FOUNDATION FOR TRAFFIC SAFETY

Physical Function and Frailty Are Associated with Self-Regulation of Driving among Older Adults: A LongROAD Study

Many older adults rely on driving a motor vehicle to maintain independence and engage with their environments (Chihuri et al., 2016; Windsor et al., 2007). However, driving safely can become a concern due to age-related changes in physical, cognitive, and sensory function (Ball et al., 2006; Doi et al., 2020; Huisingh et al., 2017; Ng et al., 2020). To extend the number of years that older adults can drive safely, some self-regulate their driving. Self-regulation refers to modifying driving habits, such as driving less frequently or avoiding challenging situations like driving at night, in bad weather, or during rush hour, due to declining abilities (Kowalski et al., 2012). The prevalence rates of self-regulation vary widely in the literature depending on the type of self-regulation avoidance behavior (e.g., avoiding night driving varies from 8% to 80% (Molnar et al., 2015). The goal of this study was to examine physical function and frailty, and their association with strategic driving self-regulation (e.g., behaviors that require planning like avoiding rush hour) using data from the AAA Longitudinal Research on Aging Drivers (LongROAD) study. It was hypothesized that poorer physical function and higher levels of frailty would be associated with greater self-regulation. Results showed that participants who had worse physical functioning self-regulated their driving more compared to those who had good physical functioning. Additionally, participants with greater frailty self-regulated their driving more than those who were not frail. The findings of the present study add to a growing body of research that seeks to help older drivers maintain mobility and safe driving.

METHOD

The AAA LongROAD study was a multisite prospective cohort of 2,990 older drivers that aimed to explore the risk factors and changes in driving behaviors, patterns, and safety that occur over time. Recruitment occurred July 2015 through March 2017 for participants aged 65–79 from: Ann Arbor, Michigan; Baltimore, Maryland; Cooperstown, New York; Denver, Colorado; and San Diego, California. To be eligible at baseline, participants had to meet the following criteria: hold a valid driver's license; plan to reside in their current location for another five years; drive at least once a week; have no significant cognitive impairment; drive one vehicle at least 80% of the time; drive a vehicle with model year 1996 or newer with an available OBDII port; not participate in another driving study; and not live with another current LongROAD participant. This was a five-year longitudinal study with the final annual data collection completed by September 30, 2022. In-person visits were conducted at baseline and Year 2, while Year 1 and Year 3 visits were conducted via telephone. Due to the COVID-19 pandemic, in-person visits were only conducted for 33% of participants in Year 4 and 35% in Year 5 with the remaining follow-up visits conducted via telephone. Further details on the specific study methods are described elsewhere (Kelley-Baker et al., 2017; Li et al., 2017).

The present study used data from in-person functional assessments and self-report questionnaires across five years. Three major constructs were assessed and used in this study: self-regulation as the primary outcome, and physical function and frailty as the primary exposure variables.

Strategic self-regulation was measured using an annual self-reported questionnaire that asked participants whether they tried to avoid the following specific driving situations: driving at night, driving in bad weather, driving in unfamiliar areas, driving in rush hour traffic, and driving on the freeway (Molnar et al., 2009). For each situation that participants reported avoiding, they were asked about their reasons for doing so. Based on these responses, participants were classified into whether they modified their driving due to self-regulation or if they modified for other reasons (e.g., changes in lifestyle). Then a count variable was created to identify the number of situations in which each participant self-regulated their driving each year.

Physical function was measured at the in-person visits at baseline, Year 2, and Year 4 or 5 using the National Health and Aging Trends Study (NHATS) Short Physical Performance Battery (SPPB) consisting of three timed components of walking speed, repeated chair stands, and standing balance. Based on scoring criteria established by NHATS, each of the three components was assigned a score ranging from 0 (inability to carry out task) to 4 (best score). Then, a summary score was created based on the three components (range: 0–12). The summary scores were categorized into three groups: poor physical function (0–7), fair physical function (8–10), and good physical function (11–12). If this value was missing at a certain time point, then the most recent available year's data were used.

Frailty status was measured at in-person visits using the frailty phenotype (Fried et al., 2001). A frailty score (range: 0–5) was assessed on five categories: weakness (grip strength), slowness (walking speed), low physical activity (self-reported not having recently walked for exercise or engaged in vigorous physical activity), exhaustion (self-reported low energy and poor endurance), and shrinking (unintentional weight loss of at least 10 pounds in the past year or underweight according to a Body Mass Index (BMI)). Frailty scores were categorized into three groups: not frail (0), pre-frail (1–2), and frail (3–5). As with physical function, frailty was measured at baseline, Year 2, and Year 4 or 5, and the most recent available year's data were used when missing.

