Neck kinematics of average female and male dummy sizes in rear-impact tests at 16 km/h and 24 km/h

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I. INTRODUCTION

A considerable period has elapsed since the introduction of neck injury assessment in low severity rear impacts, and a certain reduction in injury risk during rear impacts has been observed. However, recent injury statistics indicate that whiplash-associated disorders remain a significant problem, and it has been shown that women have a substantially higher risk of this injury [1]. Meanwhile, the anthropometric test device (ATD) used in whiplash testing, such as the Euro NCAP whiplash tests, represents the average male population, and evaluations addressing female occupants are insufficient. This issue has been recognised as an important challenge [2]. In this study, the risk of neck injury sustained by female occupants in low severity rear impacts is addressed as a key concern. Using the Seat Evaluation Tools (SET) [3], which enable the evaluation of both male and female physical models, this study examines how sex differences affect neck kinematics during low severity rear impacts. The objective of this study is to quantify differences in neck kinematics between male and female dummy responses in low severity rear impacts, using a case study involving the front seat of a single vehicle model.

II. METHODS

Rear-impact sled tests were conducted using the SET 50M and SET 50F dummies seated in a 2025 model-year vehicle regular seat. The test conditions were in accordance with the Euro NCAP test protocol [4], including the seat position and acceleration pulses. Two acceleration pulses were applied: the Medium (16km/h) and High (24km/h) severity pulses, maximum acceleration 11g and 7.5 g respectively.

Regarding the head restraint position, anthropometric differences between the SET 50M and SET 50F were considered. For the SET 50F, the vertical positional relationship between the head restraint and the head was adjusted prior to testing to match that of the SET 50M. The head restraint was positioned in its lowest position for the tests with the SET 50F and in the mid position for the 50M. In the seating configuration, the H-point position of the SET 50M was adjusted to match that of the BioRID-II dummy. The head-to-head restraint distance (backset) was 50 mm for the 50M, and the pelvis angle was 31°. The pelvis angle for the SET 50F was aligned with that of the SET 50M to match the torso posture, and the head-to head restraint distance was 46 mm for the 50F. Tri-axial acceleration was measured in the head and at 1st and 8th thoracic vertebrae in addition to the pelvis. Evaluation was performed using a combined tri-axial accelerometer and tri-axial gyroscope (TE Connectivity model 633 6-DOF sensor) [5], enabling the assessment of the Neck Injury Criterion (NIC) [6] and head rotation. In addition, dummy kinematics were recorded using video imaging. Based on these measurement data and video recordings, comparative analyses were conducted to investigate the kinematic differences between the SET 50M and SET 50F dummies.

III. INITIAL FINDINGS

The results of the sled tests conducted using the SET 50M and SET 50F dummies are summarised as follows. Under the Medium Pulse condition, the NIC value for the SET 50M was 9.2 m^2/ s^2 while the SET 50F exhibited a lower value of 6.3 m^2/ s^2 (Table I). A similar tendency was also observed under the High Pulse condition. Differences were observed between the SET 50M and SET 50F in terms of the timing at which the maximum NIC value occurred. For the SET 50M, the NIC peak appeared shortly after head restraint contact (HRC), whereas for the SET 50F, the maximum NIC value was observed during the later phase of the event (Fig. 1). Furthermore, the head and the T1 x-displacement relative to the sled were smaller for the SET 50F than for the SET 50M (Fig. 2). Analysis of the high-speed film showed that the SET 50F exhibited a larger relative rotation angle between the head and T1 compared to the SET 50M (Fig. 3).

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TABLE I
NIC

Pulse	Model	Max. (m^2/s^2)	Time (ms)
Medium	SET 50F	6.3	129
	SET 50M	9.2	72
High	SET 50F	6.1	104
	SET 50M	7.8	69

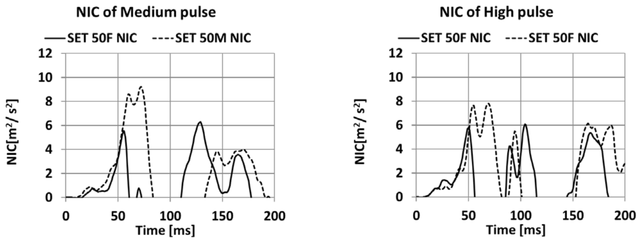

Fig. 1. NIC of SET 50F and SET 50M.

