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Relationship Between Physical Activity and Motor Vehicle Crashes Among Older Adult Drivers

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Abstract

Background: There are approximately 42 million licensed drivers aged 65 years or older in the United States, who face unique age-related risks while driving. While physical activity affects several chronic conditions thought to be associated with motor vehicle crashes (MVCs), it is unclear if increased physical activity leads to fewer MVCs. This study explores whether self-reported vigorous and moderate physical activity is associated with MVCs in the previous year. **Methods:** Using cross-sectional data from the LongROAD study, a large multisite prospective cohort study of 2990 older adult drivers, we examined variables related to physical activity and performed a multivariate regression analysis to examine the association of physical activity health behaviors with self-reported MVCs. **Results:** Overall, 41.2% of participants reported vigorous and 69.6% of participants reported moderate exercise at least once per week. Eleven percent of participants reported at least 1 MVC in the previous year. Neither vigorous nor moderate physical activity was significantly associated with self-reported MVCs in the previous year. Select variables that were significantly associated with self-reported MVC included self-reported unsafe driving practices (odds ratio [OR] 1.55, confidence interval [CI] 1.05-2.29), and fall in the past 12 months (OR 1.46, CI 1.14-1.85). **Conclusions:** We were unable to detect a significant association between self-reported physical activity and MVCs in the past year among this group of older drivers. Use of objective measures of activity may better clarify this relationship.

Keywords
physical activity, motor vehicle crashes, older adults, driving

Introduction

With approximately 42 million licensed drivers aged 65 years or older in the United States, it is important to define and mitigate the unique risks that this driving population faces while on the road.[1] Drivers aged 65 years and older are 16% more likely than younger drivers (aged 25-64 years) to experience a fatal, at-fault motor vehicle crash (MVC).[2] There are a number of known health-related issues that contribute to this increased likelihood, such as decreased visual acuity, depression, and cognitive impairment.[3-5] These conditions are thought to affect immediate determinants of driver performance, including attention, perception, level of arousal, emotional state, and decision making.[6]

Physical activity levels have a well-known impact on several of the chronic conditions thought to be associated with MVCs among older drivers.[7] In addition, multiple studies have shown that physical activity is associated with lower rates of cognitive decline, which may likewise affect driving ability.[8,9] Indeed, studies have directly suggested that physical activity may be necessary to preserve driving-related cognitive abilities.[10,11] Perhaps of greatest importance, physical activity improves musculoskeletal fitness and energy levels,[12,13] which may have a more immediate effect on driving responsiveness. In fact, in many studies

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working to develop and evaluate screening tests, physical activity has been tested as a marker for both physical and cognitive driving readiness. However, it is less clear if increased physical activity levels ultimately lead to fewer MVCs in this population. Existing studies examining this association have been limited by a lack of demographic diversity as well as little attention paid to the unique effects of more rigorous forms of physical activity such as structured exercise and sports, despite research demonstrating that increased physical activity intensity is associated with superior health outcomes.[14-16]

To more thoroughly investigate the relationship between physical activity and MVCs among older adults, we analyzed data from the LongROAD study, which enrolled 2990 older adult drivers across the United States. At the baseline assessment, participants were asked about their participation in various forms of physical activity and the number of MVCs that they had experienced in the previous year. This study explores whether self-reported moderate or vigorous physical activity levels are associated with a lower number of self-reported prior MVCs, after controlling for relevant confounders. Understanding the impact of physical activity on MVC involvement will help inform policies and interventions designed to enhance safe driving among the older adult population.

Materials and Methods

Study Population

The study population for this analysis was derived from the LongROAD study, a multisite prospective cohort study of older drivers that seeks to further our understanding of the underlying factors related to safe driving among older adults.[17] The study sites included the following locations: Ann Arbor, MI; Baltimore, MD; Cooperstown, NY; Denver, CO; and San Diego, CA. Institutional review board approval was received at each study site. Recruitment and enrollment were conducted between July 2015 and March 2017. Potential participants were selected after screening of electronic medical records at participating clinical sites for preliminary eligibility, including age and, for some sites, cognitive impairment. A total of 40 806 recruitment letters were mailed to these potential participants. Study staff then screened potential participants by telephone to determine full eligibility and interest. Eligible participants were English-speaking adults aged 65 to 79 years who possessed a valid driver's license, drove a motor vehicle of model year 1996 or newer at least once a week, and resided in the catchment area for at least 10 months out of the year and had no plans to move outside the area for the next 5 years. A total of 2990 participants, or 7.3% of potential participants, were subsequently enrolled in the study.

