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Association of falls and fear of falling with objectively-measured driving habits among older drivers: LongROAD study

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Abstract

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Author contributions

CGD, MEB, DWE, LLH, VCJ, TJM, LJM, DS and GL conceptualized and designed the study and its methods; CGD, MEB, KAS, DWE, LLH, VCJ, TJM, LJM, DS and GL oversaw acquisition of subjects; CGD and HAH analyzed the data and drafted the manuscript; CGD, HAH, MEB and KAS interpreted the data; all authors revised the manuscript critically for important intellectual content and approved the version to be published.

Institutional review board approval

This study was approved under the following Institutional Review Board (IRB) protocol/human subjects approval numbers: Colorado Multiple IRB (COMIRB No. 14-0528, PI: C. DiGuiseppi), Columbia University IRB (Study No. IRB-AAAN9950, Principal Investigator [PI]: G. Li), Johns Hopkins Bloomberg School of Public Health IRB (Study No. 00006200, PI: V. Jones), Mary Imogene Bassett Hospital IRB (No. IRB0000200, PI: D. Strogatz), University of California, San Diego IRB (IRB No. 141800, PI: L. Hill), and University of Michigan IRB (Study No. HUM00094031, PI: D. Eby).

Declaration of interest

The authors have no conflicts of interest to declare.

Objective: Falls in older adults are associated with increased motor vehicle crash risk, possibly mediated by driving behavior. We examined the relationship of falls and fear of falling (FOF) with subsequent objectively measured driving habits.

Methods: This multi-site, prospective cohort study enrolled 2990 active drivers aged 65–79 (53% female). At enrollment, we assessed falls in the past year and FOF (Short Falls Efficacy Scale-International). Driving outcomes included exposure, avoidance of difficult conditions, and unsafe driving during one-year follow-up, using in-vehicle Global Positioning System devices.

Results: Past-year falls were associated with more hard braking events (HBE). High FOF was associated with driving fewer days, miles, and trips, driving nearer home and more HBE. Differences were attenuated and not significant after accounting for health, function, medications and sociodemographics.

Discussion: Differences in objectively measured driving habits according to past-year fall history and FOF were largely accounted for by differences in health and medications. Rather than directly affecting driving, falls and FOF may serve as markers for crash risk and reduced community mobility due to age-related changes and poor health.

Keywords

Falls; Fear of falling; Traffic safety; Mobility; Aging; Automobile driving

1. Introduction

Over the past two decades, the number of licensed older drivers and the miles they drive have steadily risen (Pomidor, 2019). In many societies, driving is vital to maintaining mobility -- the ability to move within one's environment – which is essential for healthy aging (Webber et al., 2010). However, fatal motor vehicle crashes per vehicle mile traveled begin to increase at ages 70–74 and continue to increase with age (Cox & Cicchino, 2021), making the prevention of crashes among older drivers an important public health concern.

The risk of crashes for older drivers relates in part to age-related functional changes, medical conditions and medications that affect driving ability (Pomidor, 2019). Falls are one such age-related condition, common among older adults (Bergen et al., 2016), that have been associated with an increased risk of motor vehicle crashes (MVC). In a systematic review of 15 studies of varying designs, sizes and geographic locations, Scott et al. (2017) found a fall history to be associated with a 40% increased risk of subsequent MVC, as well as a higher risk of MVC-related hospitalization and death. The mechanisms underlying the relationship between falls and crashes are unclear but might result from changes in driving behaviors and patterns after a fall. Fall injuries may cause functional impairments (e.g., fracture that reduces range of motion) that directly affect driving ability or behaviors. Falls, regardless of injury, might also lead to changes in driving behaviors through their psychological impact. Older adults who fall are significantly more likely to develop fear of falling (FOF) (Friedman et al., 2002), a concern that can lead to limitations in physical and social activity (Scheffer et al., 2008; Tinetti & Powell, 1993), self-care and household activities (Liu et al., 2021), and could potentially result in changes in driving habits as well. Finally, falls may be markers for age-related health and functional declines that influence both falls and driving abilities and behaviors, such as cognitive, vision and hearing impairment, gait and balance problems, and use of psychotropic medications (Deandrea et al., 2010; Karthaus & Falkenstein, 2016; Pomidor, 2019).

While changes in driving behavior associated with falls or FOF might explain the observed association between falls and MVC, the relationship between falls, FOF and driving habits has not been well-delineated. Scott et al. (2017) did not find consistent evidence of an association between falls and subsequent driving habits from the seven studies identified that had examined and reported driving habits. These studies were limited by their cross-sectional design (Forrest et al., 1997; Lyman et al., 2001; Vance et al., 2006), small samples (Crizzle et al., 2013; Lyman et al., 2001; Marie Dit Asse et al., 2014) and use of self-reported driving behavior outcomes, which may be subject to bias (Dugan & Lee, 2013; Forrest et al., 1997; Lyman et al., 2001; Marie Dit Asse et al., 2014; MacLeod et al., 2014; Vance et al., 2006). Only one study examined the relationship between falls and objectively measured driving habits, assessing 27 older adults with Parkinson's disease followed for two weeks (Crizzle et al., 2013). This study found that participants who had fallen in the past year exhibited more hard braking and drove more slowly than those without a fall. In addition to the small sample restricted to persons affected by Parkinson's, this study did not account for demographic or health-related differences between individuals who had and had not fallen. The literature examining FOF in relation to driving habits is similarly limited. One cohort study found that older women expressing high FOF were more likely to report driving cessation or reduction in the subsequent six years than women with low FOF, although this pattern was not found for men (Marie Dit Asse et al., 2014). A study with older residents of retirement communities (71% women) found that FOF was negatively associated with the number of objectively measured vehicle trips taken per day over six days' follow-up, but not with daily distance or minutes for vehicle trips (Takemoto et al., 2015). Studies in larger samples examining objectively measured driving habits over a longer period of time could help to establish whether falls or FOF (or both) are associated with changes in driving habits and driving behaviors among older adults.

The current study aimed to examine associations of self-reported history of having fallen, and of fear of falling, with objectively measured driving patterns during one year of follow-up in a large, geographically diverse cohort of older drivers.

2. Materials and methods

2.1. Study design

The AAA LongROAD study is a prospective cohort study designed to examine medical, behavioral, environmental, and other factors associated with safe driving in older adults. LongROAD enrollment occurred at five US sites (Ann Arbor, MI; Baltimore, MD; Cooperstown, NY; Denver, CO; and San Diego, CA). The study design and population have been described in detail previously; the study collects self-reported and objectively measured data on health, functioning, and driving behaviors (Li et al., 2017). A sample of 3000 drivers with average follow-up of 2.5 years was planned to provide study power >80% to detect an age-adjusted risk ratio of 3.0 for crash involvement associated with mild cognitive impairment (see Li et al., 2017). The study was approved by the institutional review board at each site, including Bassett Research Institute, Columbia University, Johns Hopkins University, University of California San Diego, University of Colorado Anschutz Medical Campus, and University of Michigan. All enrolled participants provided written informed consent for participation and received $100 at the baseline visit. The STROBE cohort reporting guidelines were followed for this report (von Elm et al., 2007).