Several objective measures (again, measured at baseline, Year 2, and Year 4 or 5) from the in-person assessments were included in this study such as visual perception (motor free visual perception test (MVPT)), visual acuity of both eyes (Tumbling E Chart), and cognitive health (measured by performance on immediate and delayed word recall tasks). Higher scores on the MVPT and Tumbling E Chart were, respectively, indicative of worse visual perception and poorer visual acuity. For the word recall tests, immediate and delayed recall scores were combined indicating greater cognitive health for higher scores.

Miles driven per week were self-reported every year and then categorized into four different groups: 1–49, 50–99, 100–150, and 151–800 miles driven per week (Ng et al., 2020). Additionally, participant demographics, specifically age category, sex, and Rural-Urban Commuting Area (RUCA) code were used in analyses.

Descriptive statistics were conducted to characterize the sample at baseline. Because this is repeated measures data, we used a mixed-effect Poisson model with person-level random intercept to examine frailty and physical function in relation to self-regulation of driving behaviors over time. Two separate Poisson models were used to evaluate the association of physical function and frailty with strategic self-regulation across five years, with physical function and frailty as the main exposure in each of their respective models. In conjunction with the exposure variable and self-regulation outcome, each model was adjusted for the following variables: age category, sex, MVPT, visual acuity, cognitive health, miles driven per week, and RUCA code. All variables, except for sex and RUCA code, were treated as time-varying variables.

RESULTS

The majority of the sample were female (53.1%) and drove on average at least 100 miles per week at baseline (52.1%). Of the 2,962 participants in the AAA LongROAD cohort who had frailty status data at baseline, 41.2% were classified as non-frail, 55.9% were classified as pre-frail, and 2.9% were classified as frail. Of the 2,945 participants who had physical function data at baseline, 19.4% were classified as having poor physical function, 45.8% had fair physical function, and 34.8% had good physical function. Other characteristics of the sample are presented in Table 1.

Table 2 shows that in the unadjusted Poisson model, pre-frail and frail status were

Table 1. Sample characteristics at baseline (N=2990).

Variable	N	Mean or %	SD	Range
Number of Self-regulatory behaviors	2988	1.16	1.28	0–5
SPPB	2945			
Poor	572	19.42%		
Fair	1348	45.77%		
Good	1025	34.80%		
Frailty	2962			
Non-frail	1220	41.19%		
Pre-frail	1656	55.91%		
Frail	86	2.90%		
Age	2988			
65–69	1242	41.57%		
70–74	1036	34.67%		
75–80	710	23.76%		
Sex	2988			
Male	1401	46.89%		
Female	1587	53.11%		
Motor Free Visual Perception Test	2978	11.54	1.69	0–13
Cognitive Health	2904	10.44	3.01	1–20
Visual acuity	2964	.11	.13	.10–1.00
Miles driven per week	2917			
1–49	696	23.86%		
50–99	701	24.03%		
100–150	793	27.19%		
151–800	727	24.92%		
RUCA	2990			
Urban	2181	72.94%		
Suburban	415	13.88%		
Rural	394	13.18%		

Note. The self-regulation variable is a count of the number of types of situations in which a participant self-regulated their driving. RUCA= rural urban commuting area. SPPB= Short Physical Performance Battery.

significantly associated with increased rates of strategic self-regulation compared to non-frail participants at incidence rate ratios (IRRs) of 1.08 (95% CI = 1.02–1.14) and 1.38 (95% CI = 1.22–1.56), respectively. After adjusting for other variables, the results showed that those with pre-frail and frail status had a higher incidence rate of strategic self-regulation, 1.07 (95% CI = 1.01–1.13) and 1.26 (95% CI = 1.11–1.43) times that of non-frail participants, respectively.

Table 2. Results of the unadjusted and adjusted* Poisson model for the association between frailty and strategic self-regulation over five years ($n_{adjusted\ model}$=6543).

Variable	Incidence Rate Ratio	
	Unadjusted (95% CI)	Adjusted (95% CI)
Frailty		
Non-frail	Reference	Reference
Pre-frail	1.08 (1.02–1.14)	1.06 (1.00–1.13)
Frail	1.38 (1.22–1.56)	1.26 (1.11–1.44)

*Adjusted for age, sex, MVPT, visual acuity, cognitive health, miles driven per week and RUCA.