Research Design and Questionnaire

The LongROAD study is a 5-year longitudinal study in which participants are being followed and assessed for their health status and driving performance through in-person and telephone interviews, vehicle data recording, and review of medical and driving records. At the beginning of the study, baseline information regarding the following was collected: demographics; vehicle condition, maintenance, and in-vehicle technologies; driving behaviors, including previous MVCs and traffic stops; health; functional performance; and medication usage. The baseline questionnaire elicited specific health information regarding the following: physical, mental, and level of social support; health behaviors; health conditions; and health care utilization. PROMIS (Patient-Reported Outcomes Measurement Information System) measures were utilized, of which the following were included in the present study: PROMIS v1.0—Emotional Distress—Depression SF4a; PROMIS v1.0—Emotional Distress—Anxiety SF4a; PROMIS v1.0—Emotional Distress—Anger SF4a; PROMIS v2.0—Informational Support 4a; PROMIS v2.0—Emotional Support 4a; PROMIS v2.0—Instrumental Support 4a; and PROMIS v1.0—Applied Cognition–General Concerns SF4a.[17] Following completion of the questionnaire, research staff reviewed participant medical and driving records, including MVC data within the previous 4 years at the time of data collection. A data collection device was installed in each participant's primary vehicle to collect driving information. Annual follow-up for up to 3 years for each participant is being done, in addition to annual review of medical and driving records. Baseline data collection was completed in March 2017, and the study continues to collect follow-up data at this time.

Study Variables

The present study examines the association of moderate and vigorous physical activity health behaviors with the number of self-reported MVCs while driving within the previous year ("none" vs "one or more") utilizing the information collected during the LongROAD study. Measures of physical activity were derived from the Health and Retirement Study, a longitudinal study of American adults older than 50 years.[18] For the LongROAD study, vigorous physical activity was defined as participation in "sports or activities that are vigorous, such as running or jogging, swimming, cycling, aerobics or gym workout, tennis, or digging with a spade or shovel," while moderate physical activity was defined as participation in "sports or activities that are moderately energetic such as gardening, cleaning the car, walking at a moderate pace, dancing, floor or stretching exercises." Based on these definitions, vigorous physical activity is equivalent to activities above 6 metabolic equivalents (METs), while moderate physical activity is equivalent to 3 to 6 METs.[19] We examined the associations of moderate and vigorous physical activity with self-reported MVCs separately, due to evidence showing that vigorous activity (≥6 METs) has a significantly greater association with reductions in cardiovascular disease and all-cause mortality, as well as improvements in glucose control; thus, it may have a greater impact on the disease processes that potentially mediate the association between physical activity and MVCs.[15,16] Of the 2990 LongROAD participants, 99.7% responded to the questionnaire item asking about the number of MVCs that they were involved in within the past year—these individuals were included in the present study. Twenty-three additional covariates assessing demographic information, driving behaviors, physical and mental health, and level of social support (average of the PROMIS *t* scores for informational, emotional, and instrumental support) were also examined for this study.

Statistical Analysis

All computer analyses were performed using SAS Version 9.4 (SAS Institute, Inc, Cary, NC), except where otherwise indicated. Descriptive statistics for data from the study population were compiled, with categorical or dichotomous variables reported as number of subjects in each category, and continuous variables reported as means with standard deviations. Bivariate associations between the above-described risk factors and the number of MVCs reported were then assessed. Associations involving categorical or dichotomous risk factors were tested using chi-square analysis (or Fisher's exact test for expected cell sizes less than 5), while associations involving continuous risk factors were tested using 2-sample *t* tests. Crude odds ratios (ORs) and confidence intervals (CIs) were calculated using logistic regression. A multivariate logistic regression model with variables significantly associated with whether or not one or more self-reported MVCs was reported was subsequently built, and associated ORs, 95% CIs, and *P* values were reported. The vigorous and moderate physical activity measures, demographic information (including age, gender, ethnicity, education level, marital status, income, and study site), miles driven in a normal week, and any additional covariate that had a *P* value of less than .25 on bivariate analysis were included in this regression model and used in the model-building procedure to derive the final regression model.