2.2. Sample

Study participants were aged 65–79 years at enrollment, had a valid driver's license, drove on average at least once a week, drove one car (1996 or newer with an accessible OBDII port) at least 80% of the time, spoke English, without significant cognitive impairment (e.g., Alzheimer's disease) based on medical record review and a Six-Item Screener score ≥4 (sensitivity 67.5% and specificity 96.1% for clinically diagnosed dementia) (Callahan et al., 2002), and resided in the catchment area at least 10 months a year with no plans to move away within 5 years (Li et al., 2017). Using electronic medical records from healthcare systems affiliated with study sites, study staff identified potentially eligible patients, sent initial recruitment letters followed by telephone calls for eligibility screening, and scheduled eligible, interested participants for a baseline study visit for enrollment and data collection. Of 40,806 individuals sent recruitment letters, 19.0% could not be contacted by phone, 29.7% declined eligibility screening, 19.0% were ineligible (most often due to no/infrequent driving or ineligible residence), 25.0% were eligible but declined, and 7.3% (range 5.1–18.3% across study sites) (n = 2990 participants) enrolled (Li et al., 2017). Recruitment and enrollment were completed between July 2015 and March 2017.

2.3. Driving outcomes

We objectively measured driving outcomes with a device installed in each participant's vehicle that collected data when the vehicle was turned on. The device could determine if the participant was the driver using a Bluetooth receiver to detect participant codes and signal strengths transmitted by Bluetooth beacons carried by the participant. This study used data recorded during the first 12 months after the baseline fall history. Driving measures are defined in Table 1. Driving habit measures were based on previous work (Molnar et al., 2013a), conceptualized based on three components of the Driving Habits Questionnaire (DHQ) (Owsley et al., 1999): driving space, driving exposure, and driving avoidance. Two driving measures - rapid deceleration ("hard braking") events and speeding events (Table 1) - served as proxies for unsafe driving (Chevalier et al., 2017; Eby et al., 2019; Williams et al., 2006). We excluded participants if they were missing all driving measurements (n = 15) or drove fewer than 14 days or 100 miles during the 12-month period (n = 18). We derived means and standard deviations for each driving habit measure from the full 12 months of data. Two variables with skewed distributions (proportion of trips at night and number of rapid deceleration events) were log-transformed. Speeding events, which were uncommon (median = 1 event/1000 miles driven), were categorized as any versus none during the 12-month period.

2.4. Exposures

At enrollment, research staff administered questionnaires about demographics, health and healthcare utilization. We used the following variables as primary exposures: (1) "In the last 12 months have you fallen down?" (Yes/No), and (2) the 7-item Short Falls Efficacy Scale-International (Short FES-I), which assesses concerns about falling (categorized as Low [<11]/High [11–28]) (Delbaere et al., 2010). For those who answered "Yes" to having fallen, we also asked, "In the last 12 months, have you fallen down more than one time? (Yes/No)." We excluded participants from all analyses if they did not answer the question about falling in the last 12 months (n = 16) and from analyses of FOF if they were missing Short FES-I scores (n = 3).

2.5. Covariates

Demographic characteristics collected at baseline included age group, gender, race, marital status, educational attainment, household income, work for pay in the past month and urbanicity of the participant's residence. Self-reported health characteristics included: vision with correction (rated as poor to excellent); Patient-Reported Outcomes Measurement Information System short form (PROMIS SF) measures of physical function, cognitive health ("applied cognition - general concerns"), depression and anger (HealthMeasures, 2020) (as detailed in Li et al. (2017)); and self-reported driving reduction due to a health condition in the past 12 months (Yes/No). Moderate and severe categories of physical (dys)function were combined for analysis due to small numbers. None of the participants had more than slight concerns about their cognition; these scores were categorized into tertiles for analysis. We assessed self-reported health-care utilization in the past 12 months (i.e., emergency department visits [None, 1, 2 or More] or hospitalizations [None/Any]). Use of potentially impairing substances included assessment of alcohol and medication use. Alcohol consumption frequency in the past three months was categorized into any versus none, as few reported more than light-to-moderate drinking. Current medication use (prescribed and over-the-counter) was collected and categorized according to the American Hospital Formulary System (AHFS) classification, as described in Hill et al (2020). We examined medications that act on the central nervous and cardiovascular systems, which have been associated with fall risk (Hartikainen et al., 2007; Park et al., 2015). Individuals who reported taking one or more psychotherapeutic, anxiolytic, sedative, hypnotic or anticonvulsant agent were categorized as taking a central nervous system (CNS) medication. Individuals who reported taking one or more antiarrhythmic, cardiotonic, or diuretic agent were categorized as taking a cardiovascular medication.

2.6. Statistical analysis

Chi-Square tests (or Fisher's exact tests) were used to assess each covariate's association with each exposure of interest. Unadjusted associations between each exposure and each driving habit of interest were examined using separate linear or logistic regression models, as appropriate. For each driving outcome, we accounted for potential differences in age group, gender, race and marital status between participants with and without a past-year history of falls (Yes/No) or concern about falling (High/Low) in all multivariable models ("base models"). Participants missing data on any of these four sociodemographic variables were excluded from adjusted analyses (n = 75). Self-reported measures of health, health care utilization, medication or alcohol use, and additional sociodemographic factors were assessed as potential covariates if they were associated with both fall history or concern about falling and the driving outcome measure at $p < 0.20$. As a sensitivity analysis, we also examined exposure to past-year falls categorized as none, one and more than one. Model assumptions and fit were assessed using residuals, probability plots, and Akaike information criterion (AIC) as appropriate. All results are reported as beta estimates or odds ratios, as indicated, with 95% confidence intervals (CI), using an alpha level of 0.05 for testing statistical significance. All analyses were conducted using SAS University Edition software (version 9.04.01, SAS Institute, Inc., Cary, North Carolina).

3. Results

Of the 2990 participants enrolled in LongROAD, 2941 (98.4%) had complete data on both self-reported falls and objective driving measures; 2938 of these (99.9%) also had FOF data. Adjusted base models examining self-reported falls and FOF included 2866 and 2863 participants, respectively.

A substantial proportion (28.2%) reported having fallen at least once in the 12 months prior to enrollment, and 5.1% had fallen more than once, while 18.6% expressed a high FOF (Table 2). Table 2 shows characteristics of the sample by fall history. At baseline, compared to participants who had not fallen in the past year, participants who had fallen were twice as likely to report high FOF (28.7% vs 14.6%, $p < 0.001$). Those with a past-year fall history were significantly more likely to be female (59.5% vs 50.4%, $p < 0.001$) and of white race (91.3%% vs 88.2%, $p = 0.015$). They also perceived their visual acuity, physical and cognitive function to be poorer, described more current symptoms of depression and anger, and were more likely to have reduced their driving due to a health condition and to have had greater healthcare utilization in the past 12 months, and to use central nervous system medications currently (Table 2).

