Alterations of Muscle Activation and Moment Characteristics at Neck Joint due to Brake Force applied to Stationary Lead Vehicle in Low-speed, Rear-end Collision

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I. INTRODUCTION

Rear automobile impacts can cause musculoskeletal injury to the facet joints, spinal ligaments, intervertebral discs, vertebral arteries, dorsal root ganglia, or neck muscles [1]. Much research has been conducted, based on sled tests, to investigate how to reduce the risk of the injury, particularly whiplash injury, in low-speed, rear-end collisions. However, the majority of previous studies did not consider the brake force likely to be applied to a stationary lead vehicle in low-speed, rear-end collisions. The primary aim of this study is to analyze the alterations of muscle activation and moment characteristics at the neck joint due to brake force applied to a stationary lead vehicle in low-speed, rear-end collision.

II. METHODS

Subjects

Ten healthy adult males who had no musculoskeletal or nervous system disorder, who could move their cervical spine and lumbar spine freely and who had no history of whiplash injury (average age, 25.5 ± 0.7 years; average height, 173.6 ± 2.3 cm; average weight, 69.9 ± 2.9 kg) were selected and subjected to low-speed, rear-end collision tests. The study was approved by Sejong University Institutional Review Board (IRB: SJU-2015-003).

Low-speed, Rear-end Collision Test Platform (Sled Test Platform)

The test platform was designed with a brake force control component and validated by comparing with the acceleration pulses specified in the IIWPG test procedure [Society of Automotive Engineers (SAE), 211-1] (Fig. 1A). Here, the low-speed, rear-end collision was caused by the pendulum component in the test platform and favorably compared to acceleration pulses of real low-speed, rear-end collision. A mountain bicycle (MTB) oil hydraulic brake equipment (BR-M675, Japan) was mounted as the brake force control component in the test platform.

Analyses of Muscle Activation and Moment Characteristics

The low-speed, rear-end collision tests for two conditions – one with and one without brake force applied to stationary lead vehicle – were performed and human responses at the neck joint were measured (Fig. 1B). The participants were then instructed to sit in the car seat in a similar posture to their real sitting postures for driving, with relaxed neck and arm muscles (Fig. 1C). Muscle activations were measured in both low-speed, rear-end collision tests via a wireless surface electromyogram (EMG; Tringo Wireless EMG System, Delsys, USA; sampling rate, 2,000 Hz) attached to the sternocleidomastoid, splenius capitis muscles. Head and neck joint angles and accelerations and the headrest impact force were then measured together using a three-dimensional motion capture system with eight infrared cameras (T-10s, Vicon Motion Systems Ltd., UK; sampling rate: 200 Hz) and a pressure pad (Pliance, Novel gmbh, Germany), respectively, for the calculation of moments at the neck joint. The equation, modified from that reported by Kroonenberg *et al*., used to calculate the moments was:

$$M = Ia \pm mgsin\theta(t) + mgcos\theta(t) + \left(T_0 sin\theta(t) + T_0 cos\theta(t)\right)u(t - t_0)$$

where I=moment of inertia of the head [2], m=mass of the head [2], a=neck joint angular acceleration, g=acceleration due to the gravity, $\theta(t)$=angle at the head, T_0=the headrest force and t_0=time when subject's head crashed into the headrest. Here, head and neck joint angles were defined as shown in Fig. 1D.

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Statistical Analysis

A paired students' t-test was used to identify the difference between human responses (muscle activation and moment) in low-speed, rear-end collision with/without brake force applied to stationary lead vehicle.