A directed acyclic graph (DAG) of the associations between these variables based on a priori knowledge of these relationships was created and used to derive the final explanatory model (see Figure 1). At its core, a DAG is a type of causal diagram utilizing unidirectional arrows to demonstrate causation among different variables; based on such a diagram, the minimum set of variables that need to be controlled for to produce nonconfounded effect estimates can be identified.[20] On constructing this DAG, associations between physical activity and several of the covariates were found to be bidirectional. For example, while physical activity is protective against depression, depressed individuals tend to have reduced energy, aches, or pains that may lead to reduced physical activity levels.[21,22] Similar bidirectional relationships can be found between physical activity and problems with fatigue and cognitive health.[8,9,13,23,24] As confounders, these covariates would be expected to attenuate the hypothesized relationship between physical activity levels and MVCs. That is, although we expect increased physical activity to be associated with fewer MVCs, responses consistent with increased depression or fatigue as well as poorer cognitive health would be expected to result in movement toward the null hypothesis (that there is no relationship between physical activity and number of MVCs). Because retaining these covariates as confounders would thereby produce the more conservative model, they were treated as such in the DAG. Six minimally sufficient sets of covariates necessary to adjust for confounding were subsequently generated through construction of the DAG in DAGitty Version 2.3.[25] The set chosen for the final model included age, cognitive health, depression, level of social support, study site, and unsafe driving behaviors because this set was thought to best encompass known and likely contributors to MVCs.* These variables, along with the moderate and vigorous physical activity variables and miles driven per week, were included in the final regression model. Associated ORs, 95% CIs, and *P* values were subsequently derived and reported.

Multiple Imputation

For each variable examined, less than 5% of observations lacked a response; however, 17 percent of all observations had at least one missing response. In addition, Little's MCAR (missing completely at random) test was performed using SPSS Statistics Version 25 (IBM, Inc, Armonk, NY) and was found to be significant for the variables assessed, meaning that the test's null hypothesis that the data are

*The other 5 sets include the following:

- Age, Cognitive Health, Depression, Marital Status, Race, Social Support Level
- Age, Cognitive Health, Depression, Marital Status, Social Support Level, Study Site
- Age, Cognitive Health, Depression, Race, Social Support Level, Unsafe Driving Behaviors
- Hearing, Cognitive Health, Depression, Social Support Level, Study Site, Unsafe Driving Behaviors
- Cognitive Health, Depression, Hearing, Race, Social Support Level, Unsafe Driving Behaviors