Drivers who did and did not report any past-year fall at baseline had similar driving exposure, driving space and driving avoidance (as defined in Table 1) during the first 12 months after baseline, after accounting for gender, age group, race, and marital status (Table 3). Participants who fell had a median of four rapid deceleration events per 1000 miles driven versus three per 1000 miles among participants who had not fallen. There were significantly more hard-braking events per 1000 miles driven in participants who had fallen in the past year versus participants who had not. Drivers who did and did not report any past-year fall at baseline did not differ significantly in their odds of having had at least one speeding event per 1000 miles driven. The difference in rapid deceleration events was attenuated and no longer statistically significant when group differences in general concerns about cognition and current use of CNS medications were taken into account. Neither cognitive concerns nor central nervous system medication use substantively affected the magnitude, direction or statistical significance of the other results (Table 3). No other differences in participant characteristics between groups were retained in adjusted models.

Sensitivity analysis revealed similar results for persons with more than one fall and persons with only one fall in the past year, compared to participants with no falls, except that persons with more than one fall made a significantly smaller proportion of driving trips during morning rush hour (adjusted beta = −0.79 [95%CI: −1.35, −0.22]).

Nearly all sociodemographic characteristics differed significantly between participants with high versus low concern about falling. Participants with high concern were more likely to be female (63.3% vs 50.6%, $p < 0.001$), ages 75–79 years (30.7% vs 22.2%, $p < 0.001$), and non-white race (14.4% vs 10.0%, $p = 0.002$), and less likely to be married or living with a partner (55.6% vs 68.6%, $p < 0.001$). Further, they were less likely to have a Bachelor's or higher degree (53.6% vs 66.6%, $p < 0.001$) or to work full-time in the last month (5.7% vs 10.6%, $p < 0.001$), and more likely to have a total household income less than $50,000 (38.0% vs 23.0%, $p < 0.001$). Differences between participants with high versus low FOF in perceived vision with correction, concerns about cognition, emergency department (ED) visits, hospitalizations, use of CNS medications and decreased driving due to a health problem were similar to differences observed between participants who had and had not fallen. In addition, participants who expressed high FOF reported poorer physical function (median t-score 43.4 vs 56.9, $p < 0.001$) and more often used cardiovascular medications (32.9% vs 23.9%, $p < 0.001$) compared to participants with low FOF.

Compared to participants with low FOF, participants with high FOF drove significantly fewer miles, days, and trips per month (all $p < 0.01$) and made more trips within 15 miles of home ($p < 0.001$) during the 12 months after baseline (Table 4). Driving avoidance was similar between participants with high versus low FOF, except that the former were significantly more likely to avoid trips during morning rush hour. Participants with high FOF, like participants with a fall history, had significantly more hard braking events but did not differ in speeding events.

After adjusting for additional sociodemographic, cognitive, and health factors, healthcare utilization and CNS medication use, participants with high FOF did not differ significantly from participants with low FOF in their driving exposure, driving space, or unsafe driving (Table 4). However, individuals with high FOF took a significantly smaller percentage of trips in morning rush hour and a significantly greater percentage of trips during evening rush hour. Groups did not differ significantly by any other measure of driving avoidance.

4. Discussion

Older drivers who reported at least one fall in the past year had a modestly higher rate of rapid deceleration events, a potential marker for unsafe driving, compared to adults who did not report falling. The observed difference was attenuated after accounting for differences in cognitive concerns and CNS medication use. Otherwise, driving habits measured objectively over a 12-month period were essentially unrelated to recent fall history. On the other hand, older drivers with a high FOF drove significantly differently than participants with low FOF; that is, they drove shorter distances, less often, and closer to home, and demonstrated more hard braking. Nearly all differences between participants with high versus low FOF were accounted for by health and sociodemographic differences between these two groups.

Like our study, the systematic review by Scott et al. (2017) did not find consistent evidence of an association between prior self-reported falls and driving frequency, distance or space. However, all but one of those studies were based on subjectively-measured driving habits. The one included study with objectively-measured naturalistic driving (Crizzle et al., 2013) was limited to a small number of patients with Parkinson's disease followed for only two weeks, but similarly found no significant differences in driving exposure between those who had and had not fallen. Overall, our data suggest that having a past-year fall history does not lead older drivers to substantially reduce where or how often they drive. In contrast, FOF was found to be significantly associated with driving less often and for shorter distances. Previous research has shown that FOF is associated with cognitive decline, frailty, poor health, and gait abnormalities (Scheffer et al., 2008). While actual functional declines influence driving ability, both actual capacity and self-perceived physical, cognitive and perceptual deficits influence driving behavior (Anstey et al., 2005; Betz & Lowenstein, 2010; Molnar et al., 2013a,b; Molnar et al., 2015). Consistent with past research, we found that greater concerns about cognitive function and poorer perceived physical function helped explain observed differences in driving exposure and space between participants with high and low FOF. FOF may be a marker for perceived sensory, cognitive or physical deficits that lead participants to limit their driving exposure. FOF has previously been shown to be associated with restrictions in amount and type of physical and social activity (Scheffer et al., 2008). Our findings demonstrate that FOF is similarly associated with reduced driving mobility, with potentially serious adverse effects on access to goods and services and on social and civic engagement (Dickerson et al., 2019; Oxley & Whelan, 2008; Satariano et al., 2019; Webber et al., 2010).

We found little evidence that either FOF or a history of falls was associated with avoidance of difficult driving situations (e.g., driving during rush hour or at night). Evidence from prior studies is limited and inconsistent. Crizzle et al. (2013) similarly found no evidence that those with a history of falls had greater objectively-measured driving avoidance. In contrast, Vance et al. (2006) found that the number of self-reported falls was positively correlated with a composite driving avoidance score. Regardless of fall history or FOF, older drivers enrolled in our study generally avoided challenging driving situations, making relatively small percentages of trips on highways, during rush hour or at night.

Both a history of falls and a high FOF were associated with a modestly higher rate of rapid deceleration events (RDEs), whch indicate hard braking. Crizzle et al. (2013) also found significantly more hard braking among those with a fall history in a small sample with Parkinson's disease during two weeks of objectively-measured driving. Rapid deceleration events (RDEs) may relate to near crashes or crashes (Chevalier et al., 2017; Dingus et al., 2006; Yan et al., 2008), and have also been associated with driving violations (Zhao et al., 2012) and declining functional abilities (Eby et al., 2019). Cognitive impairment, which is associated with both fall risk (Deandrea et al., 2010) and FOF (Scheffer et al., 2008), may contribute to rapid deceleration events (Eby et al., 2019) and poorer driving performance (Hird et al., 2016; Jekel et al., 2015). In our sample, participants who had fallen assessed their cognitive function to be poorer than did those who had not fallen. We also found that participants with a fall history were more likely to currently take CNS medications, which may adversely impact driving performance. Use of drugs affecting the CNS are independent risk factors for both falls (Hartikainen et al., 2007; Park et al., 2015) and impaired driving (Hill et al., 2020; Hetland & Carr, 2014). Accounting for CNS medication use and participants' concerns about their cognition attenuated the estimated association of past-year falls with rapid deceleration events, supporting the concept of underlying risk leading to both increased falls and poorer driving performance. It must be noted that the median difference in rapid deceleration events between those who fell and those who did not was less than one event per 1000 miles driven.Whether such a small difference translates into meaningful differences in crash risk is uncertain.

