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The Impact of Health Problems on Driving Status among Older Adults

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Abstract

Objective—This study assesses the impact of health problems on driving status (current driver vs. ex-driver) among older adults to identify which of those health problems have the greatest individual and population impact on driving cessation.

Methods—Data were from baseline and 5 year follow-up waves of a longitudinal survey of adults age 55 years and older (N=1,279). The impact of several health problems on driving status was assessed using a relative risk ratio and a population attributable risk percent. Analyses controlled for age, gender, and the presence of additional baseline health problems.

Results—Many health conditions were not associated with driving cessation. Functional limitations, cognitive function, and measures of vision were significant predictors of driving cessation. Self-care functional limitations were associated with the highest risk for driving cessation, while visual function was associated with the highest attributable risks.

Discussion—In order to effectively address healthy aging and mobility transitions, it is important to consider the implications of targeting individuals or populations who are most at risk for driving cessation. The risk ratio is relevant for evaluating individuals; the attributable risk is relevant for developing interventions in populations.

Keywords

health; driving status; driving cessation; older adults

1. Introduction

In the U.S. and in many developed and developing countries, personal driving is relied upon for access to employment, goods, services, and social contacts. After years of relying on personal driving, many older adults reduce and modify driving behavior or stop driving completely (Ball et al., 1998; Gilhotra, Mitchell, Ivers & Cumming, 2001; McGwin, Chapman & Owsley, 2000; Stewart, Moore, Marks, May & Hale, 1993; West et al., 1997).

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The impact of driving reduction or driving cessation can be substantial. Driving cessation among older adults is associated with decreased activity, mobility, and independence, and increased depressive symptoms (Carp, 1988; Fonda, Wallace & Herzog, 2000; Marottoli & Richardson, 1998; Ragland, Satariano & MacLeod, 2005). This is a problem that may be especially acute in the US. In countries where mobility is less dependent on the automobile, the risk of adverse impacts maybe be reduced.

A number of studies document the association between health problems and driving status (current vs. ex-driver) (Adler & Kuskowski, 2003; Brayne et al., 2000; Campbell, Bush & Hale, 1993; Dellinger, Sehgal, Sleet & Barrett-Connor, 2001; Foley, Masaki, Ross & White, 2000; Forrest, Bunker, Songer, Coben & Cauley, 1997; Freeman, Munoz, Turano & West, 2005; Freund & Szinovacz, 2002; Gallo, Rebok & Lesikar, 1999; Gilhotra et al., 2001; Hakamies-Blomqvist & Wahlstrom, 1998; Marottoli et al., 1993; Siren, Hakamies-Blomqvist & Lindeman, 2004). In general, findings indicate that some health problems increase with age and that participants with various health problems are at an increased risk for driving cessation. Vision impairments, physical limitations, cognitive impairments, and a number of health conditions are associated, to varying degrees, with driving cessation and driver performance (Dobbs, 2005). While this research is valuable, a majority of these papers focused on the impact of the conditions on individuals. Some studies reported prevalence of relevant conditions, but did not translate this into a population risk (Brayne et al., 2000; Gilhotra et al., 2001; Siren, Hakamies-Blomqvist & Lindeman, 2004; West et al., 1997). There are different implications for addressing driving cessation at the individual- and population-level. From a public health perspective, it may be important to help older adults at lower levels of risk take specific preventive care measures and to prepare for mobility transitions (Rose, 1985).This study aims to identify health problems which have the greatest individual *and* population impact on driving cessation. The study is based on a longitudinal examination of a cohort of adults 55 years and older in Sonoma, California, with a focus on assessing the association between several functional limitations, health conditions, and measures of vision at baseline and driving status at 5 year follow-up. This information can be used to develop strategies to extend safe driving years and for planning transportation alternatives.

2. Material and Methods

2.1 Participants

As part of the Study of Physical Performance and Age-Related Changes in Sonomans (SPPARCS), the participants were adults ages 55 years and older who were living in the city and surrounding area of Sonoma, California. The City of Sonoma is a relatively small area (2.7 square miles) in the rural county of Sonoma and is approximately 45 miles north of San Francisco, California. SPPARCS is a community-based longitudinal study of age-related changes in physical activity and functioning. A community-based census identified 3,057 age-eligible individuals, of whom 2,092 (68.4%) agreed to participate in the study and were enrolled between May 1993 and December 1994.