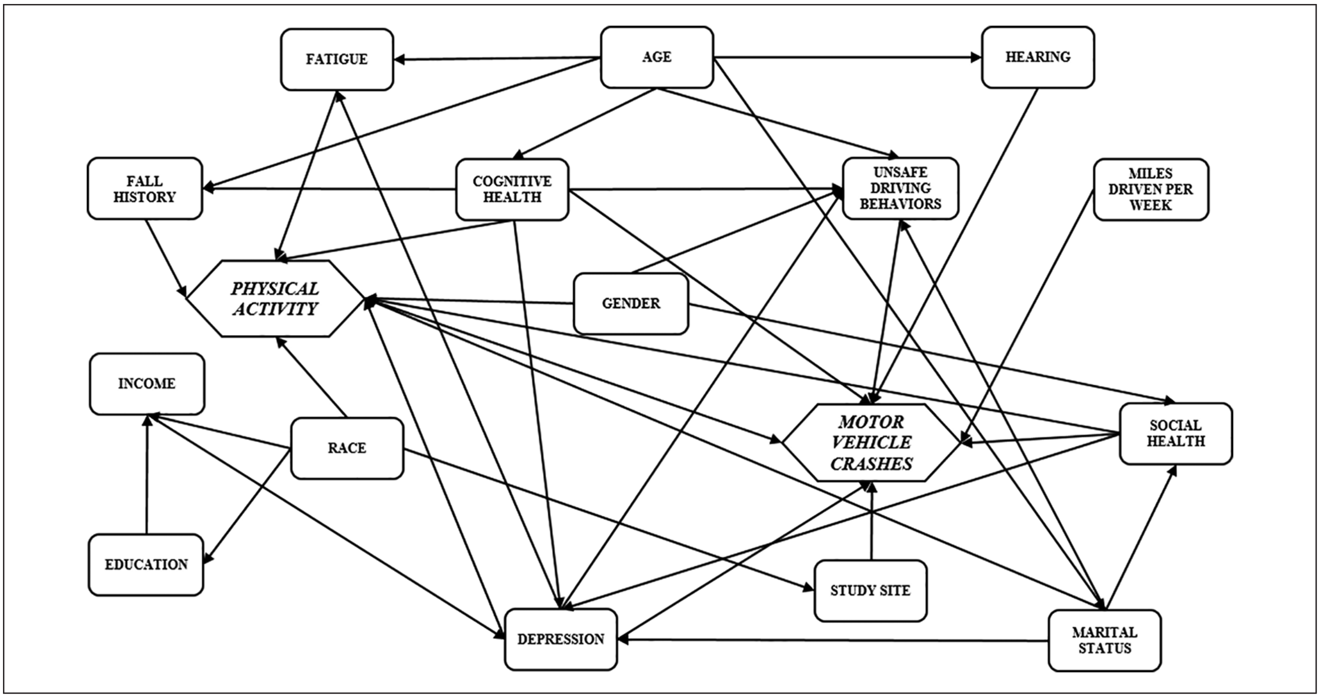

Figure 1. Directed acyclic graph (DAG) demonstrating relationship between physical activity and motor vehicle crashes as well as associated covariates.

missing completely at random must be rejected. As such, listwise deletion would likely introduce bias in parameter estimation. Missing observations were therefore imputed for all predictor and outcome variables using the fully conditional method of multiple imputation with the assumption that missing data were missing at random only. We believe that this assumption is reasonable, since respondents were only included in the study if they agreed to complete the survey, and reporting bias here is more likely to manifest as an inaccurate answer than a failure to answer—in other words, respondents would perceive a nonresponse as more liable to scrutiny (and judgment) compared to an inaccurate answer. Ten imputed datasets were subsequently created and used to derive the logistic regression model with all variables as well as the final logistic regression model.

Results

As shown in Table 1, over half of the LongROAD participants were female with the majority younger than 75 years. Most were White, married, had an associate's degree or above, and had a total household income of \$50 000 or more. A total of 11.2% reported one or more MVCs in the previous year. Overall, 41.2% of participants reported performing vigorous physical activity more than once a week or daily, while 16.2% of participants reported performing vigorous physical activity 1 to 3 times a month or weekly. On the other hand, 69.6% of participants reported performing moderate physical activity more than once a week or daily, while 21.9% of participants reported performing moderate physical activity 1 to 3 times a month or weekly.

Based on bivariate analysis, neither vigorous ($P = .31$) nor moderate physical activity ($P = .12$) were significantly associated with reporting one or more MVCs in the previous year (Table 1). However, marital status, unsafe driving practices, hearing, history of falls, cognitive health, depression, fatigue, and level of social support were significantly associated with reporting one or more MVCs in the previous year ($P < .05$). Based on the results of the bivariate analysis, these variables met the criteria for inclusion in the logistic regression model looking at all variables showing a significant association, in addition to demographic information, miles driven in a normal week, and physical activity level (Table 2). Adjusting for the other variables in the model, neither vigorous nor moderate physical activity were significantly associated with reporting one or more MVCs in the previous year. However, those with an associate's or bachelor's degree were significantly less likely to report one or more MVCs compared to those with a graduate degree (adjusted OR = 0.72, 95% CI 0.54-0.97). Those reporting good hearing were significantly less likely to report one or more MVCs compared with those reporting very good or excellent hearing (adjusted OR = 0.74, 95% CI 0.56-0.97). Finally, reporting a history of falls in comparison with not reporting a fall history in the previous year

Table 1. Characteristics and Crude Odds Ratios for Self-Reported Motor Vehicle Crashes Within the Past Year.