Our results showed that participants with high concern about falling had significantly lower education level and household income than those with low FOF. Numerous studies of community-dwelling older adults in diverse countries have similarly documented an association between lower education and increased fear of falling, after accounting for demographic, social and physical risk factors (Braga Lde et al., 2016; Choi et al., 2015; Curcio et al., 2020; Dierking et al., 2016; Kumar et al., 2014; Lee et al., 2018; Mane et al., 2014; Oh et al., 2017), although a few studies found no association (Malini et al., 2016; Moreira et al., 2017; Pirrie et al., 2020). Several studies have also noted a relationship of FOF with lower socioeconomic status (SES) (Kumar et al., 2014; Vellas et al., 1997), although most studies examining SES have reported no association in adjusted models (Choi et al., 2015; Lee et al., 2018; Lee et al., 2018; Malini et al., 2016; Mane et al., 2014). Substantial evidence exists that lower education and income are correlated with poor health (Glymour et al., 2014). Thus, the greater odds of fear of falling reported by older drivers with lower education and income in our study may primarily reflect poorer health, although we did adjust for diverse measures of health in models of driving outcomes, such as cognitive and physical function, selected medications and hospitalization. Low education and socioeconomic status may also have a more direct effect on fear of falling, as Paiva et al. (2020) suggests: "Individuals who live in situations of social vulnerability experiencing material deprivation, a higher level of stress, fewer options, …, and limited access to healthcare services suffer more intense consequences of falls." Thus, greater FOF may reflect awareness on the part of socioeconomically disadvantaged older adults of the potentially more serious consequences for them in the event of a fall. Regardless of the mechanism, this suggests that social disadvantage may lead to greater reductions in access to goods and services and to social and civic engagement as a consequence of higher FOF and associated reduced driving mobility, thus further exacerbating social inequalities in older adults.

This study had several limitations. Past-year fall history was self-reported. Research suggests under-reporting of falls by older adults (Ganz et al., 2005; Peel, 2000), which may have biased results toward the null. However, in the systematic review by Scott et al. (2017) all studies that specified the method of fall assessment used self-report; hence, our measure is consistent with other studies examining falls in relation to driving and crash risk. There were few speeding and rapid deceleration events, which reduced the study's power to identify differences between those who did and did not fall in the past year. We were unable to determine from our data whether participants' driving habits had changed subsequent to their fall or to examine temporal relationships between falls and use of CNS medication. We examined self-reported health characteristics as covariates. While perceived health is likely to be an important influence on both FOF and driving habits, we acknowledge that inclusion of objective sensory and physical function may have yielded differing results in adjusted models. Further, we lacked data on fall injuries, precluding evaluations of fall injuries' influence on driving habits. Although study participants were mostly relatively affluent, well-educated older drivers, approximately-one-third lacked a bachelor's degree and more than half had household incomes below the US average. Nevertheless, the adverse effects of FOF on driving may have been underestimated due to the sample characteristics. These same characteristics may also reduce the generalizability of our findings to other more socioeconomically diverse populations. Participants were recruited at sites that were selected for geographic diversity and may not represent the general US population. Among the strengths of this study are its inclusion of a large sample of older drivers recruited at geographically diverse sites, the use of objective driving data over a 12-month period after baseline, and the ability to account for differences in demographics, health and functional ability, and health care utilization between those with and without a fall history, and between those with high versus low FOF.

In conclusion, we found little evidence that the previously observed motor vehicle crash risk associated with a history of falls in older adults could be explained by differences in driving habits subsequent to the fall(s), when driving behaviors are measured objectively. The few differences in driving habits observed between those who fell and those who did not were largely explained by differences in perceived cognitive function and use of CNS medications. Rather than directly causing crash risk, falls may serve as a marker for older drivers who are at higher risk for motor vehicle crashes due to underlying age-related changes. We also found that older drivers with high FOF drove fewer days and miles, made fewer trips, and drove closer to home. Whether FOF itself reduces driving mobility or is a marker for actual or perceived physical, visual, and/or mental declines associated with aging or disease, remains unclear. Further studies with prospective collection of data on falls, fall injuries, and FOF, and examination of changes in driving habits in relation to each of these, can help to clarify the underlying relationships among them. Clinical trials may determine whether addressing the underlying factors that may have led to the fall, for example, careful assessment of cognitive function and consideration of dosage, frequency or class of medications taken that are known to have CNS effects, is more effective for reducing crashes than on-road driver training or similar measures to improve driving practices among those who have fallen. Similarly, clinical trials in persons with high fear of falling should evaluate the effects on mobility, quality of life, and independence of interventions to counteract physical, visual, and/or mental declines associated with aging, and of interventions to identify and access alternative transportation resources.

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Biography

Dr. Carolyn DiGuiseppi, a board-certified preventive medicine physician, is Professor of Epidemiology in the Colorado School of Public Health and Professor of Pediatrics and Director of Evidence-Based Medicine in the School of Medicine at the University of Colorado Anschutz Medical Campus. She has published more than 200 scientific journal articles, book chapters and scholarly reviews. A primary focus of her research has been the epidemiology and prevention of unintentional injuries, including motor vehicle injuries and falls. Her recent work focuses on the epidemiology of injuries among older adults and among persons with autism spectrum disorder. She has served on a variety of federal and state advisory committees and is currently on the editorial boards of *Injury Prevention* and *Injury Epidemiology*.

References

Anstey KJ, Wood J, Lord S, & Walker JG (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. Clinical Psychological Review, 25 (1), 45–65. 10.1016/j.cpr.2004.07.008.

Bergen G, Stevens MR, & Burns ER (2016). Falls and fall injuries among adults aged ≥65 years – United States, 2014. Morbidity and Mortality Weekly Report, 65 (37), 993–998 10.15585/mmwr.mm6537a2. [PubMed: 27656914]

Betz ME, & Lowenstein SR (2010). Driving patterns of older adults: Results from the Second Injury Control and Risk Survey. Journal of the American Geriatrics Society, 58(10), 1931–1935. 10.1111/j.1532-5415.2010.03010.x. [PubMed: 20670376]

Braga Lde S, Lima-Costa MF, César CC, & Macinko J (2016). Social inequalities on selected determinants of active aging and health status indicators in a large Brazilian City (2003–2010). J Aging Health, 28(1), 180–196. 10.1177/0898264315589575. [PubMed: 26129699]

Chevalier A, Coxon K, Chevalier AJ, Clarke E, Rogers K, Brown J, Boufous S, Ivers R, & Keay L (2017). Predictors of older drivers' involvement in rapid deceleration events. Accident; Analysis and Prevention, 98, 312–319. 10.1016/j.aap.2016.10.010. [PubMed: 27810673]

Choi K, & Ko Y (2015). Characteristics associated with fear of falling and activity restriction in south Korean older adults. Journal of Aging and Health, 27(6), 1066–1083. 10.1177/0898264315573519. [PubMed: 25804899]

Cox AE, & Cicchino JB (2021). Continued trends in older driver crash involvement rates in the United States: Data through 2017–2018. Journal of Safety Research, 77, 288–295. 10.1016/j.jsr.2021.03.013. [PubMed: 34092320]

Crizzle AM, Myers AM, Roy EA, & Almeida QJ (2013). Associations between falls, balance confidence, driving speed, braking, and other driving practices in Parkinson's Disease. Physical & Occupational Therapy in Geriatrics, 33(1), 72–86. 10.3109/02703181.2014.991057.

