Challenges to Position Obese Human Body Models to Reclined Configurations.

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I. INTRODUCTION

As new seating configurations, including reclined or unconventional postures are emerging, dedicated safety assessment protocols are being proposed using 50th percentile male dummies [1]. At the same time, an effort is made to account for obesity in safety assessment protocols (Euro NCAP roadmap and Vision 2030). Even in upright position, abdominal tissues associated with obesity can modify the seat belt interaction, potentially affecting the restrain kinematics [2]. The combined effect of obesity and reclined seating was also recently investigated experimentally [3].

Numerical simulations using reclined obese finite element human body models (HBMs) could also help investigate this combination. However, this requires positioning obese HBM in reclined positions. HBM positioning methods (e.g. by simulation) were mainly used with non-obese HBM, and their performance for obese hbm with large volumes of abdominal tissues needs further assessment.

In this study, we investigate the feasibility to position by simulation an existing obese HBM [4] in reclined seating paying particular attention to soft tissues.

II. METHODS

Lebarbé *et al*. acquired CT scans of four post-mortem human subjects (PMHS) in both supine and seated positions [2]. These scans were completed with surface scans and lateral lumbar spine X-rays in supine, seated and intermediate reclined positions. Janak [4] created seated subject-specific HBMs for three of the PMHS. For this, the GHBMC M50-O v5.0 was morphed and partially remeshed to approach the subject-specific geometry in the seated posture, including skeleton, skin (notably the abdominal fold), and subcutaneous fat thickness. Following adjustments to improve the stability and compliance of the soft tissues, the models were checked against matching seated experiments [2][4].

To highlight potential challenges related to abdominal soft tissues, this study focuses on the PMHS with the highest BMI (46 kg/m²). The corresponding model in the seating position was placed on a sled seat model. While seating with a 14° seat pan and 22.5° back (defined with respect to the horizontal and vertical planes, respectively, denoted (14°,22.5°) hereafter), there are small differences between the model, CT-scan trunk region, and surface scan for example for the limbs or pelvis positions. Therefore, the HBM was first positioned to the (14°,22.5°) configuration of the surface scan. Then, from that position, it was positioned to the reclined position with a 45° seatback (14°,45°).

In both cases, the positioning methodology was a two-step process. First, a bone target position was defined using the pre-positioning module in the PIPER 1.10 software (www.piper-project.org). For this, the sacral angle measured on the X-rays was applied to the pelvis, and the positions of the shoulders and femurs that were estimated based on the surface scan were used to change the thigh-to-trunk angle. Then, beams pulled the skeleton towards the bone positions exported from PIPER in an Ls-Dyna simulation (ANSYS). Gravity was applied concurrently.

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III. INITIAL FINDINGS

The HBM skin surface was compared to the PMHS surface scans as illustrated in Fig. 1 for the reclined configuration. A large opening (approximately 70mm wide) appeared between the abdomen and the thighs (abdominal fold) despite the application of the gravity. This opening is not present for this PMHS at 45° nor at higher angles. For the quantitative assessment, the displacements of 23 markers stitched to the PMHS abdominal skin were compared to those of HBM nodes at similar initial locations. For the 45° recline position, the marker displacements are slightly smaller for the HBM in magnitude (mean ± standard deviations: 127±20 mm vs. 141±29) and along X (122±21 vs. 137±29) but the Z displacement is higher for the model (28±17 vs. 10±27) which is attributed to the gap opening.

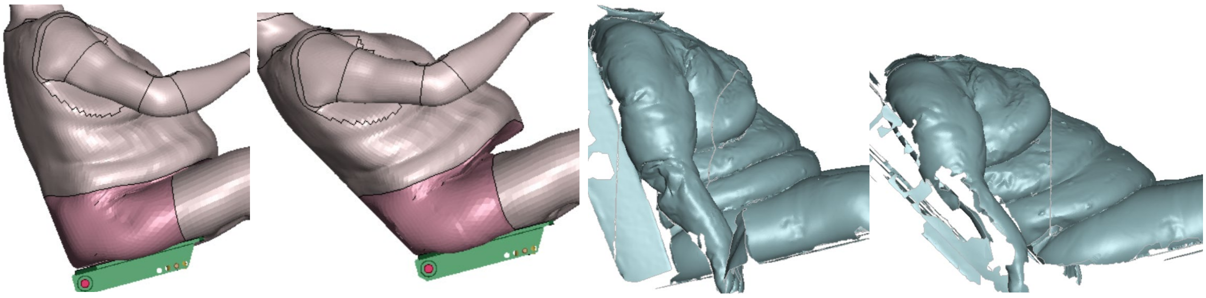

Figure 1. Model (left) and PMHS (right) in initial (22.5° back angle) and reclined (45° back angle)

IV. DISCUSSION

These first simulations highlight the difference of abdominal tissue response between the model and PMHS under gravity loading. The model abdomen deforms more like a rigid object while the PMHS abdomen unfolds. The fact that mean marker displacements on the visible skin surface are not that different between the HBM and PMHS does not describe what happens inside the abdominal fold. The resulting shape difference led to a gap opening near the abdominal fold which would be problematic for belted interactions. The issue may be exacerbated by the high BMI of the PMHS and further comparisons will be performed with lower BMI and a more recent version of the HBM. Multiple reasons could have contributed to this issue including (1) mechanical properties of soft tissues may be adjusted for impact responses and may be too stiff under gravity loading (2) the initial strains and stresses present in the tissues are not considered although the considerable deformations resulting from gravity loads suggest the presence of significant pre-existing strains (3) the incompressibility of the abdomen in the HBM may over-constrain its volume while large quantities of air are visible on the CT-scans (4) the internal organ kinematics and sliding may not be well described. Future work will investigate each of these factors separately to assess their effects and highlight needs for improvements.

V. REFERENCES

[1] Wang *et al.*, 2025 RCCADS Workshop
[2] Lebarbé, M. *et al.*, Stapp Car Crash J. 2021
[3] Somasundaram, *et al*. Stapp Car Crash J. 2023.
[4] Janák, PhD. Thesis, Université de Lyon. Available https://theses.hal.science/tel-03426591 2020