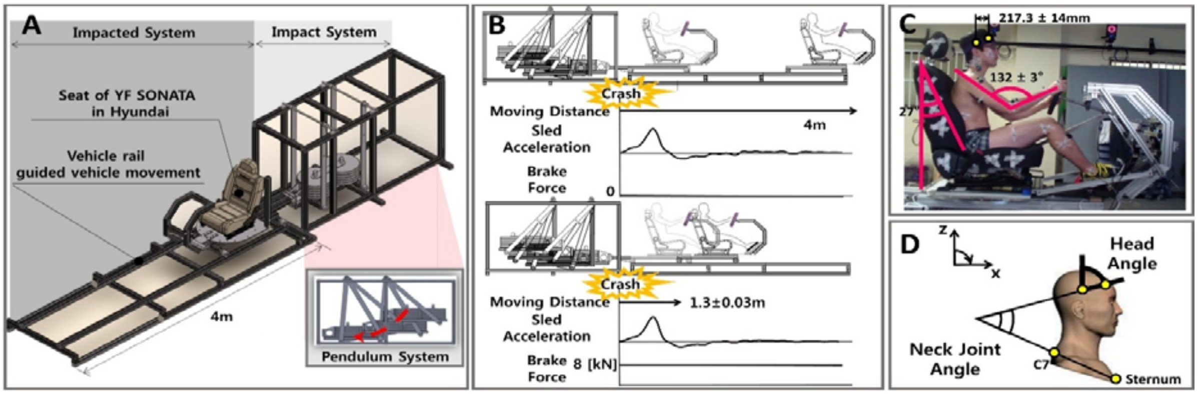

Fig. 1. (A) Low-speed, rear-end collision test platform; (B) conditions for low-speed, rear-end collision tests with/without brake force applied to stationary lead vehicle; (C) actual experimental configuration; (D) definition of neck joint angle.

III. INITIAL FINDINGS

Maximum muscle activation and moment at the neck joint were increased roughly 1.4 and 1.3 times, respectively, in the low-speed, rear-end collision with brake force applied to stationary lead vehicle ($p<0.05$) (Fig. 2). The muscle activation and moment were generally distinguished after the retraction phase (initial phase in low-speed, rear-end collision) and maximized for extension-flexion phase (phase occurred after retraction phase in low-speed, rear-end collision). Particularly, the moment was increased rapidly after the retraction phase by sudden, simultaneous increases of agonistic and antagonistic muscle activations.

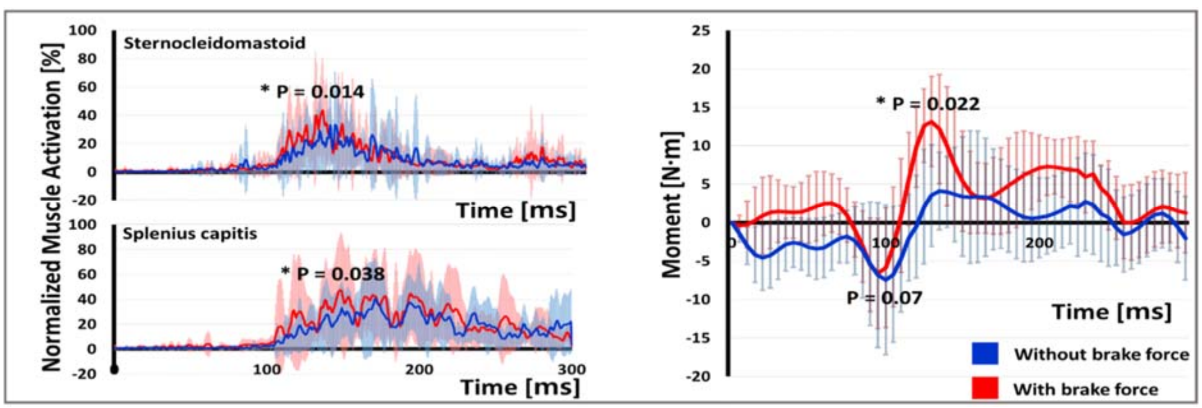

Fig. 2. Alteration patterns of muscle activations (*left*) and moment (*right*) at the neck joint.

IV. DISCUSSION

The results show that the muscle activation and moment characteristics at the neck joint may be altered due to brake force applied to a stationary lead vehicle in a low-speed, rear-end collision. This indicates that brake force applied to stationary lead vehicle may increase the possibility of injury occurring (e.g. whiplash injury) at the neck joint in the low-speed, rear-end collision. However, our findings must be validated through various low-speed, rear-end collision tests by controlling the parameters (a degree of brake force, habitation, awareness, etc.) influencing the muscle activation and moment at the neck joint.

V. REFERENCES

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