Categorical Variables[a]	One or More Self-Reported Crashes in Previous Year Yes (n = 335)	No (n = 2646)	Total (n = 2981)	Crude Odds Ratio[b]	95% Confidence Interval	P[c]
Vigorous physical activity						.31
More than once a week or daily[d]	136 (11.1)	1091 (88.9)	1227	1.00	—	
1-3 times a month or weekly	64 (13.2)	420 (86.8)	484	1.22	(0.89, 1.68)	
Hardly ever or never	135 (10.7)	1132 (89.3)	1267	0.96	(0.74, 1.23)	
Moderate physical activity						.12
More than once a week or daily[d]	223 (10.7)	1853 (89.3)	2076	1.00	—	
1-3 times a month or weekly	88 (13.5)	564 (86.5)	652	1.30	(0.996, 1.689)	
Hardly ever or never	24 (9.6)	227 (90.4)	251	0.88	(0.56, 1.37)	
Gender						.18
Male[d]	146 (10.4)	1255 (89.6)	1401	1.00	—	
Female	189 (12.0)	1391 (88.0)	1580	1.17	(0.93, 1.47)	
Age (years)						.44
65-69[d]	144 (11.6)	1093 (88.4)	1237	1.00	—	
70-74	121 (11.7)	916 (88.3)	1037	1.00	(0.78, 1.30)	
75-79	70 (9.9)	637 (90.1)	707	0.83	(0.62, 1.13)	
Race						.19
White[d]	285 (11.2)	2265 (88.8)	2550	1.00	—	
Black	29 (13.8)	181 (86.2)	210	1.27	(0.84, 1.92)	
Hispanic	4 (4.9)	77 (95.1)	81	0.41	(0.15, 1.14)	
Other	17 (12.1)	123 (87.9)	140	1.10	(0.65, 1.85)	
Education						.12
Graduate degree[d]	153 (12.6)	1066 (87.5)	1219	1.00	—	
Associate's or bachelor's degree	84 (9.4)	808 (90.6)	892	0.72	(0.55, 0.96)	
Some college or other postsecondary training	63 (12.0)	463 (88.0)	526	0.95	(0.69, 1.30)	
High school or less	34 (10.2)	301 (89.9)	335	0.79	(0.53, 1.17)	
Marital status						.02
Married or living with a partner[d]	199 (10.1)	1769 (89.9)	1968	1.00	—	
Divorced or separated	67 (14.1)	408 (85.9)	475	1.46	(1.09, 1.97)	
Widowed	45 (12.0)	331 (88.0)	376	1.21	(0.86, 1.71)	
Never married	21 (15.9)	111 (84.1)	132	1.68	(1.03, 2.74)	
Study site						.42
Ann Arbor	65 (10.8)	536 (89.2)	601	1.00	—	
Baltimore	74 (12.7)	511 (87.4)	585	1.19	(0.84, 1.70)	
Cooperstown	56 (9.3)	544 (90.7)	600	0.85	(0.58, 1.24)	
Denver	68 (11.4)	530 (88.6)	598	1.06	(0.74, 1.52)	
San Diego	72 (12.1)	525 (87.9)	597	1.13	(0.79, 1.62)	
Total household income						.44
Less than $20,000	11 (8.2)	123 (91.8)	134	0.73	(0.38, 1.42)	
$20,000 to $49,999	83 (13.0)	557 (87.0)	640	1.22	(0.88, 1.70)	
$50,000 to $79,999[d]	78 (10.9)	639 (89.1)	717	1.00	—	
$80,000 to $99,999	50 (11.6)	380 (88.4)	430	1.08	(0.74, 1.57)	
$100,000 or more	101 (10.6)	854 (89.4)	955	0.97	(0.71, 1.33)	
Self-rated hearing						.03
Excellent or very good[d]	205 (11.8)	1528 (88.2)	1733	1.00	—	
Good	82 (9.1)	817 (90.9)	899	0.75	(0.57, 0.98)	
Fair or poor	48 (13.9)	297 (86.1)	345	1.21	(0.86, 1.69)	

(continued)

Table 1. (continued)

Categorical Variables[a]	One or More Self-Reported Crashes in Previous Year Yes (n = 335)	No (n = 2646)	Total (n = 2981)	Crude Odds Ratio[b]	95% Confidence Interval	P[c]
Excellent or very good[d]	230 (11.5)	1769 (88.5)	1999	1.00	—	
Good	91 (10.4)	788 (89.7)	879	0.89	(0.69, 1.15)	
Fair or poor	14 (13.9)	87 (86.1)	101	1.24	(0.69, 2.21)	
History of falls in the past 12 months						.002
No[d]	215 (10.09)	1916 (89.91)	2131	1.00	—	
Yes	118 (14.03)	723 (85.97)	841	1.46	(1.14, 1.85)	
Sleep quality						.45
Very good or good[d]	210 (10.8)	1743 (89.3)	1953	1.00	—	
Fair	94 (12.1)	685 (87.9)	779	1.14	(0.88, 1.48)	
Poor or very poor	31 (12.8)	211 (87.2)	242	1.22	(0.82, 1.83)	

