

Characteristics of Driving Reaction Time of Elderly Drivers in the Brake Pedal Task

HWA-KYUNG SHIN, PhD, PT¹⁾, HO-CHEOL LEE, PhD²⁾

¹⁾ Department of Physical Therapy, Collage of Medical Science, Catholic University of Daegu

²⁾ Department of Mechanical and Automotive Engineering, College of Engineering, Catholic University of Daegu: 330 Geumrak 1-ri, Hayang-eup, Geongsan-si, Gyeongbuk, Republic of Korea.
TEL: +82 53-850-2721, E-mail: hcle21@cu.ac.kr

Abstract. [Purpose] Driving is a complex activity involving cognitive and motor skills. It is an essential component of daily life for older adults. However, aging may decrease a driver's psychomotor performance and increase the risk of traffic accidents. Driving reaction time (DRT) requires visuo-motor coordination and fast DRTs are needed to cope with unexpected conditions or traffic lights. The purpose of the current study was to compare the DRT of elderly drivers and young drivers using a tri-axial accelerometer and a foot switch. [Methods] Twenty-four subjects (younger=12, elderly=12) participated in this study. DRT was measured with a tri-axial accelerometer and foot switch. DRT was classified by initiation and termination as on or off according to contact with the brake pedal during the brake pedal task. [Results] The ANOVA model for accelerometer-DRT yielded significant main effects for phase, but not for axis. Termination was delayed significantly more than initiation. The elderly group showed significantly more delay than the younger group. In the elderly group, termination was delayed more than initiation, but there was no difference in delay between initiation and termination in the young group. In foot switch-DRT, termination was delayed much more than initiation in both groups ($p<0.05$). The elderly group showed significantly more delay than the young group. [Conclusion] We suggest that the driving ability of elderly drivers can be assessed with reasonable accuracy using accelerometer-DRT, which minimizes the expense and risk associated with on-road assessments of this population.

Key words: Driving reaction time, Elderly driver, Tri-axial accelerometer

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INTRODUCTION

Driving is a complex activity involving cognitive and motor skills. It is an essential component of daily life for the elderly. However, aging may decrease a driver's psychomotor performance, and increase the risk of traffic accidents^{1, 2)}. Researchers have found that driving errors are responsible for most accident involving elderly drivers. Such errors include misjudging the time available to proceed, making improper turns or improper stops, failing to yield the right of way, and speeding³⁾.

One objective measure of driving ability is driving reaction time (DRT)⁴⁾. DRT requires visuomotor coordination and fast DRTs are needed to cope with unexpected situations or traffic lights. DRT may be influenced by ergonomic factors, including the pedal layout, human factors, including age and vision, and environmental factors, including the type of brake light³⁾. The DRT has commonly been measured using a foot switch. The foot switch method measures the time it takes for the plantar surface to contact the brake pedal. However, it is difficult to find the exact contact point if the foot has structural or pathological problems using this method⁵⁾. A tri-axial accelerometer is a suitable tool for measuring the characteristics of physical movement such

as speed, frequency, and distance, including direction⁶⁾. In addition, this method is inexpensive, easy to carry out, and convenient⁷⁾.

The purpose of the present study was to compare the driving abilities of elderly drivers with those of young drivers with respect to the initiation and termination of pressing the brake pedal using a tri-axial accelerometer and a foot switch.

METHODS

Twenty-four subjects (young=12, elderly=12) participated in this study. The eligibility criteria for the elderly group (age>65) included the following: intact visual perception and cognition, no musculoskeletal impairment, and normal sitting balance. The same inclusion criteria were

Table 1 . Demographic data

Variables	Elderly	Young
Number	12	12
Gender (F/M)	6/6	6/6
Age (y)	68.9 ± 1.2	22.3 ± 2.1
Height (cm)	162.4	168.2
Weight (kg)	66.3	64.4

used for the young. Before commencing the experiments, the purpose and method were fully explained to all subjects. The demographic data of the subjects is presented in Table 1. All subjects provided their signed informed consent to participation.

A renovated car (Tuson, Hyundai, Korea) was used for this research. DRT was measured with a tri-axial accelerometer and foot switches. The foot switches were attached to the middle of the accelerator and brake pedals. Foot switches with built-in force sensitive resistors (TSD111A, Biopac inc, USA) were used to measure the elapsed time between contact of the right foot and its removal from the brake pedal. In addition, a tri-axial accelerometer was attached to the lateral malleolus of the right foot. The accelerator signal consists of three directional components, X, Y, and Z, where the X-axis represents acceleration through the medio-lateral direction, the Y-axis represents the up-downward direction, and the Z-axis represents the antero-posterior direction. Subjects adjusted the height and inclination of the car seat to establish a comfortable posture. The height of the shoe heel was limited to 5 cm. All subjects were given the same instructions regarding the brake pedal task. The subjects were instructed to move their right foot from the accelerator pedal to the brake pedal as quickly as possible after a red light appeared in a monitor. Similarly, as soon as the red light turned off, they were instructed to move their right foot from the brake pedal to the accelerator pedal as quickly as possible. To prevent anticipation of stimulus onset, the trigger signal was randomly set. The subjects were given three practice trials and then performed 5 actual trials. The shortest and longest reaction times were ignored and the remaining three trials were averaged. Before commencing the current study, the reproducibility of tests was assessed. Selected acceleration signals were sent to a MP150 A/D converter and processed by Acknowledgesoftware (Biopac System Inc., USA) on a PC.