Curcio CL, Wu YY, Vafaei A, Barbosa JFS, Guerra R, Guralnik J, & Gomez F (2020). A regression tree for identifying risk factors for fear of falling: The International Mobility in Aging Study (IMIAS). The Journals of Gerontology: Series A, 75(1), 181–188. 10.1093/gerona/glz002.

Deandrea S, Lucenteforte E, Foschi R, La Vecchia C, & Negri E (2010). Risk factors for falls in community-dwelling older people: A systematic review and meta-analysis. Epidemiology, 21(5),658–668.10.1097/ede.0b013e3181e89905. [PubMed: 20585256]

Delbaere K, Close JCT, Mikolaizak AS, Sachdev PS, Brodaty H, & Lord SR (2010). The Falls Efficacy Scale International (FES-I). A comprehensive longitudinal validation study. Age and Ageing, 39(2), 210–216. 10.1093/ageing/afp225. [PubMed: 20061508]

Dickerson AE, Molnar LJ, Bedard M, Eby DW, Berg-Weger M, Choi M, Grigg J, Horowitz A, Meuser T, Myers A, O'Connor M, & Silverstein NM (2019). Transportation and aging: An updated research agenda to advance safe mobility among older adults transitioning from driving to non-driving. The Gerontologist, 59(2), 215–221. 10.1093/geront/gnx120. [PubMed: 28958085]

Dierking L, Markides K, Al Snih S, & Kristen PM (2016). Fear of falling in older Mexican Americans: A longitudinal study of incidence and predictive factors. Journal of the American Geriatrics Society, 64(12), 2560–2565. 10.1111/jgs.14496. [PubMed: 27783403]

Dingus TA, Klauer SG, Neale VL, Petersen A, Lee SE, Sudweeks J, Perez MA, Hankey J, Ramsey D, Gupta S, Bucher C, Doerzaph ZR, Jermeland J, & Knipling RR (2006, March). The 100-car naturalistic driving study, Phase II – Results of the 100-car field experiment. US Department of Transportation. https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/100carmain.pdf.

Dugan E, & Lee CM (2013). Biopsychosocial risk factors for driving cessation: Findings from the health and retirement study. Journal of Aging & Health, 25, 1313–1328. [PubMed: 24067290]

Forrest KY, Bunker CH, Songer TJ, Coben JH, & Cauley JA (1997). Driving patterns and medical conditions in older women. Journal of the American Geriatrics Society, 45, 1214–1218. [PubMed: 9329483]

Eby DW, Molnar LJ, Zakrajsek JS, Ryan LH, Zanier N, St. Louis RM, Stanciu SC, LeBlanc D, Bogard S, Kostyniuk LP, Smith J, Yung R, Nyquist L, Betz ME, DiGuiseppi C, Jones V, Li G, Mielenz TJ, Strogatz D, & on behalf of the AAA LongROAD Research Team (2019). Factors related to rapid deceleration events among a large cohort of older drivers. Transportation Research Part F: Traffic Psychology and Behaviour, 66, 76–86. 10.1016/j.trf.2019.08.021.

Friedman SM, Munoz B, West SK, Rubin GS, & Fried LP (2002). Falls and fear of falling: Which comes first? A longitudinal prediction model suggests strategies for primary and secondary prevention. Journal of the American Geriatrics Society, 50(8),1329–1335.10.1046/j.1532-5415.2002.50352.x. [PubMed: 12164987]

Ganz DA, Higashi T, & Rubenstein LZ (2005). Monitoring falls in cohort studies of community-dwelling older people: Effect of the recall interval. Journal of the American Geriatrics Society, 53(12), 2190–2194. 10.1111/j.1532-5415.2005.00509.x. [PubMed: 16398908]

Glymour MM, Avendano M, & Kawachi I (2014). Socioeconomic status and health. Social Epidemiology, 2, 17–63.

Hartikainen S, Lönnroos E, & Louhivuori K (2007). The journals of gerontology. Series A, Biological Sciences and Medical Sciences, 62(10), 1172–1181. 10.1093/gerona/62.10.1172.

HealthMeasures (2020, December). PROMIS® Score and Interpret. http://www.healthmeasures.net/score-and-interpret/interpret-scores/promis.

Hetland A, & Carr DB (2014). Medications and impaired driving. The Annals of Pharmacotherapy, 48(4), 494–506. 10.1177/1060028014520882. [PubMed: 24473486]

Hill LL, Andrews H, Li G, DiGuiseppi CG, Betz ME, Strogatz D, Pepa P, Eby DW, Merle D, Kelley-Baker T, Jones V, & Pitts S (2020). Medication use and driving patterns in older drivers: Preliminary findings from the LongROAD study. Injury Epidemiology, 7(1), 38 10.1186/s40621-020-00265-y. [PubMed: 32741358]

Hird MA, Egeto P, Fischer CE, Naglie G, & Schweizer TA (2016). A systematic review and meta-analysis of on-road simulator and cognitive driving assessment in Alzheimer's Disease and mild cognitive impairment. Journal of Alzheimer's Disease: JAD, 53(2), 713–729. 10.3233/jad-160276. [PubMed: 27176076]

Jekel K, Damian M, Wattmo C, Hausner L, Bullock R, Connelly PJ, Dubois B, Eriksdotter M, Ewers M, Graessel E, Kramberger MG, Law E, Mecocci P, Molinuevo JL, Nygård L, Olde-Rikkert MG, Orgogozo J, Pasquier F, Peres K,… Frölich L (2015). Mild cognitive impairment and deficits in instrumental activities of daily living: A systematic review. Alzheimers Research & Therapy, 7 (1), 17. 10.1186/s13195-015-0099-0.

Karthaus M, & Falkenstein M (2016). Functional changes and driving performance in older drivers: Assessment and interventions. Geriatrics (Basel), 1(2), 12 10.3390/geriatrics1020012. [PubMed: 31022806]

Kumar A, Carpenter H, Morris R, Iliffe S, & Kendrick D (2014). Which factors are associated with fear of falling in community-dwelling older people? Age and Ageing, 43(1), 76–84. 10.1093/ageing/aft154. [PubMed: 24100619]

Lee S, Lee C, Ory MG, Won J, Towne SD Jr, Wang S, & Forjuoh SN (2018). Fear of outdoor falling among community-dwelling middle-aged and older adults: The role of neighborhood environments. Gerontologist, 58(6), 1065–1074. 10.1093/geront/gnx123. [PubMed: 28958081]

Lee S, Oh E, & Hong GS (2018). Comparison of factors associated with fear of falling between older adults with and without a fall history. International Journal of Environmental Research and Public Health, 15(5), 982. 10.3390/ijerph15050982. [PubMed: 29757960]