Continuous Variables[a]	Yes (n = 335)	No (n = 2646)	Total (n = 2981)	Crude Odds Ratio[b]	95% Confidence Interval	P[c]
Driving behaviors						
Miles driven in a normal week	126.6 (116.0)	119.7 (104.1)	120.3 (105.4)	1.00	(1.000, 1.002)	.30
Self-rated driving ability	5.88 (0.69)	5.92 (0.68)	5.91 (0.68)	0.93	(0.79, 1.09)	.36
Self-reported safe driving practices	2.88 (2.15)	2.88 (2.16)	2.88 (2.16)	1.00	(0.95, 1.06)	.97
Self-reported unsafe driving practices	1.58 (0.29)	1.54 (0.29)	1.55 (0.29)	1.55	(1.05, 2.29)	.03
Health utilization						
Number of visits to emergency room in past year	0.38 (0.70)	0.34 (0.82)	0.34 (0.81)	1.07	(0.94, 1.21)	.28
Number of times hospitalized overnight in last year	0.18 (0.48)	0.21 (0.65)	0.21 (0.63)	0.92	(0.75, 1.14)	.34
Cognitive concerns	31.54 (4.96)	30.79 (4.69)	30.89 (4.72)	1.03	(1.01, 1.06)	.01
Mental health						
Depression	44.41 (5.90)	43.67 (5.21)	43.75 (5.29)	1.02	(1.00, 1.05)	.03
Anxiety	44.26 (6.02)	44.20 (5.78)	44.21 (5.81)	1.00	(0.98, 1.02)	.86
Anger	43.05 (7.55)	42.72 (7.40)	42.77 (7.41)	1.01	(0.99, 1.02)	.45
Fatigue	46.34 (8.55)	44.99 (7.99)	45.14 (8.06)	1.02	(1.01, 1.04)	.004
Level of social support	56.34 (6.46)	55.40 (6.81)	56.23 (6.51)	0.98	(0.962, 0.996)	.01

[a]Continuous variables are reported as means with standard deviations. Categorical variables are reported as number of subjects in the group with percentage of total respondents answering "Yes" or "No" in parentheses.
[b]Crude odds ratios calculated using logistic regression.
[c]Two-sample *t* test was used for continuous variables. Chi-square test and Fisher's exact test were used for categorical variables. *P* values provided from these analyses.
[d]Indicates reference value.

was significantly associated with reporting one or more MVCs (adjusted OR = 1.38, 95% CI 1.07-1.77). In the final logistic regression model described in Table 3, which adjusts for the subset of potential confounders identified by the DAG analysis, none of the variables analyzed were found to be significantly associated with reporting one or more MVCs.

Discussion

Based on our analysis, neither form of physical activity examined was significantly associated with self-reported MVCs. This agrees with previous observational studies that also failed to demonstrate any significant association between physical activity and MVCs. In a prospective cohort study by Marottoli et al,[26] 283 individuals aged 72 years or older from Connecticut were assessed for predictors for involvement in any MVC. Physical activity was assessed using the Yale Physical Activity Survey, which evaluates participants on the basis of performance of a number of work, exercise, and recreational activities; estimated kilocalorie expenditure, as well as frequency of participation for each activity, were subsequently derived. No significant association was found between kilocalorie

Table 2. Multivariate Logistic Regression Model for Effects of Significant Risk Factors on Self-Reported Motor Vehicle Crashes Within the Past Year.

Characteristic	Adjusted Odds Ratio[a]	95% Confidence Interval	P
Vigorous physical activity level			
More than once a week or daily[b]	1.00	—	—
1-3 times a month or weekly	1.09	(0.78, 1.53)	.60
Hardly ever or never	0.83	(0.62, 1.10)	.20
Moderate physical activity level			
More than once a week or daily[b]	1.00	—	—
1-3 times a month or weekly	1.30	(0.97, 1.74)	.08
Hardly ever or never	0.86	(0.53, 1.39)	.55
Education			
High school or less	0.80	(0.51, 1.26)	.34
Some college or other postsecondary training	0.91	(0.65, 1.29)	.61
Associate's or bachelor's degree	0.72	(0.54, 0.97)	.03
Graduate degree[b]	1.00	—	—
Self-rated hearing			
Excellent or very good[b]	1.00	—	—
Good	0.74	(0.56, 0.97)	.03
Fair or poor	1.12	(0.79, 1.60)	.52
History of falls in the past 12 months			
Yes	1.38	(1.07, 1.77)	.01
No[b]	1.00	—	—

[a]Adjusted for age, gender, race, marital status, income, driving behaviors, general cognition, depression, fatigue, level of social support, and clustering by study site.
[b]Indicates reference value.

Table 3. Final Logistic Regression Model for Effects of Risk Factors on Self-Reported Motor Vehicle Crashes Within the Past Year.