The initiation and termination of DRT were classified according to the contact with the brake pedal during the brake pedal task. When DRT was measured by the foot switch, initiation was defined as the time interval between the onset of the visual signal in the monitor and the first contact of the foot on the brake pedal. Termination was defined as the time interval between when the visual signal was turned off and the first contact of the foot on the accelerator pedal. When DRT was measured by the accelerometer, it was determined as “the temporal midpoint of maximum and minimum acceleration”, as in a previous study⁸⁾. This method is based on the fact that all of the accelerating and braking motions include a positive maximum and a negative minimum pair, a representative figure of which is shown in the Figure 1⁸⁾. This midpoint was determined using MATLAB version 7.13 (Mathworks, USA)^{9, 10)}. Moreover, the peak pair of maximum and minimum acceleration appears twice for each motion. The temporal min-point is obtained by finding the mid-point between the maximum peak and the following minimum peak. Previous findings have reported that the “temporal mid-point of maximum and minimum acceleration” using an accelerometer was significantly correlated with DRT determined by a foot switch.

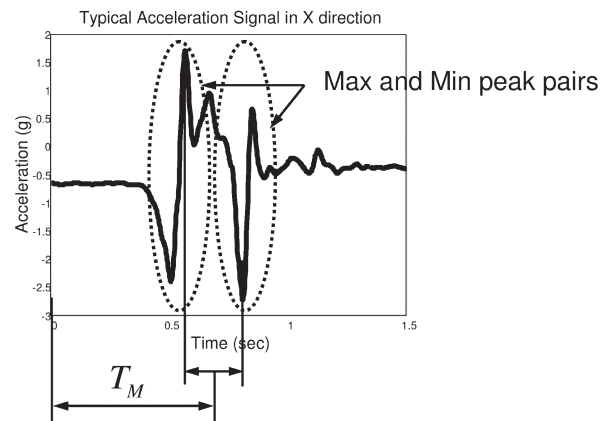


Fig. 1. Arithmetic average value between maximum and minimum peaks

The mean values of the three trials of brake pedal pressing were used as the summary measure. Accelerometer data were analyzed using a two-way repeated-measures design. This model assessed the within-subject effects, which included axis factors (X, Y and Z) and temporal factors (initiation and termination) as the repeated factor, and between-subjects effect (young group and elderly group). For foot switch-DRT, the paired t-test was used to compare initiation and termination, and the independent t-test was used to compare the elderly group with the young group for initiation and termination. An alpha level of <0.05 was accepted as significant. All statistical analyses were performed using SPSS 17.0 for Windows (SPSS Inc, Illinois).

RESULTS

The data of 24 subjects (elderly group=12, young group=12) were pooled for analysis. The data acquired from the accelerometer are summarized in Table 2. Our ANOVA model for the accelerometer-DRT yielded significant main effects for phase ($F=16.20$, $p=0.00$), but not for axis. Termination was delayed significantly more than initiation. The interaction effects, axis \times group ($F=0.71$, $p=0.50$), phase \times group ($F=3.85$, $p=0.06$), axis \times phase ($F=0.22$, $p=0.80$), and axis \times phase \times group ($F=0.89$, $p=0.42$), were not significant. In the analysis of the between-subjects effect, the elderly group showed significantly more delay than the younger group ($F=16.68$, $p=0.00$). The result of the paired t-test, in the comparison of delay in initiation and termination within groups, showed that termination in the elderly group was delayed much more than initiation ($p<0.05$), but that the delay in initiation and termination of the younger group did not show a significant difference ($p>0.05$).

In the foot switch-DRT, termination was delayed much more than initiation in both groups ($p<0.05$). The elderly group showed significantly more delay than the younger group ($p<0.05$)(Table 3).