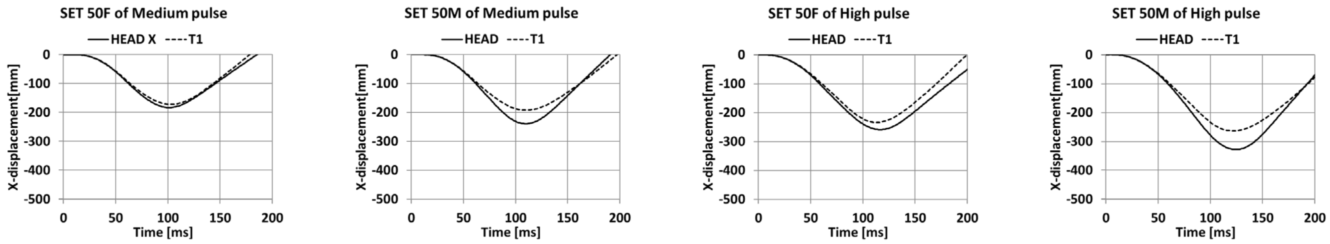

Fig. 2. X-displacement of head and T1 relative to the sled reference of SET 50F and SET 50M.

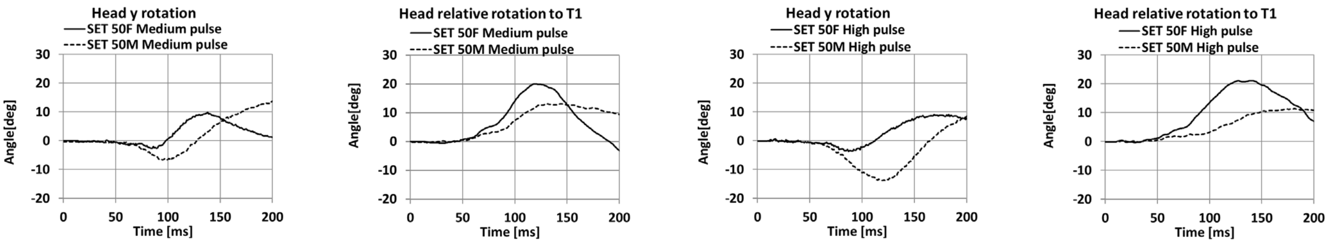

Fig. 3. Head rotation and relative rotation angle between the head and T1 of SET 50F and SET 50M.

IV. DISCUSSION

Differences in cervical spine kinematics between the male and female dummy were observed. In low-speed volunteer tests, it has been reported that females tend to exhibit lower NIC values compared to males [7] [8] [9] [10] [11]. A similar tendency was found in the present study using the SET 50M and SET 50F dummies. One possible factor contributing to the lower NIC values observed for the SET 50F is the adjustment of the vertical positional relationship between the head restraint and the head to match that of the SET 50M, while accounting for the body size of the SET 50F. In addition, a lower injury threshold for NIC is suggested for the 50F than for the 50M [12]. In this study, compared with the SET 50M, the SET 50F exhibited earlier HRC and a smaller velocity phase difference between the head and T1. These kinematic characteristics are considered to have contributed to the reduction in NIC. Analysis of the kinematic behaviour revealed that the SET 50F exhibited a larger forward relative rotation angle between the head and T1 than the SET 50M. A more in-depth analysis into this is needed to identify the main contributors to these results.

This study represents an example demonstrating that sex differences can manifest in different cervical spine kinematics under the given test conditions. Future studies should continue to investigate a wider range of test conditions and injury criteria to achieve a more comprehensive understanding of differences between average female and male kinematic response in rear impacts related to soft tissue neck injury risk in a crash.

V. REFERENCES

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