Characteristic	Adjusted Odds Ratio[a]	95% Confidence Interval	P
Vigorous physical activity level			
More than once a week or daily[b]	1.00	—	—
1-3 times a month or weekly	1.17	(0.84, 1.63)	.36
Hardly ever or never	0.90	(0.68, 1.18)	.44
Moderate physical activity level			
More than once a week or daily[b]	1.00	—	—
1-3 times a month or weekly	1.28	(0.96, 1.70)	.09
Hardly ever or never	0.91	(0.57, 1.45)	.68

[a]Adjusted for age, driving behaviors, general cognition, depression, level of social support, and clustering by study site.
[b]Indicates reference value.

expenditure and any self-reported adverse event, including being pulled over by police, a motor vehicle violation, or MVC involvement while driving. Another prospective study showed similar results among female drivers aged 65 to 84 years.[27] Using the Paffenbarger Physical Activity Questionnaire, the authors assessed the amount of time 1416 female participants from Oregon performed light, moderate, and vigorous physical activity in addition to activities such as participation in any sports, which they then used to estimate total kilocalories expended per week. No significant association was found between kilocalorie expenditure and involvement in any state-reported MVC while driving. The present study builds on these prior studies by assessing whether MVC involvement varies by the level of physical activity engaged in by participants and by recruiting subjects from several different geographic locations.

Several studies that employed randomized control trials to evaluate the effects of exercise interventions on driving outcomes found significant improvements in response time, attention, psychomotor performance, and tests of driving skills among participants randomized to the intervention groups.[10,28,29] We would therefore expect that such improvements would lead to a reduction in MVCs, although this has not been shown to be the case among various observational studies. The reasons for this apparent disconnect are unclear, although it may be attributable to over-reporting of the amount of physical activity undertaken by study participants as well as overestimation of the degree of vigor of the activities that they do participate in. This would likely reduce any strength of association between physical activity levels and the outcome of interest. However, while our study showed that 69.6% of participants reported performing moderate physical activity more than once a week or daily, in a survey of health insurance enrollees, 76.7% of respondents aged 65 years or older stated that they performed light-moderate physical activities such as gardening, walking, or playing golf at least three days a week, indicating the possibility that respondents in our study were actually underreporting their physical activity levels.[30] In fact, it has been shown that both under- and overreporting of one's physical activity level is common and that there is at best a moderate correlation between indirect and direct measures of physical activity among older adults.[31] Future studies should evaluate the relationship between direct measures of physical activity and both self-reported and government records of MVCs.

In addition, our study shows that 11.2% of drivers aged 65 to 79 years reported involvement in one or more MVCs as the driver within the previous year. However, data from the National Highway Traffic Safety Administration (NHTSA) showed that only around 3.1% of licensed drivers aged 65 to 74 years were involved in MVCs in the year 2016.[32] Using NHTSA and state MVC data, it has been shown that involvement in non-fatal injury MVCs for drivers 70 years and older decreased by 39% from 1997 to 2008, while involvement in property damage-only crashes decreased by 15% during this time period[33]; by comparison, fatal injury MVCs for drivers aged 70 years and older decreased by 42% from 1997 to 2012.[33] Although concerning for a potential reversal in the overall trend of MVC incidence among older drivers, this result may in part reflect underreporting to law enforcement about involvement in minor MVCs that result in negligible property damage or injury. Indeed, 29.3% of all crashes may be unreported to the police.[34] In addition, NHTSA only reports nonfatal traffic crashes that ultimately result in a police report.[34] A future study utilizing follow-on data from LongROAD regarding DMV-reported MVCs would help clarify the extent of underreporting. Additionally, such a study could more clearly delineate any significant changes in government-reported MVC incidence among older drivers.

Two covariates were shown to have a significant association with either fewer or increased MVCs on both bivariate analysis and in the complete regression model. Good hearing was found to be associated with fewer self-reported MVCs in comparison with excellent or very good hearing, while there was no association between reported reductions in vision and MVCs. This contradicts other studies showing a clear relationship between hearing and visual deficits and increased MVCs.[35] It is possible that many respondents reporting very good or excellent hearing were overestimating their hearing abilities; however, if this was the case, we would also expect respondents to overestimate their visual abilities, resulting in a more significant association between visual acuity and MVCs than was found in this study. Given this inconsistency, we believe that this association is most likely a spurious finding. A reported history of falls was also found to have a significant association with MVCs, which agrees with previous findings identifying falls as a risk factor for both MVCs and overall difficulty driving.[36,37] Our study likewise found that being divorced or separated was found to have a significant association with self-reported MVCs on bivariate analysis and a notable (although not significant) association in the complete regression model. Several health effects which are known to be associated with social isolation, such as depression, may act as mediators between social isolation and MVCs, as demonstrated in Figure 1. Although possession of an associate's or bachelor's degree was significantly associated with an MVC in comparison with possession of a graduate degree on both bivariate analysis and in the complete regression model, previous studies have shown no significant association between education level and MVC involvement.[38,39] We would anticipate that increasingly lower levels of education would have an increased association with MVCs given the relationship between education and health-promoting behaviors like seatbelt use.[40] However, this was not shown to be the case in this study, and so we suspect that this finding is also likely spurious and may reflect the disproportionately high level of educational attainment in the study population. Last, we note that reporting risky driving behaviors was significantly associated with MVCs on bivariate analysis, as anticipated. However, this was not found to be the case on multivariate analysis. Since a number of known contributors to unsafe driving, such as diminished cognitive ability and vision,[41] were adjusted for in the multivariate analysis, this is an unsurprising finding.