Table 3 shows that in the unadjusted Poisson model, fair and poor physical function status were significantly associated with increased rates of strategic self-regulation compared to those with good physical function. After adjusting for other variables, the results showed that those with fair and poor physical function status had a higher incidence rate of strategic self-regulation.

Table 3. Results of the unadjusted and adjusted* Poisson model for the association between physical function and strategic self-regulation over five years ($n_{adjusted\ model}$=6539).

Variable	Incidence Rate Ratio	
	Unadjusted (95% CI)	Adjusted (95% CI)
Physical function		
Good	Reference	Reference
Fair	1.22 (1.14–1.30)	1.17 (1.09–1.25)
Poor	1.55 (1.43–1.68)	1.38 (1.27–1.51)

*Adjusted for age, sex, MVPT, visual acuity, cognitive health, miles driven per week and RUCA.

DISCUSSION

Objectively measured physical function and frailty were both found to be associated with self-reported driving strategic self-regulation. Specifically, poorer physical function and being more frail were each associated with greater strategic self-regulation. These findings support our hypothesis and are consistent with previous research that suggests that older drivers with worse physical function self-regulate to avoid challenging driving situations due to declining abilities (Braitman & Williams, 2011; Molnar et al., 2009). Although studies have examined the effect of frailty status on other driving related outcomes (Crowe et al., 2020; Doi et al., 2020), this study was the first to examine frailty and the association with strategic self-regulation among older drivers. Additionally, covariates associated with self-regulation were consistent with previous research including sex, age, and vision (Kostyniuk & Molnar, 2008; Molnar et al., 2014; Naumann et al., 2011; Sargent-Cox et al., 2011).

The strengths of this study include the use of longitudinal data and objective measures of physical function and frailty. Using longitudinal data allows us to examine changes in participants' physical function, frailty, and self-regulatory behaviors over a period of five years, which provides more insight into the onset and rates of declining abilities and self-regulation rather than a snapshot of these factors at one point in time. Additionally, having objective measures of physical function and frailty provides more precise information on the health status of participants compared to self-reported measures (Guralnik et al., 1994).

One of the limitations of this study is the use of self-reported driving strategic self-regulation. Objective information from the LongROAD study could tell us the percentage of trips taken at night or in rush hour traffic (7:00–9:00 AM and 4:00–6:00 PM on weekdays). However, this information could not tell us whether a participant was driving in unfamiliar areas, nor could it shed light on whether a particular situation was avoided due to self-regulation, so it could be argued that self-reported information may be just as useful if not more useful than objective data. Another limitation is that this sample may not be representative of older drivers in the U.S. population given the majority of the sample at baseline were healthy, high functioning, and held at least a bachelor's degree.

Implications of Findings and Future Research

Self-regulation is often promoted as a tool to extend the years of safe driving; however, there is insufficient evidence for this claim (Molnar et al., 2015). Future research should test whether self-regulation is associated with lower crash risk over time to determine if self-regulation truly promotes safe driving among older adults. If there are significant safety benefits, self-regulation should become a topic of conversation amongst families with older drivers to increase awareness in changes of abilities and how self-regulation could help maintain independence while also maintaining safe driving. For example, if an older driver in your family experiences visual declines you might suggest they avoid driving at night or in bad weather. This modification will still allow them to drive but will remove them from situations in which optimal vision is needed to drive safely.

Another way to promote safe mobility among older drivers is by improving physical function. Many studies have shown that engaging in physical activity such as aerobic, strength, and balance exercises can improve older adults' physical function (LIFE Study Investigators et al., 2006; Mielenz et al., 2017; Perera et al., 2006) and frailty (Cesari et al., 2015; Nagai et al., 2018). According to the CDC, it is recommended that older adults partake in moderate-intensity activity for 150 minutes per week as well as muscle-strengthening activities at least two days per week (Centers for Disease Control and

Prevention, 2023). Some examples of physical activity for older adults could include attending a water-aerobics class at a local fitness center, yoga, going for a brisk walk around the neighborhood, or even gardening at home. Engaging in physical activity to improve physical function may also help promote safe mobility among older drivers.

In conclusion, the findings of the present study add to a growing body of research that seeks to help older drivers maintain mobility and safe driving. Several findings replicate previous research such as poorer physical function being associated with greater self-regulation. In addition, our finding that frailty was also associated with greater strategic self-regulation is a novel relationship that had previously not been examined. These findings significantly contribute to the literature in ways that help promote safe driving among older adults as well as a resource for families to have a discussion on this important topic.

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