Relationship Between Ankle Proprioception and Driving Performance During Simulator Driving in Post-stroke Drivers: A Pilot Study Results

Hwakyung Shin[1], Joonwoo Son[2], Seokhun Kim[3]
[1]Department of Physical Therapy, Catholic University of Daegu, Daegu, Korea
[2]Daegu Gyeongbuk Institute of Science and Technology, Daegu, Korea
[3] University of South Florida,School of Physical Therapy & Rehabilitation Science
Corresponding Author : hkshin1@cu.ac.kr

Abstract

Stroke is a major cause leading to motor disability. Impaired motor function is one of the most serious causes of disabling sequelae of strokes, with over 50% of stroke patients experiencing a residual motor deficit. Researchers have shown an increased interest in proprioception deficits of the paretic side in hemiplegic patients. We examined the relationship between ankle proprioception and driving performance during simulator driving in post-stroke drivers. Four post-stroke drivers participated in this study. We developed an assessment environment using a driving simulator to evaluate driving performancce of stroke patients. The driving scenario consists of 3.5 km urban traffic conditions (3 minutes), 10 km divided 4-lane straight highway (6 minutes), and 7 km 2-lane curved or hilly rural roads (6 minutes). Performance parameters during the simulated drive were automatically generated by the simulator software. The parameters included time-to-collision (TTC), number of road edge excursions, centerline crossings, speed limit violations, collisions, reaction time, and runtime. Ankle proprioception was measured by tracking test that represent the scaling or grading as an essence of coordination of the ankle joint. Double-axis electrogoniometer was used to record the instantaneous angle of the ankle joint dorsiflexion–plantar flexion. We suggest that ankle proprioception may have effects on driving performance of post-stroke driving performance.

Introduction

Driving is an important activity of daily living and an integral part of mobility and independence that affects physical, social, and economic well-being. The driving ability can be affected by various motor, visual, cognitive, perceptual and sensory deficit, commonly experienced after stroke[1]. Impairment of proprioceptive sense, such as joint position and movement sense, may for some patients result in failure to recognize that movement is occuring[2]. Especially proprioceptive sensory deficit of ankle joint can cause a negative effect for driving. The purpose of this study is to exam the effect of ankle proprioception on driving performance

Methods

Participant

Four stroke patients with hemi-paretic stroke were recruited. Their mean age was 50.3 (SD 5.19) years, and the mean duration of illness was 15.3 (SD 2.83) months. Driver 1, 2 was left hemiplegia and driver 3,4 was right hemiplegia. Inclusion criteria were: (1) at least 1 year from the onset of stroke; (2) without ankle joint flexion contracture (3) possession of a valid state driver's license. Exclusion criteria were: (1) severe spasticity of the ankle (modified Ashworth's scale: > 2) or tremor; (2) visual problem to see the sine waves are displayed on a PC monitor at 80 cm distance or severe cognitive impairments (scoring < 25 on the Mini-Mental State Examination). (3) visual problem or severe cognitive impairment(scoring <25 on the Mini Mental State Examination). Informed consent form was obtained from the all subjects prior to study.

Driving Simulation

The experiment was conducted in a fixed based driving simulator, which incorporated STISIM DriverTM software and ax fixed car cab. Graphical updated to the virtual environment were computed using STISIM DriveTM based upon inputs recorded from the accelerator, brake and steering wheel with tactile force feedback. The virtual roadway was displayed on a wall-mounted screen at a resolution of 1024 x 768. Sensory feedback to the driver was also provided through auditory and kinetic channels. Distance, speed, steering, throttle inputs were captured at a nominal sampling rate of 30 Hz.

The participants received 5 minutes of driving experience and adaptation time in the simulator. In a main experiment session, the patients drove on the urban, highway and rural traffic condition in a session. Driving scenario consists of 3.5 km urban traffic conditions (3minutes), 10km straight highway with divided 4 lanes(6minutes), and 7 km 2-lane curved and hilly rural roads(6minute). Performance parameters during the simulated driving were collected through the simulator software. The parameters included runtime, mean speed, collisions and number of road edge excursion and centerline crossing, which calculated from every road condition. The reaction time was calculated using time-to-brake firm the start time of a sudden back-up car event on an urban road. The parked vehicle was triggered by the simulated vehicle location based on 4 seconds of time-to-collision(TTC).

Visual biofeedback tracking test

Double-axis electrogoniometer (Biometrics Ltd, USA) was used to record the instantaneous angle of ankle joint doriflexion(DF)-plantar flexion(PF) in the hemiplegic ankle. PC generated sine waves at 0.2 Hz were displayed on a PC monitor at 80 cm distance from the eyes of the subject. Two sets of sine wave amplitude ranges were employed: −20◦ ~ +10◦ (30◦ tracking) or -50◦~ 0◦ (50◦ tracking). A double-axis electrogoniometer (Biometrics Ltd. Ladysmith, VA) was used to record the instant degrees of ankle PF-DF. Its proximal arm was secured on lateral midline of the fibular using the head of fibular for reference, and movable arm was secured on parallel to the lateral aspect of the fifth metatarsal bone. The instant degrees of ankle joint were then collected with a MP150 physiologic data acquisition system (Biopac Systems Inc., Goleta, CA) at a sampling rate of 100 Hz and went through a 1.5 Hz low-pass filter. Those two waves (the imposed sine wave and the electrogoniometer data) were adjusted to the same scale and displayed on the PC monitor as overlays.