Limitations

In addition to concerns over the use of self-reported data and reporting bias, the LongROAD questionnaire also used a handful of examples about what constituted different physical activity levels rather than providing a detailed list of activities per MET category. The questionnaire also did not ask respondents to specify the number of MVCs that they were involved in, so any relationship between the actual number of MVCs and physical activity levels was unable to be assessed. Furthermore, although the study's large sample size and geographic diversity are strengths, only one study site was located in a rural area,

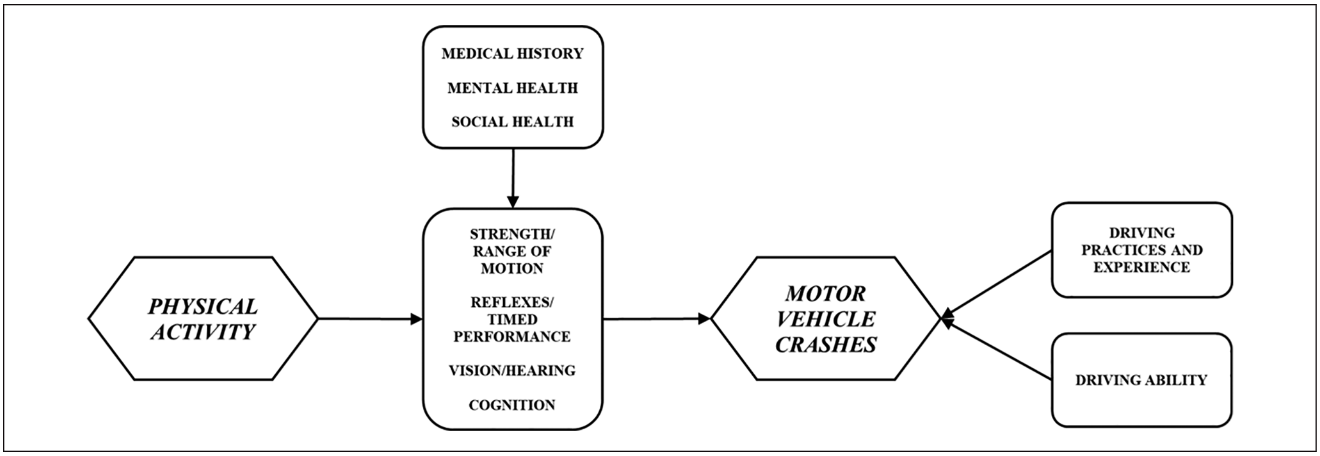

Figure 2. Proposed research framework to further investigate relationship between physical activity and motor vehicle crashes.

and only one was located in a climate with low precipitation or few days below freezing. In addition, the sample of LongROAD participants was predominantly White with high levels of education and income. DAGs have found increasing use in epidemiological studies, since they integrate known and likely relationships among different variables within a singular framework; however, the evidence for some relationships may be more extensive than for others, such that a DAG may not accurately reflect the true nature of those relationships. Also, although widely used as a minimally biased approach to missing data, multiple imputation may lead to the misrepresentation of associations of interest since the actual responses may have differed from the imputed responses. Finally, since this is a cross-sectional study, we cannot establish if there is a temporal relationship between any of the exposures examined and MVCs; for example, while it is possible for unsafe driving practices to have led to an MVC, it is also possible that an MVC might have led to safer driving practices.

Conclusion

This study found no significant association between measures of physical activity and self-reported MVCs in the prior year among this group of older drivers. In addition to the ongoing prospective data being gathered by the LongROAD study, future studies should incorporate direct measures of physical activity such as activity trackers as well as objective measures of MVCs. A prospective cohort study looking at the association between objectively measured levels of physical activity and MVC occurrence among older drivers, while accounting for demographic, health, social, and behavioral risk factors, would more fully clarify this relationship (Figure 2). As the larger LongROAD study itself continues, we can additionally adjust for time-varying covariates to obtain more information.

Authors' Note

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Declaration of Conflicting Interests

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