Table 2. Descriptive data for accelerometer

Axis	Initiation			Termination		
	Elderly	Young	t	Elderly	Young	t
x	0.99 ± 0.28	0.64 ± 0.12	3.71*	1.19 ± 0.32	0.74 ± 0.19	3.98*
y	0.94 ± 0.33	0.66 ± 0.11	3.05*	1.20 ± 0.33	0.74 ± 0.18	4.05*
z	0.91 ± 0.26	0.68 ± 0.13	2.80*	1.21 ± 0.32	0.75 ± 0.18	4.00*

* p<0.05

DISCUSSION

Accurate measurement of physical activity is a prerequisite for monitoring movements and for designing effective interventions. In this study, we measured DRT, one of the criteria used for measuring driving error¹¹⁾. DRT is an important factor in the total stopping distance of a vehicle and is an important factor in traffic accident prevention. Several devices and analysis methods have been used for measuring DRT. Foot switches have been the most commonly used devices for measuring DRT in clinical studies. The type of an accelerometer used in this study has rarely been used for measuring the brake pedal task. The tri-axial accelerometer can measure the variation of acceleration produced by body movement in one (vertical; uniaxial) or three planes (anterior-posterior, lateral, and vertical; triaxial)¹²⁾. Acceleration is equivalent to the intensity of motion because it is directly related to force under Newton's second law. The accelerometer is small and non-invasive^{6, 13)}.

It is important to specify the time when the brake pedaling motion occurs and there are several methods for defining it^{14, 15)}. In a previous study, we studied the correlation between the foot switch method and the accelerometer method in the brake pedal task performed by healthy adult drivers⁸⁾. The data corrected from accelerometers can be analyzed by 3 methods: 'maximum acceleration time', 'geometrical center', and 'temporal mid-point of maximum and minimum acceleration'. Of these methods, 'temporal mid-point of maximum and minimum acceleration' was the most significantly correlated with the foot switch method¹⁰⁾. The merits of this method are that it reflects the starting acceleration and final deceleration of motion and simultaneously takes the dominant motion and the whole motion span into account.

Our objective in this study was to elucidate the characteristics of ankle acceleration of elderly drivers in the brake pedal tasks. We compared within-group effects (axis and temporal factor) and between-group effects (young and elderly) with respect to the delay of initiation and termination as determined by the accelerometer. In the case of the within-group effects, the delay in termination was more significant than that of initiation in the temporal factor. In the case of the between-group effects, the elderly group showed significantly more delay than the young group. Delay in termination in the elderly group was much greater than the delay in initiation. However, the delay in the young group was not statistically significant, although the delay in termination was greater than the delay in initiation. In the

Table 3. Driving response time using a foot switch

Time	Elderly	Young	t
Initiation	1.70 ± 1.10	0.96 ± 0.26	2.91*
Termination	2.06 ± 0.92	1.32 ± 0.73	2.60*
t	2.73*	2.51*	

* p<0.05

foot switch method, the results of the elderly group were more significant than those of the young group. Termination was significantly longer than initiation in both groups.

Unlike the foot switch variables, the accelerometer variables can compare the reaction time between axes. In this study, delay in initiation on the X-axis was greater than delay in initiation on the Y and Z axes in the elderly group. However, in the young group, delay in initiation to the X-axis was smaller than the delay in initiation on the Y and Z axes. Finally, the delay in initiation of the elderly group was greater than that of young group. Although the delay in termination did not differ between axes, the delays in termination of the elderly group in all axes were greater than those of the young group. Also, the delay in termination of the elderly group was more significant than the delay in the termination of the young group in the foot switch-DRT.

In a previous study, which compared the delay in initiation and termination of post-stroke patients, Chae et al. (2001) reported that the delay in initiation or termination of muscle contractions was significantly greater for the paretic than in the non-paretic limbs¹⁶⁾. Similarly, delay in termination of muscle contraction was significantly greater than delay in initiation of muscle contraction for both the paretic and non-paretic limbs. In this study, the delay in termination was significantly greater than the delay in initiation, similar to what was seen in stroke patients. This finding may be related to the decrease of inhibitory control of the neuromuscular system due to aging. As a result, the time taken to take the right foot off the brake pedal was delayed and restarting after stopping may be delayed. Therefore, we must consider termination delay as well as initiation delay when we perform the driving evaluations for the elderly group.

In laboratory settings with the use of simulators, the age of drivers influenced DRT^{17, 18)}. Elderly drivers react more slowly than younger drivers because it is more difficult for older people to properly judge traffic environments and to stop initiated movements. Therefore, for safe driving, drivers must perceive and respond to sensory information as fast and accurately as possible. This is one of the fields that has been

studied in traffic accident prevention, because delayed DRT after an unexpected external stimulus is a leading cause of traffic accidents. Through appropriate screening and driving evaluation and rehabilitation, physical therapists can help identify unsafe drivers, give advice to clients who need to stop driving, provide intervention strategies for those with remedial potential, and assist in optimizing driving skills that may be affected by age-related conditions. In addition, physical therapists need to understand more clearly the characteristics of driving errors of disabled people and develop clinical tools for driving evaluation.

In conclusion, we determined the characteristics of DRT from ankle acceleration of elderly drivers performing the brake pedal task. Accelerometer-DRT of the elderly group was delayed more significantly than that of the young group in both initiation and termination. Termination was delayed more significantly than initiation. We suggest that the driving ability of elderly drivers can be assessed with reasonable accuracy using the accelerometer-DRT, which minimizes the expense and risk associated with on-road assessments of this population.

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