Comparison of the imposed sine wave and the measured joint angle wave was performed off-line. The Microsoft Excel program was used to calculate the AI (accuracy index; Eq., which was introduced and has been verified by Carey et al.)[1]

$$AI = \frac{100\,(P - E)}{P}$$

According to their description, E is the root mean square error between the target line and the response line, and P is the r.m.s. value between the sine wave and the midline separating the upper and lower phases of the sine wave. The magnitude of P is determined by the scale of the vertical axis, which is the range of knee motion of the subject. Therefore, the AI is normalized to the range of motion of each individual subject and takes into account any differences between subjects in the excursion of the tracking target. The maximum possible score is 100%. Negative scores occur when the response line is so distant from the target that it falls on the opposite side of the midline.

Results

As results of ankle joint tracking test, the driver 3 represented the best performance and the driver 2 is the worst performance comparing with other drivers. Results of driving performance was similar to tracking accuracy index. Also, The driver 1, 2 with left hemiplegia were worse driving performance comparing with the driver 3,4.

Discussion

As an alternative and often in conjunction with on-road driving evaluation, the use of a driving simulator can offer several unique advantages to determining driving readiness[3]. For example, driving simulation can allow clinicians to offer repeatable, standardized evaluatioins of driving performance in a variety of challenging scenarios that can be composed to the individuals level of impairment. More recent work examining the use of driving simulation and stroke drivers has focused on the use of thease systems to better identify scientific difference in driving capacity in difference type of stroke. For example, Kotterba eo al., compaired performance on neurological tests(relavant to driving) and simulator driving in a group of individuals with acute ischemia in the middle cerebral artery(MCA) and the the vertebral artery (VA) and matched healthy control. The findings indicated that although all patients had only mild deficits, the MCA ischemia patients demonstrated poor results in the driving simulator and in accident rates[4]. The researchers concluded that driving simulation assess various physical and neuropsychological functions that influence driving, even in mildly impaired population and thus may discriminate driver not measured in more traditional driving assessment tool[4].

Several studies have examined the lesion location and the extent of brain damage incurred to better determine the impact of the resulting impairments on driving performance. In relation to driving difficulties, individuals who have sustained a right hemisphere stroke represent poor performance. Cortical damage in the area of the temporoparietal lobe of the right hemisphere often results in impairment in spatial and perceptual abilities and attentional and visual skills deficits. So Impact of visuo-spatial and perceptual deficits on driving capacity in critical. What is more commonly seen after stroke and more challenging to evaluated are visual measures that are more cognitively loaded; for example visual attention, visual processing, speed, and visual scanning skills. In addition, survivors of right-hemisphere stroke may also experience left side neglect. Visual field impairment and left side neglect causes the survivor of right hemisphere stroke to “forget’ or’ ignore’ objects or people on their left side. Joint tracking test may reflect the capacity of visuomotor performance, and be used to measure the scaling or grading as an essence of coordination.

In this study, we intended to exam the relevance between the ankle proprioception and driving performance. Currently there are no universally accepted guidelines for what constitutes a complete assessment of an individual for determining the ability to return to driving. We found the possibility which joint tracking test that reflects visuomotor capacitycan serve to determin an individuals' readiness for on-road assesment. Future research is needed to better define driving criterion or driving outcome measure and large sample size.

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Contact

More information is available at:
hkshin1@cu.ac.kr
(Assistant Professor at the Catholic University of Daegu)

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Table 1. Ankle tracking test

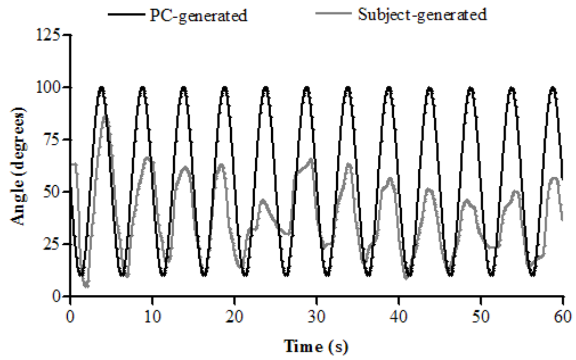

Table 2. Driving performance

STISIM	average speed			accident			line crossing (shoulder)			Line crossing (center)		
	Ur	Hi	Ru	Ur	Hi	Ru	Ur	Hi	Ru	Ur	Hi	Ru
Driver 1	45.1	96	66	1	0	0	0	0	0	0	0	1
Driver 2	44.9	79.7	58	0	0	1	0	7	9	0	0	3
Driver 3	39.2	89.9	50.3	0	0	0	0	0	0	0	0	0
Driver 4	49.6	88.8	56.7	1	0	0	0	1	0	1	0	0
Mean	45	88.6	57.8	0.5	0	0.25	0	2	2.25	0.25	0	1
SD	3.7	5.82	5.58	0.5	0	0.43	0	2.92	3.9	0.43	0	1

Ur: Urban, Hi: Highway, Ru: Rural

Table 3. Ankle tracking test

Tracking	−20◦ ~ +10◦ tracking		−50◦ ~ 0◦ tracking	
	0.2 Hz	0.4Hz	0.2 Hz	0.4Hz
Driver 1	55.3	65.8	65.7	75
Driver 2	44.1	46.9	52.4	54.1
Driver 3	65.7	70.1	73.1	72.1
Driver 4	58.5	59.1	62.4	66.1
Mean	55.0	60.9	63.4	66.8
SD	9.0	10.1	8.6	9.3