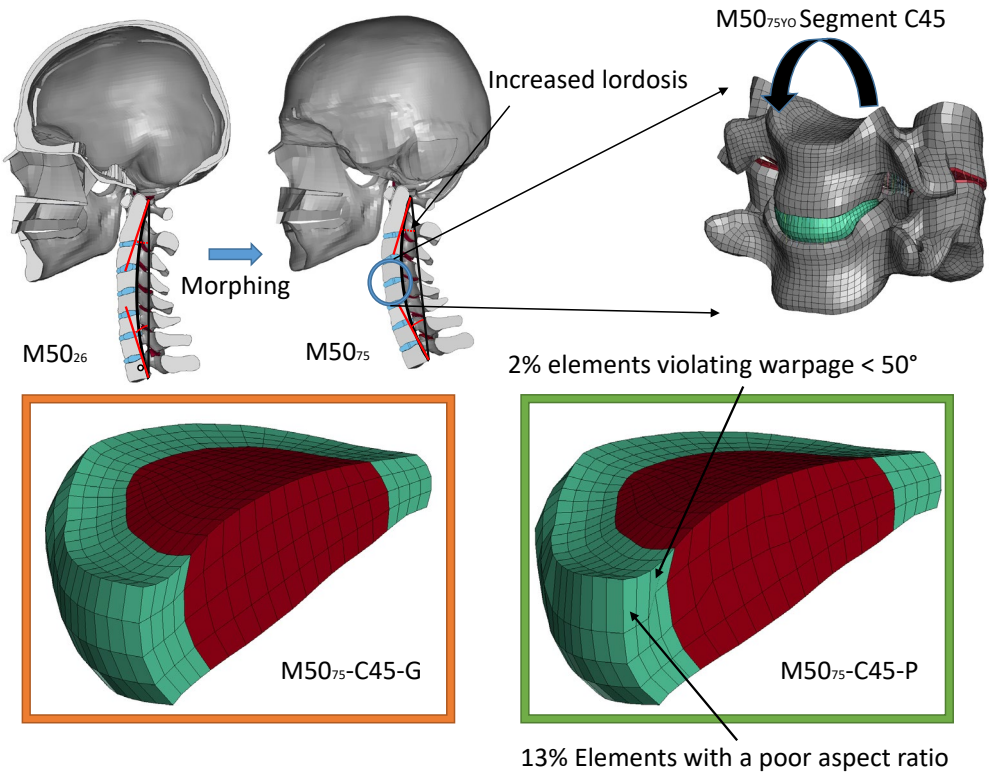

Fig. 1. $M50_{26}$ and the $M50_{75}$ models [5]. $M50_{75}$ motion segment extracted (C45) and loading schematic for flexion. The two versions of the IVD mesh (bottom) highlight the poor-quality mesh.

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At the full segment level, the mesh quality meets the minimum mesh quality requirements of the GHBMC for both the C45-G and the $M50_{75}$-C45-P. The segment models were exercised in flexion (distorted elements compressed) and extension (distorted elements in tension) loading and compared to experimental data [6].

III. INITIAL FINDINGS

In flexion loading, the response of the $M50_{75}$-C45-P was different from the response of the $M50_{75}$-C45-G; moreover, the $M50_{75}$-C45-P was outside of one standard deviation of the experimental data while the $M50_{75}$-C45-G was within one standard deviation of the experimental data. Specifically, the moment to failure was 15% higher for the $M50_{75}$-C45-P and there was a 27% higher angle to failure. In extension loading, the response of both models was comparable.

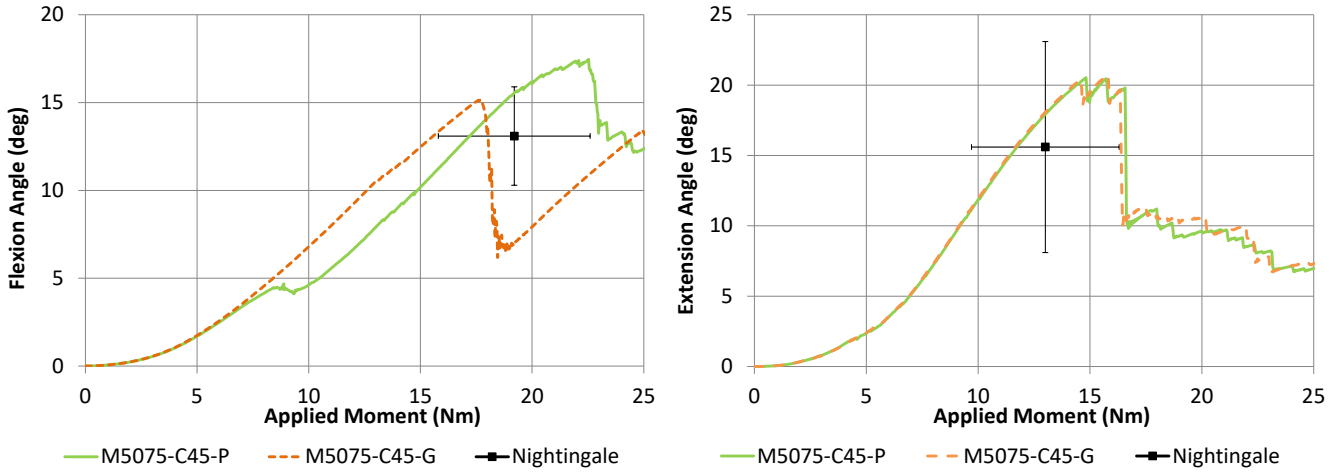

Fig. 2. Model response of the segment with comparable mesh quality to the original model (dashed orange) and the segment with poor mesh quality (solid green) compared to experimental data (black marker).

IV. DISCUSSION

The effect of mesh quality on soft tissues was assessed using a motion segment model with lower mesh quality than the $M50_{75}$ ($M50_{75}$-C45-P) but within the industrial thresholds. The $M50_{75}$-C45-P was taken from a published model prior to the full mesh quality enhancement, offering a numerical exercise over a realistic morphing outcome. The mesh quality demonstrated to have the greatest effect on the model response when the elements are subjected to compression loading (flexion loading at the segment level). In this numerical exercise, the IVD contributes greatly to the motion segment response. The mesh quality might be particularly important in the flexion loading condition compared to other loading conditions or body regions. The mesh quality at the full segment level meets the GHBMC requirements in both models. However, the results presented suggest that efforts should be made towards achieving industry-standard mesh quality in HBMs at the tissue level, particularly in structurally relevant tissues or where the mesh interacts with other components (e.g. seat belt). These findings might be most relevant in studies where the mesh is modified (e.g. morphing); it is possible that the extensive multilevel validation achieved by contemporaneous HBMs is transferable if the mesh quality at the tissue level is maintained.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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