U.S. Department of Transportation
National Highway Traffic Safety Administration

TRAFFIC TECH
Technology Transfer Series

NHTSA

DOT HS 812 389

July 2017

Older Drivers' Foot Movements

Background

A previous NHTSA report, *Pedal Application Errors* (Lococo, Staplin, Martell & Sifrit, 2012), showed that pedal error crashes were more common among older drivers and among female drivers. However, the study provided limited information about driver characteristics that may play a role in pedal errors such as medical conditions, physical attributes or fit in vehicles.

Objectives

This study explored how older drivers use their accelerator and brake pedals, to identify characteristics that could pose an increased risk of a pedal application error. The study also explored whether driver-vehicle fit was related to these characteristics.

The study collected and analyzed data from older adult drivers to address the following research questions:

1. Is medical status associated with drivers' foot positions and movements?
2. Is drivers' sex or anthropometry (e.g., height, foot size and leg length) associated with foot positions and movements?
3. Is drivers' sex or anthropometry related to driver-vehicle fit?

Method

The ***foot movement study***, which addressed the first two research questions, included the following groups of cognitively normal drivers age 60 and older:

- *Normally aging (NA)* participants who did not have functional limitations.
- *Medical conditions (MC)* participants included drivers in two groups:
  - *Peripheral neuropathy (PN)* participants with limited sensation in their feet, and
  - *Orthopedic (OP)* participants with a fracture or replacement of the right hip in the 18 months preceeding the study.

Table 1 contains the distribution of the 26 participants across medical condition groups and sex.

Table 1: Foot Movement Study Participants

	NA	PN	OP	Total
Female	7	2	1	10
Male	11	4	1	16
Total	18	6	2	26

All participants completed an in-clinic assessment comprised of measures of physical functioning, cognition, perceptual motor abilities, and vision. Following the in-clinic session, participants drove an instrumented vehicle (2011 Chevrolet Malibu) over a 27-mile course that included on-road suburban, urban, and freeway driving. The course also required negotiating a parking garage and outdoor parking lot, both with gated access. The study evaluated driving performance using two methods: data from vehicle instrumentation, and scores from a certified driving rehabilitation specialist (CDRS) who directed participants through the course.

The route included 10 locations where all participants were required to brake, and the study used vehicle instrumentation data to characterize foot behavior in each situation. The CDRS scored behaviors during 18 specified tasks that included 8 on-road and 4 parking maneuvers. Table 2 summarizes the test conditions.

Table 2: Summary of Test Conditions

	Required Braking Locations	CDRS Scored Maneuvers
On-Road	1	8
Emergency Stop	1	0
Backing	4	4
Straight Parking	2	4
Gate Access	2	2
Total	10	18

The ***driver-vehicle fit study,*** which addressed the third research question, included most of the participants from the foot movement study plus additional participants who had incomplete foot-movement data. The 33 participants included 12 females and 21 males. Participants arrived at the study site, parked, and sat in their vehicles with their hands on the steering wheel and their right foot on the brake pedal. A researcher measured each participant's self-selected position. The participant then got out of the vehicle while the researcher gathered additional measurements of seat position.

While one researcher completed measuring the vehicle, another recorded the participant's height, upper leg (femur) length, lower leg (tibia) length, foot length, and distance from the knee to the ball of the foot. The researcher used these measures to calculate the "right leg functional reach," the distance from the hip to the ball of the foot when the foot is at a right angle to the leg.

When the participant returned to the driver's seat, the researcher demonstrated how to adjust the seat optimally as defined by CarFit guidelines. CarFit states that drivers should be able to use the full range of the pedals without fully extending their leg or stretching

with their toes (for more information, visit www.car-fit.org). After a researcher recorded the adjusted seat position, the participant returned to the vehicle. The driver then considered the adjustments and, if desired, readjusted the seat to a comfortable position before leaving the site.

