Development and Validation of an Active 50th Percentile Chinese Male Human Body Model

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I. INTRODUCTION

The human body's muscle response during the pre-crash and crash phases significantly influence occupant posture and the resultant injury severity in motor vehicle collisions [1-2]. Meanwhile, the occupant injury risk is highly associated with the populational characteristics at multiple physical scales, such as geometric size [3]. Yet, existing restraint systems are often designed through crash safety tests using anthropomorphic test devices representing western occupants (i.e. European and American). As an efficient research tool, active Human Body Model (aHBM) can capture human kinematics and muscle state [4-5], and looks promising in terms of reflecting the population factors. However, there is no unified method to map aHBMs of different anthropometries. The current work aims to develop an aHBM with the body stature of a representative Chinese 50th%ile male (C50M-aHBM) and to validate the model using kinematic corridor generated from volunteer tests. Preliminary comparison on injury difference was made between the C50M-aHBM and Western 50th%ile male aHBM (W50M-aHBM).

II. METHODS

The technical flow of the model development is as follows (Fig. 1). To obtain the detailed Chinese anthropometries of a Chinese 50th%ile male, we first used the differences in parameters from different databases provided by the China National Institute of Standardization (CNIS), and established a linear regression function (input: height or weight, output: anthropometric parameters). Using the height and weight of a Chinese 50th%ile male (169 m, 69 kg), we obtained nine anthropometric parameters (e.g. sitting height, chest width) from the regression. Following this, we adopted the W50M-aHBM provided in MADYMO (R2020.1) as a baseline model, given its computational efficiency to generate the Chinese 50th%ile male facet human model at the MADYMO/Scaler platform. Specifically, to match the transformation of the muscle element nodes, the radial basis function (RBF) was chosen to morph the muscle nodes' location in the newly generated model. The extraction and the definition of the nodal position were executed in batches using in-house MATLAB scripts. The control strategy of the muscle element remained after the morphing.

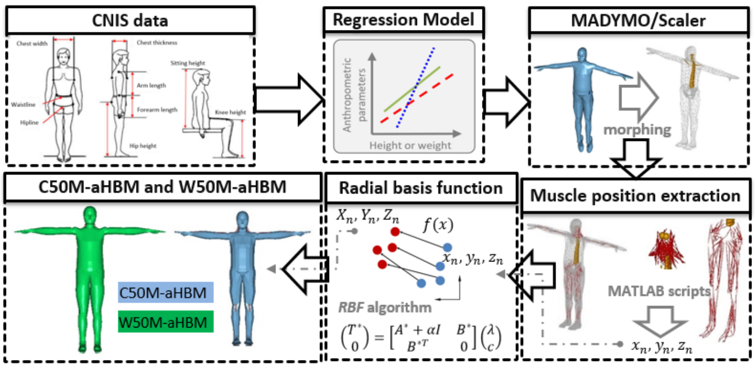

Fig. 1. The flowchart of developing the C50M-aHBM.

The biofidelity of the generated aHBM was validated through available volunteer experiments. We established the simulation model of occupant-restraint interaction based on the layout dimensions and physical properties at the driver side in Volvo V60 T4 model (Fig. 2(a)). After positioning the C50M-aHBM and W50M-aHBM, we adjusted the models according to the volunteer experiment in autonomous braking events with reversible pre-tensioned restraints [6]. The excursion corridors for the occupant movement in the volunteer experiment were collected to compare the kinematics of the two models.

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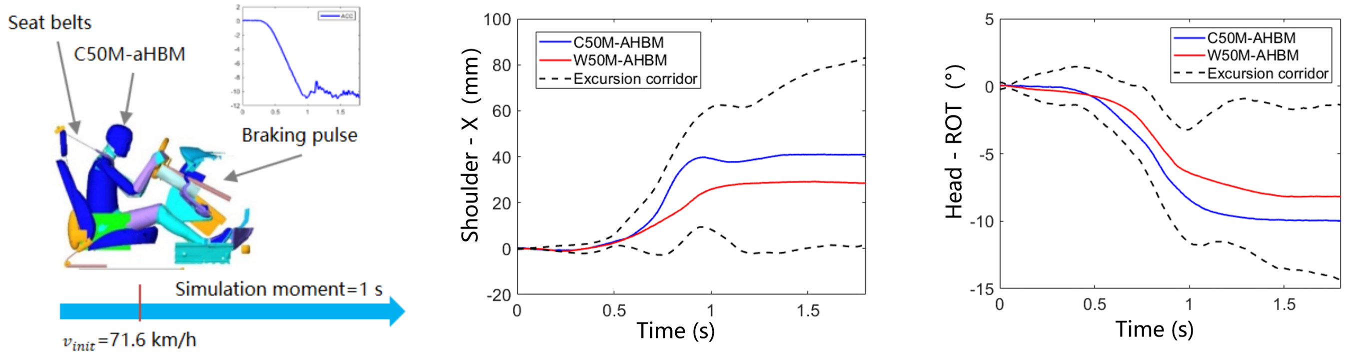
III. INITIAL FINDINGS

All kinematic responses of the C50M-aHBM and W50M-aHBM were within the experimental corridor, indicating an acceptable biofidelity of body models. Two examples of the kinematic response, i.e. shoulder x-direction displacement and head rotation angle, are presented in Fig. 2. In the braking phases, the active muscles led to different posture changes. The C50M-aHBM exhibited a higher excursion of the upper body (i.e. 40.11 mm vs. 29.78 mm of the peak shoulder displacement).

To obtain the injury outputs of the Chinese and Western aHBM under the same restraint system condition, we designed a collision simulation based on the US-NCAP frontal collision test (No.MC5106, Frontal collision, v_0=56 km/h). Under the same simulation condition, most of the injury indicators of C50M-aHBM are higher than those of W50M-aHBM (Table I). For example, the C50M-aHBM exhibited a higher neck injury (N_{ij}) (Δ_{neck}= 26.09%) and a similar chest compression (Δ_{chest}= 3.16%) compared to the W50M-aHBM.



(a) (b) (c)

Fig. 2. (a) A C50M-aHBM in braking phase, (b) excursions recorded of the displacement of shoulder in the X-axis in braking, (c) excursions recorded of head – ROT (Rotation) in braking.

TABLE I
COLLISION SIMULATION INJURY RESULTS

Model	HIC_{36}	BrIC	N_{ij}	Chest compression (mm)	Force of femur (kN)
C50M-aHBM	522	0.97	0.58	26.1	6.23
W50M-aHBM	471	0.91	0.46	25.3	5.15
Δ(%)	10.83	6.59	26.29	3.16	20.97

IV. DISCUSSION

This work presents our attempts to map the aHBMs into different Chinese anthropometries for studying the possible injury outcome differences in MVCs. In the model validation phase, the head rotation of C50M-aHBM is significantly increased ($\Delta_{rotation}$= 19.33%) compared with that of W50M-aHBM. The C50M-aHBM has long upper body and short legs, resulting in higher upper body relative mass, which perhaps limits the protection performance of the restraint system. Furthermore, the difference in the injury between Chinese and Western aHBMs indicates that traditional restraint systems based on Western physical anthropometries cannot fully match Chinese physical characters, restricting occupant protection in real-world applications. Following on from this, a simulation matrix will be established using aHBM to study the population-specific injury mechanisms.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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