

Discomfort and muscle activation during car egress in drivers with hemiplegia following stroke

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Abstract. [Purpose] This study investigated and compared the discomfort experienced during car egress with the car door opened at different angles and muscle activation in drivers with hemiplegia following stroke and non-disabled drivers. [Subjects and Methods] The participants were five drivers with hemiplegia and five non-disabled drivers. The discomfort experienced during car egress was measured using the nine-point Likert scale when the door was opened wide and when it was opened 45°. Muscle activation was measured using the TeleMyo 2400T G2 electromyography system. Electromyograph electrodes were placed on the erector spinae, rectus abdominis, and rectus femoris muscles. [Results] In the non-disabled drivers, there was no significant difference in the discomforts they experienced during car egress when the door was opened wide and when it was opened 45°. However, the discomfort experienced by drivers with hemiplegia when the door was opened 45° was significantly higher than that experienced when it was opened wide. There was a significant difference in the activation of the erector spinae, but no difference in the activation of the rectus abdominis or rectus femoris muscles. [Conclusion] This study will help to understand the difficulties experienced by drivers with hemiplegia following stroke during car ingress and egress.

Key words: Car egress, Driving, Muscle activation

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INTRODUCTION

The numbers of drivers with hemiplegia following stroke is increasing. Driving rehabilitation tends to focus only on the task of driving. While driving, people with hemiplegia have difficulties not only in keeping a safe distance from the car ahead, maintaining a proper speed, and responding quickly¹⁾, but also with car ingress and egress²⁾. Car ingress and egress are challenging tasks for people with hemiplegia, especially when they cannot open the door wide due to a narrow parking space; moreover, they have a harder time getting into and out of the vehicle when they cannot open the door wide; therefore, they take more time.

To provide better assistance to drivers with hemiplegia, the specialists in driving rehabilitation need to consider the activities the drivers with hemiplegia will perform before and after actually driving a car, as well as with the actual task of driving. Although it is believed that drivers with hemiplegia struggle to get into and out of the car, there is little evidence of this³⁾. To better understand the problems

drivers with hemiplegia face during car ingress and egress, it is important to understand muscle activation during car ingress and egress in drivers with hemiplegia following stroke and the discomfort they experience, in according with the angle at which the door is opened, and how this is different from that in non-disabled drivers. Therefore, this study investigated differences in muscle activation during car egress and differences in discomfort according to the angle of the door opening between non-disabled drivers and drivers with hemiplegia following stroke.

SUBJECTS AND METHODS

There were 10 participants in this study. Five participants were drivers with left-sided hemiplegia following stroke, and five were non-disabled drivers. All participants signed a consent form prior to participation. This research was approved by Inje University's Institutional Review Board. General information regarding these participants is provided in Table 1. The car used in this study was the Hyundai Avante. To measure discomfort during car egress, the participants got out of the car when the door was opened wide and when it was opened at 45°. The discomfort the drivers experienced was measured based on self-assessment using the nine-point Likert scale as recommended in a prior study⁴⁾. One point was 'extremely uncomfortable', two points was 'very uncomfortable', three points was 'discomfort', four points was 'a little discomfort', five points was 'normal', six points

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Table 1. General characteristic of participants

		Drivers with hemiplegia (N=5)	Non-disabled drivers (N=5)
Gender	Male	3	3
	Female	2	2
Age	30s	1	2
	40s	1	0
	50s	1	1
	60s	2	2
Driving career (years)	Less than 5	1	2
	Above and 5-less than 10	2	1
	Over than and 10	2	2
Type of car	Car	5	3
	Van	0	1
	Truck	0	1
Type of driving license	Regular in class 1	3	3
	Large in class 1	2	1
	Regular in class 2	0	1

Table 2. Discomfort point according to angles of the door opening (N=10)

	Drivers with hemiplegia*	Non-disabled drivers
45°	1.8±0.37	3.4±0.93
Wide	4.2±0.37	4.4±0.68

*Significant difference between when the door was opened at 45° and opened wide at 0.05 level

Table 3. Comparison of muscle activation between two groups (N=10)

	Drivers with hemiplegia	Non-disabled drivers
Erector spinae*	69.28±6.31	38.39±8.04
Rectus abdominal	95.5±17.54	48.94±15.97
Rectus femoris	39.50±5.48	75.98±14.28

*Significant difference between drivers with hemiplegia and non-disable drivers at 0.05 level

was 'a little comfortable', seven points was 'comfortable', eight points was 'very comfortable', and nine points was 'extremely comfortable'.

Muscle activation was measured using surface electromyography (EMG) (TeleMyo 2400T G2, Noraxon U.S.A., Inc., Scottsdale, AZ, USA). The collected signals were converted into digital signals in a TeleMyo 2400T G2; and were then processed by a Myoresearch XP 1.07. The EMG signal sampling rate was set to 1,000 Hz. The sampled EMG signals were filtered at 20–500 Hz using 60 Hz notch filters as band-pass filters. Electrodes were attached to the skin superficial to the erector spinae, right rectus abdominis, and right rectus femoris muscles⁵). The value of the muscle activation was based on the percentage of reference voluntary contraction. The start of the egress phase was set as the point at which the driver's trunk, pelvis, and leg were turned to the left after the driver had been sitting in the driver's seat facing toward the front of the vehicle. The end of the egress phase was set as the point at which the driver was standing outside of the car planting his or her feet on the ground. Muscle activation was measured while moving from the sitting position in the driver's seat, while standing up without support, and while standing outside the car without support.