Li G, Eby DW, Santos R, Mielenz TJ, Molnar LJ, Strogatz D, Betz ME, DiGuiseppi C, Ryan LH, Jones V, Pitts SI, Hill LL, DiMaggio CJ, LeBlanc D, Andrews HF, & for the LongROAD Research Team (2017). Longitudinal Research On Aging Drivers (LongROAD): Study design and methods. Injury Epidemiology, 4(1), 22. 10.1186/s40621-017-0121-z. [PubMed: 28736796]

Liu M, Hou T, Li Y, Sun X, Szanton SL, Clemson L, & Davidson PM (2021). Fear of falling is as important as multiple previous falls in terms of limiting daily activities: A longitudinal study. BMC Geriatrics, 21, 350. 10.1186/S12877-021-02305-8. [PubMed: 34098904]

Lyman JM, McGwin G, & Sims RV (2001). Factors related to driving difficulty and habits in older drivers. Accident Analysis & Prevention, 33, 413–421. [PubMed: 11235803]

MacLeod KE, Satariano WA, & Ragland DR (2014). The impact of health problems on driving status among older adults. Journal of Transportation & Health, 1, 86–94.

Malini FM, Lourenço RA, & Lopes CS (2016). Prevalence of fear of falling in older adults, and its associations with clinical, functional and psychosocial factors: The Frailty in Brazilian Older People-Rio de Janeiro study. Geriatrics & Gerontology International, 16(3), 336–344. 10.1111/ggi.12477. [PubMed: 25869919]

Mane AB, Sanjana T, Patil PR, & Sriniwas T (2014). Prevalence and correlates of fear of falling among elderly population in urban area of Karnataka, India. Journal of Mid-life Health, 5(3), 150–155. 10.4103/0976-7800.141224. [PubMed: 25317002]

Marie Dit Asse L, Fabrigoule C, Helmer C, Laumon B, & Lafont S (2014). Automobile driving in older adults: Factors affecting driving restriction in men and women. Journal of the American Geriatrics Society, 62(11), 2071–2078. 10.1111/jgs.13077. [PubMed: 25371138]

Molnar LJ, Charlton JL, Eby DW, Bogard SE, Langford J, Koppel S, Kolenic GE, Marshall S, & Ma-Son-Hing M (2013). Self-regulation of driving by older adults: Comparison of self-report and objective driving data. Transportation Research Part F: Traffic Psychology and Behaviour, 20, 29–38. 10.1016/j.trf.2013.05.001.

Molnar LJ, Charlton JL, Eby DW, Langford J, Koppel S, Kolenic GE, & Marshall S (2013). Factors affecting self-regulatory driving practices among older adults. Traffic Injury Prevention, 15(3), 262–272. 10.1080/15389588.2013.808742.

Molnar LJ, Eby DW, Zhang L, Zanier N, St. Louis RM, & Kostyniuk LP (2015, December). Self-regulation of driving by older adults: A synthesis of the literature and framework for future research. AAA Foundation for Traffic Safety. https://aaafoundation.org/wp-content/uploads/2017/12/SelfRegulationOfDrivingByOlderAdultsReport.pdf.

Moreira BS, Sampaio RF, Diz JB, Bastone AC, Ferriolli E, Neri AL, Lourenço RA, Dias RC, & Kirkwood RN (2017). Factors associated with fear of falling in community-dwelling older adults with and without diabetes mellitus: Findings from the Frailty in Brazilian Older People Study (FIBRA-BR). Experimental Gerontology, 89, 103–111.10.1016/j.exger.2017.01.004. [PubMed: 28104446]

Oh E, Hong GS, Lee S, & Han S (2017). Fear of falling and its predictors among community-living older adults in Korea. Aging & Mental Health, 21(4), 369–378. 10.1080/13607863.2015.1099034. [PubMed: 26479777]

Owsley C, Stalvey B, Wells J, & Sloane ME (1999). Older drivers and cataract: Driving habits and crash risk. The Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 54(4), M203–M211. 10.1093/gerona/54.4.m203. [PubMed: 10219012]

Oxley J, & Whelan M (2008). It cannot be all about safety: The benefits of prolonged mobility. Traffic Injury Prevention, 9(4), 367–378. 10.1080/15389580801895285. [PubMed: 18696394]

Paiva MM, Lima MG, & Barros MBA (2020). Social inequalities in the impact of falls on health-related quality of life among older adults. Cien Saude Colet, 25 (5),1887–1896. 10.1590/1413-81232020255.34102019.English, Portuguese. [PubMed: 32402049]

Park H, Satoh H, Miki A, Urushihara H, & Sawada Y (2015). Medications associated with falls in older people: Systematic review of publications from a recent 5-year period. European Journal of Clinical Pharmacology, 71(12), 1429–1440. 10.1007/s00228-015-1955-3. [PubMed: 26407688]

Peel N (2000). Validating recall of falls by older people. Accident; Analysis and Prevention, 32(3), 371–372. 10.1016/s0001-4575(99)00066-4. [PubMed: 10776852]

Pirrie M, Saini G, Angeles R, Marzanek F, Parascandalo J, & Agarwal G (2020). Risk of falls and fear of falling in older adults residing in public housing in Ontario, Canada: Findings from a multisite observational study. BMC Geriatrics, 20(1), 11. 10.1186/s12877-019-1399-1. [PubMed: 31918674]

Pomidor A (Ed.). (2019). Clinician’s guide to assessing and counseling older drivers (4th ed.. New York: The American Geriatrics Society.

Satariano WA, Guralnik J, Jackson RJ, Marottoli RA, Phelan EA, & Prohaska TR (2019). Mobility and aging: New directions for public health action. American Journal of Public Health, 102(8), 1508–1515 10.2105/AJPH.2011.300631.

Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, & de Rooij SE (2008). Fear of falling: Measurement strategy, prevalence, risk factors and consequences among older persons. Age and Ageing, 37(1), 19–24. 10.1093/ageing/afm169. [PubMed: 18194967]

Scott KA, Rogers E, Betz ME, Hoffecker L, Li G, & DiGuiseppi C (2017). Associations between falls and driving outcomes in older adults: Systematic review and meta-analysis. Journal of the American Geriatrics Society, 65(12), 2596–2602. 10.1111/jgs.15047. [PubMed: 28873218]

Takemoto M, Carlson JA, Moran K, Godbole S, Crist K, & Kerr J (2015). Relationship between objectively measured transportation behaviors and health characteristics in older adults. International Journal of Environmental Research and Public Health, 12(11), 13923–13937. 10.3390/ijerph121113923. [PubMed: 26528999]

Tinetti ME, & Powell L (1993). Fear of falling and low self-efficacy: A case of dependence in elderly persons. Journal of Gerontology, 48, 35–38. 10.1093/geronj/48.special_issue.35. [PubMed: 8409238]

Vance DE, Roenker DL, Cissell GM, Edwards JD, Wadley VG, & Ball KK (2006). Predictors of driving exposure and avoidance in a field study of older drivers from the state of Maryland. Accident; Analysis and Prevention, 38(4), 823–831. 10.1016/j.aap.2006.02.008. [PubMed: 16545765]