Results

In general, medical status did not appear to affect foot positioning or variability in foot movements. Drivers in the MC group applied less pressure on the brake than the NA group during the required on-road braking maneuver at a three-way stop. However, there was no significant difference in maximum brake force by group during the emergency stop. The MC group also looked to the right for a longer duration than the NA group at one of four backing locations.

Sex, however, did appear to affect foot positioning and movement. Females had shorter (i.e., faster) foot transfer time from the accelerator to the brake than males during one straight parking maneuver, and female drivers' foot positioning on the brake was closer to the lateral center of the brake pedal than male drivers during on-road braking and gate access.

Anthropometric variables also had a statistically significant effect on many of the measures of foot positioning and movement. Table 3 summarizes the results.

Table 3: Anthropometric Variables and Foot Movement

Shorter Drivers	Lifting versus pivoting Faster transfer time Closer to brake center More brake coverage More hover time
Shorter Shoe Length	Closer to brake center Toe points more forward Less maximum brake force
Shorter Femur	Longer transfer time Closer to brake center More brake coverage More conformance of movement w/ direct path Toe points more forward More hover time
Shorter Tibia	Lifting versus pivoting Faster transfer time More conformance of movement w/ direct path

Group differences in clinical scores were not reflected in on-road driving performance. Each of the groups averaged high scores on combined on-road tasks. However, the MC participants demonstrated poorer performance in combined parking lot tasks. These differences reflected MC participants' errors in judging the turning radius when turning left into a parking space, taking multiple attempts to position the vehicle in the parking space, and failing to shift into park at the end of the task.

Driver-vehicle fit analyses showed that drivers whose self-selected seat positions provided a good fit had an average functional leg reach that was about three inches longer than that of drivers who had not adjusted their seats properly. Logistic regression analysis of the relationship of sex, height, and measures of right leg length showed that only functional leg reach was significantly associated with fit. As functional leg reach increased, the expected probability of acceptable fit increased.

Discussion

In-clinic data indicated that NA participants had better sensitivity on the soles of their feet than the MC group, and the NA group scored better on measures of cognition and physical performance that have been associated with driving performance. These factors may help explain why drivers in the MC group performed similarly to the NA group during the on-road evaluation but demonstrated more difficulty in the parking tasks. Drivers with medical conditions, whose cognitive scores were poorer than those in the NA group, may have devoted more attention to the vehicle control tasks necessary for parking as a result of limited lower limb sensation, pain, or poorer cognition.

Males' and females' foot movements differed significantly on only 4 measures across the 10 locations. The observed sex differences in foot movement type, transfer time, and foot position on the brake may reflect differences in anthropometry rather than sex. Females were shorter, on average, than males and had shorter tibias, femurs, and smaller feet.

Conclusion

This study showed that older adults with medical conditions performed as well as their healthier peers in on-road driving and were similar to those normally aging in terms of foot positioning and movement. However, they made more errors in negotiating parking tasks. Findings also showed that many older adults, particularly those with a shorter functional reach, may need guidance in adjusting their seats to allow easy access to the pedals.

Reference

Lococo, K., Staplin, L., Martell, C., & Sifrit, K. (2012, March). Pedal application errors. (Report No. DOT HS 811 597). Washington, DC: National Highway Traffic Safety Administration. Available at http://ntl.bts.gov/lib/45000/45700/45716/811597.pdf.

Report Access

For a copy of the research report *Older Drivers' Foot Movements* (DOT HS 812 431), visit www.nhtsa.gov. Kathy J. Sifrit was the NHTSA Project Manager for this project.

Suggested APA format citation for this document:

National Highway Traffic Safety Administration. (2017, July). *Older Drivers' Foot Movements.* (Traffic Safety Facts Traffic Tech. Report No. DOT HS 812 389). Washington, DC: Author.

U.S. Department of Transportation

National Highway Traffic Safety Administration

1200 New Jersey Avenue SE., NPD-310
Washington, DC 20590

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