Data were analyzed using SPSS 18.0. The χ^2 test was used to check homogeneity for gender, age, and driving experience between drivers with hemiplegia and non-disabled drivers. The Mann-Whitney U Test was used to compare reported discomfort and muscle activation of each muscle between the two groups and discomfort according to the angle of the door opening.

RESULTS

Gender, age, and driving experience were not significantly different between the two groups (Table 1). The discomfort that drivers experienced during car egress when the door

was opened wide and when it was opened at 45° was not significantly different between the two groups. In the drivers with hemiplegia, the discomfort that the driver experienced when the door was opened wide was 4.2 ± 0.37 points on the Likert scale, and when the door was opened at 45°, the discomfort the driver experienced was 1.8 ± 0.37 points. This was a statistically significant difference ($p < 0.05$). In contrast, among the non-disabled drivers, the discomfort that the driver experienced when the door was opened wide was 4.4 ± 0.68 points on the Likert scale, and when the door was opened at 45°, the discomfort was 3.4 ± 0.93 points. This was not a statistically significant difference ($p > 0.05$; Table 2).

Muscle activation of the erector spinae during car egress in drivers with hemiplegia was 69.28 ± 6.31%, and in the non-disabled group, it was 38.39 ± 8.04%. Muscle activation of the erector spine was significantly higher in drivers with hemiplegia than that in non-disabled drivers ($p < 0.05$). Activation of the rectus abdominis in drivers with hemiplegia was 95.5 ± 17.54, and in non-disabled drivers, it was 48.94 ± 15.97. Activation of the rectus abdominis was higher in drivers with hemiplegia than that in non-disabled drivers, but the difference was not statistically significant ($p > 0.05$). Activation of the rectus femoris in drivers with hemiplegia was 39.50 ± 5.48, and in non-disabled drivers, it was 75.98 ± 14.28. Activation of the rectus femoris was higher for the non-disabled drivers group than for the drivers with hemiplegia, but the difference was not statistically significant ($p > 0.05$; Table 3).

DISCUSSION

Many studies have addressed car ingress and egress; however, there are no such studies for investigating drivers with hemiplegia following stroke. To help understand the difficulties that drivers with hemiplegia following stroke

face during car ingress and egress, this study investigated differences in muscle activation during car egress and differences in discomfort that the drivers experienced according to the opening angle of the door; furthermore, these findings were compared with those of non-disabled drivers. Because older people and disabled people have more difficulties during car egress than during ingress⁶⁾, this study involved only car egress.

The non-disabled drivers reported no significant difference in discomfort experienced according to the opening angle of the door, but the drivers with hemiplegia felt significantly more discomfort when the door was opened at 45° than when the door was wide open. This result is an example of how the environment has a more negative impact on disabled people than on non-disabled people⁷⁾. Similarly, Chateauroux and Wang⁸⁾ analyzed the motion of car egress in older and younger people. They reported that both younger and older people gripped the steering handle or the door for support during car egress, but only the older people gripped the doorframe, the middle, or the front post. This means that car egress was a challenge for the older people, but not for the younger people.

Car egress movement is categorized into either left leg first (LLF) or two legs out (TLO). In LLF, a driver gets his or her left leg out of the car first and in TLO, a driver gets both legs out of the car simultaneously⁹⁾. Considering that older people commonly use TLO⁹⁾ and all the drivers with hemiplegia following stroke in this present study had left-sided hemiplegia, we conducted the study only using TLO. LLF can be divided into five phases of motion: move the left foot out of the car, place the left foot on the ground, move the head out of the car, stand up, and place the right foot out of the car. In the first and fifth phases, the rectus abdominis is the most activated muscle. In the stand-up phase, the erector spinae is the most activated, and in the fifth phase, the right rectus femoris is the most activated⁵⁾. When comparing muscle activation during car egress between the two groups, there was no statistically significant difference between activation of the rectus abdominis and the rectus femoris, but the activation of the erector spinae muscles of the drivers with hemiplegia was significantly higher than that of non-disabled drivers. We considered that this difference occurred because we used the TLO method, which, unlike the LLT method, mainly required the stand-up motion and did not require the foot-placing motion.

To measure the discomfort experienced by the participants, this study used a self-reported nine-point Likert scale. Recently, many objective and scientific methods for measuring discomfort during car ingress and/or egress have been proposed^{10–12)}. However, this study used the simplest

method to measure discomfort. This study failed to control for any differences that could occur due to differences in the height of the participants, which can influence the discomfort a person faces in car ingress and egress¹³⁾. The limited number of subjects was one of the limitations of this study. There are many studies which have focused on driving tasks, such as using the steering handle¹⁴⁾ and pressing the car accelerator pedal¹⁵⁾. However, there is little evidence regarding activities before and after actual driving, such as ingress or egress. This study will help to understand the difficulties experienced by drivers with hemiplegia following stroke during car ingress and egress activities.

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