Vellas BJ, Wayne SJ, Romero LJ, Baumgartner RN, & Garry PJ (1997). Fear of falling and restriction of mobility in elderly fallers. Age and Ageing, 26(3), 189–193. 10.1093/ageing/26.3.189. [PubMed: 9223714]

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, & Vandenbroucke JP (2007). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for reporting observational studies. BMJ, 335(7624), 806–808. 10.1136/bmj.39335.541782.AD. [PubMed: 17947786]

Webber SC, Porter MM, & Menec VH (2010). Mobility in older adults: A comprehensive framework. The Gerontologist, 50(4), 443–450. 10.1093/geront/gnq013. [PubMed: 20145017]

Williams AF, Kyrychenko SY, & Retting RA (2006). Characteristics of speeders. Journal of Safety Research, 37(3), 227–232. 10.1016/j.jsr.2006.04.001. [PubMed: 16872632]

Yan X, Abdel-Aty M, Radwan E, Wang X, & Chilakapati P (2008). Validating a driving simulator using surrogate safety measures. Accident; Analysis and Prevention, 40(1), 274–288. 10.1016/j.aap.2007.06.007. [PubMed: 18215559]

Zhao N, Mehler B, Reimer B, D’Amdrosio LA, Mehler A, & Coughlin JF (2012). An investigation of the relationship between the driving behavior questionnaire and objective measures of highway driving behaviors. Transportation Research Part F: Traffic Psychology and Behaviour, 15, 676–685. 10.1016/j.trf.2012.08.001.

Table 1

Means, standard deviations, definitions, and category for each driving habit measure.

Objective Driving Measure	Mean (SD)	Definition for the Monthly Variable (Trip is defined as ignition on to ignition off)	Category
Average Percent of Trips Within 15 Miles of Home	64.1 (22.4)	Percent of trips traveled in month within 15 miles of home.	Driving Space
Average Number of Miles	736.0 (433.6)	Total number of miles driven in month.	Driving Exposure
Average Number of Days Driving	21.0 (5.5)	Total number of days in month with at least one trip.	Driving Exposure
Average Number of Trips	110.8 (53.3)	Total number of trips in a month.	Driving Exposure
Average Percent of Trips at Night	1.9 (0.7)	Percent of trips in month during which at least 80% of trip was during nighttime, with nighttime defined as end of evening civil twilight to beginning of morning civil twilight or a solar angle greater than 96 degrees.	Driving Avoidance
Average Percent of Trips on High Speed Roads	12.8 (11.0)	Percent of trips in month during which at least 20% of distance travelled was at a speed of 60 MPH or greater.	Driving Avoidance
Average Percent Trips in AM Peak	7.1 (4.9)	Percent of all trips taken in month during 7:00-9:00 AM on weekdays.	Driving Avoidance
Average Percent Trips in PM Peak	9.6 (4.4)	Percent of all trips taken in month during 4:00-6:00 PM on weekdays.	Driving Avoidance
Right to Left Turn Ratio	0.9 (0.1)	Ratio of all right-hand to left-hand turning events identified for driver in month.	Driving Avoidancec
Average Speeding Events	7.8 (17.2)	Number of speeding events (speed > 80 MPH sustained for at least 8 seconds) per 1000 miles driven.	Unsafe Driving
Average Rapid Deceleration Events	5.4 (6.4)	Number of events with deceleration greater than or equal to 0.4 g (hard braking, near crash, crash) per 1000 miles driven.	Unsafe Driving

Table 2

Characteristics of Older Drivers with and without a History of Falls in the Past 12 Months, LongROAD Cohort of Older Drivers.

Characteristics	Past-Year Fall N = 828 (28.2%)	No Past-Year Fall N = 2113 (71.8%)	p-value
Short FES-I			
High Concern (≥11)	238 (28.7)	309 (14.6)	<0.001
Low Concern (<11)	590 (71.3)	1803 (85.4)	
Age Group			
65–69	329 (39.7)	893 (42.3)	0.457
70–74	296 (35.7)	722 (34.2)	
75–79	203 (24.5)	498 (23.6)	
Gender			
Female	493 (59.5)	1064 (50.4)	<0.001
Male	335 (40.5)	1049 (49.6)	
Race			
White	745 (91.3)	1830 (88.2)	0.015
Non-White	71 (8.7)	246 (11.8)	
Marital Status			
Married or Living with Partner	527 (64.1)	1420 (67.9)	0.052
Separated, Divorced, Widowed, Never Married	295 (35.9)	672 (32.1)	
Highest Level of Education			
Less than High School	18 (2.2)	43 (2.0)	0.968
High School, Vocational, Some College, Associate	282 (34.1)	702 (33.3)	
Bachelor Degree	190 (23.0)	494 (23.5)	
Master, Professional, Doctoral Degree	336 (40.7)	867 (41.2)	
Total Household Income			
$100,000 or more	252 (31.3)	693 (34.1)	0.216
$80,000–599,999	118 (14.7)	304 (14.9)	
$50,000–579,999	198 (24.6)	514 (25.3)	
Less than $50,000	237 (29.4)	523 (25.7)	
Worked for Pay Last Month			
Yes, Full-Time	66 (8.0)	220 (10.5)	0.084

Characteristics	Past-Year Fall N = 828 (28.2%)	No Past-Year Fall N = 2113 (71.8%)	p-value
Yes, Part Time	178 (21.6)	410 (19.5)	
No	579 (70.4)	1470 (70.0)	
Urbanicity of Residence			
Metropolitan Core	595 (71.9)	1545 (73.1)	0.788
Metropolitan Area/Non-Core	120 (14.5)	293 (13.9)	
Micropolitan/Small Town/Rural	113 (13.6)	275 (13.0)	
Eyesight with Correction			
Excellent	186 (22.5)	556 (26.3)	0.031
Very Good	342 (41.3)	888 (42.1)	
Good	264 (31.9)	603 (28.6)	
Fair + Poor	36 (4.4)	64 (3.03)	
Physical Function Limitations			
Moderate to Severe (T-Score ≤ 39.9)	114 (13.9)	124 (5.9)	<0.001
Mild (T- Score 40.0–55.0)	369 (45.0)	741 (35.4)	
None to Slight (T score > 55.0)	337 (41.1)	1230 (58.7)	
Applied Cognition-General Concerns (T-Score Tertiles)			
T-Score > 32.4	320 (38.7)	615 (29.2)	<0.001
T-Score 26.3–32.3	214 (25.9)	548 (26.0)	
T-Score < 26.2	292 (35.4)	941 (44.7)	
Depression (T-scores)			
Moderate to Severe (T-Score ≥ 60.0)	17(2.1)	23 (1.1)	0.022
Mild (T- Score 55.0–59.9)	50 (6.1)	94 (4.5)	
None to Slight (T score < 55.0)	759 (91.9)	1994 (94.5)	
Anger (T-Scores)			
Moderate to Severe (T-Score ≥ 60.0)	13 (1.6)	18 (0.9)	0.012
Mild (T- Score 55.0–59.9)	39 (4.7)	62 (2.9)	
None to Slight (T score < 55.0)	772 (93.7)	2030 (96.2)	
Decreased Driving Due to Health in Past 12 Months	146 (17.7)	188 (8.9)	<0.001
Emergency Department Visits Past 12 Months			
2+	75 (9.1)	110(5.2)	<0.001
1	182 (22.0)	310(14.7)	

Characteristics	Past-Year Fall N = 828 (28.2%)	No Past-Year Fall N = 2113 (71.8%)	p-value
At Least One Hospital Stay Past 12 Months	177 (21.4)	275 (13.1)	<0.001
Any Alcohol Consumption Past 3 Months	612 (73.91)	1528 (72.3)	0.391
Current Use Central Nervous System Medications *	348 (42.0)	571 (27.0)	<0.001
Current Use Cardiovascular Medications **	211 (25.5)	532 (25.2)	0.864

Missing data: race (n = 49, 1.7%), marital status (n = 27, 0.9%), total household income (n = 102, 3.5%), worked for pay (n = 18, 0.6%), hospital stay (n = 12, 0.4%), physical function limitations (n = 26, 0.9%); variables with 1–11 missing values (<0.4%) included highest level of education, emergency department visits, hospital stays, alcohol use, decreased driving due to health in past 12 months, depression, anger, applied cognition-general concerns, eyesight with correction and short FES-I. Remaining variables had no missing data.

* Anticonvulsants, Psychotherapeutic Agents, Anxiolytics, Sedatives, Hypnotics.

** Antiarrhythmics, Cardiotonic Agents, Diuretics.

Table 3

Association between Past Year Fall and Objectively-Measured Driving Habits in the Subsequent 12 Months, LongROAD Cohort of Older Drivers.

Driving Outcomes	Past-Year Fall n = 828	No Past-Year Fall n = 211	Base Model[a]	Adjusted Model
	Mean (SD)	Mean (SD)	Beta Estimate (95% CI)	Beta Estimate (95% CI)
Driving Exposure				
Miles Driven	732.7 (433.8)	737.3 (433.7)	4.16 (−30.73, 39.06)	15.92 (−19.34, 51.17) [bc]
Days Driving	20.9 (5.5)	21.0 (5.5)	−0.14 (−0.59, 0.31)	−0.06 (−0.51, 0.39)[c]
Trips Driven	110.3 (53.5)	111.0 (53.3)	0.65 (−3.70, 5.00)	1.45 (−2.93, 5.83)[c]
Driving Space				
% Trips Within 15 Miles of Home	63.9 (22.2)	64.2 (22.4)	−0.25 (−2.04, 1.53)	−1.01 (−2.81, 0.78) [bc]
Driving Avoidance				
% Trips on High Speed Roads	12.2 (10.6)	13.1 (11.1)	−0.77 (−1.66, 0.11)	−0.77 (−1.66, 0.11)
% Trips in AM Peak	6.8 (4.9)	7.2 (4.9)	−0.32 (−0.72, 0.08)	−0.24 (−0.64, 0.16)[c]
% Trips in PM Peak	9.7 (4.3)	9.5 (4.5)	0.19 (−0.17, 0.55)	0.19 (−0.17, 0.55)
Log % Trips at Night	1.8 (0.7)	1.8 (0.7)	0.01 (−0.04, 0.07)	0.02 (−0.03, 0.08)[c]
Right-to-Left Turn Ratio	0.9 (0.1)	0.9 (0.1)	0.00 (−0.01, 0.01)	0.00 (−0.01, 0.01) [bc]
Unsafe Driving				
Log Rapid Deceleration Events per 1000 Miles Driven	1.6 (0.7)	1.5 (0.7)	**0.08 (0.03, 0.14)**	0.06 (−0.00, 0.12) [bc]
	N (%)	N (%)	Odds Ratio (95% CI)	Odds Ratio (95% CI)
At Least One Speeding Event per 1000 Miles Driven	468.0 (56.5)	1236.0 (58.5)	0.94 (0.80, 1.11)	0.90 (0.76, 1.07) [b]

Bold font indicates statistical significance at $p < 0.05$.

[a] Base model adjusted for gender, age, race, and marital status.

[b] Adjusted for cognitive concerns.

[c] Adjusted for current use of central nervous system medications (psychotherapeutics, anxiolytics, sedatives, hypnotics and anticonvulsants).

Table 4

Association between Fear of Falling and Objectively-Measured Driving Habits in the Subsequent 12 Months, LongROAD Cohort of Older Drivers.

Driving Outcomes	High Fall Concern n = 547	Low Fall Concern n = 2391	Base Model[a]	Adjusted Model
	Mean (SD)	Mean (SD)	Beta Estimate (95% CI)	Beta Estimate (95% CI)
Driving Exposure				
Miles Driven	659.4 (442.5)	752.5 (427.5)	**−60.66 (−101.15, −20.18)**	−10.92 (−57.04, 35.20)[bcdef]
Days Driving	20.3 (6.0)	21.2 (5.4)	**−0.84** (**−1.36, −0.31**)	−0.31 (−0.90, 0.27)[cdef]
Trips Driven	104.0 (50.2)	112.4(54.0)	**−7.48** (**−12.56, −2.41**)	−3.00 (−8.69, 2.70)[cdefg]
Driving Space				
% of Trips Within 15 Miles of Home	68.7 (21.7)	63.1 (22.4)	**3.92 (1.84, 5.99)**	1.81 (−0.05, 4.13)[bcdg]
Driving Avoidance				
% Trips on High Speed Roads	11.5 (10.4)	13.1 (11.1)	−0.88 (−1.92, 0.15)	−0.08 (−1.11, 0.95)[efgh]
% Trips in AM Peak	6.1 (4.6)	7.3 (4.9)	**−1.08** (**−1.54, −0.62**)	**−0.57** (**−1.08, −0.06**)[cde]
% Trips in PM Peak	9.9 (4.5)	9.5 (4.4)	0.41 (−0.01, 0.83)	**0.60 (0.18, 1.02)**[deh]
Log % of Trips at Night	1.8 (0.7)	1.9 (0.7)	−0.01 (−0.07, 0.06)	0.01 (−0.06, 0.07)[bceh]
Right-to-Left Turn Ratio	0.9 (0.1)	0.9 (0.1)	0.00 (−0.01, 0.01)	−0.01 (−0.02. 0.01)[bc]
Unsafe Driving				
Log Rapid Deceleration Events per 1000 Miles Driven	1.7 (0.8)	1.5 (0.7)	**0.10 (0.03, 0.17)**	0.05 (−0.02, 0.12)[bdfi]
	N (%)	N (%)	Odds Ratio (95% CI)	Odds Ratio (95% CI)
At Least One Speeding Event	308 (56.3)	1393 (58.3)	0.95 (0.79, 1.16)	0.98 (0.80, 1.20)[bfh]

Bold font indicates statistical significance at $p < 0.05$.

[a]Base model adjusted for gender, age, race, and marital status.

[b]Additional adjustment for general cognitive concerns

[c]physical function

[d]current use of central nervous system medications (included psychotherapeutics, anxiolytics, sedatives, hypnotics, and anticonvulsants)

[e]work for pay in last month

[f] total household income

[g] alcohol consumption past three months

[h] highest level of education

[i] hospital stay past 12 months.