Based on the 1990 U.S. Census, the residential population for the city of Sonoma was 8,121. For residents ages 55 years and older, the sample over represented adults ages 65 to 73

(41.3% vs. 38.8%) and underrepresented adults ages 85 years and older (7.3% vs. 8.7%). The sample was also somewhat more affluent and educated than the Census residential population. Although some differences exist between participants and non-participants, these differences do not suggest a consistent pattern with respect to functional disability and chronic illness. The income distribution compared to the population ages 55 and older in California under represented only persons with annual incomes less than $10,000. The modal income category of our sample ($25,000–$49,000) was the same for the entire state of California in 1994. There was also little difference in the percentage of households with annual incomes of $50,000 or more (55–64 years: sample 44%, state 39%; 65–74 years: sample 23%, state 20%; 75+ years: sample 13%, state 12%). This close similarity was also observed in the three highest income categories.

Data included in the present analysis represent a subset who were current drivers at baseline (assessed in 1993–1994) and were current or ex-drivers at 5 year follow-up (N=1,279 assessed in 1998–1999). Of the current drivers at baseline, 574 participants were not included in the analysis. A third of those were deceased. Of those that were not deceased, over half were among the oldest old (age 75+ at 5 year follow-up) and were lost to follow-up. Driving status was based on driver license status (currently licensed to drive) and self-reported driving behavior. Current drivers were participants who had a driver's license and reported driving trips in the previous 30 days. Ex-drivers were participants who previously held a driver's license or had a current valid driver's license but did not currently drive.

2.2 Study Measures

Functional limitations were self-reported "difficulty" with or "needed assistance" for activities of daily living (ADL) and were examined by 2 of 4 standard categories (Fried, Ettinger, Lind, Newman & Gardin, 1994): (1) mobility and exercise and (2) self care. Mobility and exercise activities included walking three neighborhood blocks, walking up or down a flight of stairs, transferring from bed, walking across a room, and lifting a 10 lb object. Self-care activities included using the bathroom, dressing, bathing, and eating. Due to the low prevalence, eating was not included. Health conditions included self-reported diagnosed conditions such as cancer, diabetes, heart disease, high blood pressure, kidney disease, and stroke. Health conditions also included use of a hearing device, experience with falls, and limitations related to arthritis.

Visual conditions and function included self-reported diagnosed visual conditions: cataracts, glaucoma, and macular degeneration. Due to the low prevalence, diabetic eye disease was not included. Visual function was assessed by driving license restriction that required corrective lenses, and it was also measured using the Smith-Kettlewell Institute Low Luminance (SKILL) Card. The SKILL Card is a clinical test that assesses visual function under low-contrast and low- light conditions. It is a particularly sensitive measure for function as a result of certain visual impairments (e.g., optic neuritis, glaucoma, maculopathy), some of which are considered age- related impairments. The test has shown strong correspondence with driving performance in older populations and repeatability has proven as reliable as the standard Snellen Acuity Test (Haegerstrom-Portnoy, Brabyn, Schneck & Jampolsky, 1997).

Visual problems and physical symptoms affecting the eye included self-reported presence of problems or symptoms within a 30- day period such as focusing, recognizing objects at distance, seeing up or down stair-steps, impaired vision due to glare from the sun or lights, reading street signs at night, experiencing constricted peripheral vision, and judging distance. Symptoms included: watery eyes, dry eyes, and runny or itchy eyes. This category also included subjects who reported vision as a reason for limiting physical activity.

Cognitive function was assessed by the modified Mini-Mental State Examination (mMMSE). The full MMSE is a 30-point test of general cognitive function and evaluates orientation to time and place, recall, attention/calculation, language, visuospatial ability, and ability to follow instructions. Three questions related to orientation to time (date, day of week, month) were not included in this study resulting in a maximum score of 27 points. In this study population, scores on the modified and full versions of the MMSE are highly correlated (r = 0.92) (Barnes, Yaffe, Satariano, & Tager, 2003). Based on a pattern of responses, a subset of six items was selected to provide the most sensitive measure of cognitive function for this sample. The six items included the questions and tasks in which 10% or more of the subjects in this study responded or performed incorrectly. The values were grouped into the lowest quartile (scores 0–14) and upper three quartiles (scores 15–18).

2.3 Analysis

For each of the functional limitations, health conditions, and measures of vision, the impact on driving status was determined by calculating a risk ratio of (a) the percent who were ex-drivers when the condition or limitation was present to (b) the percent who were ex-drivers when the condition or limitation was absent. This ratio represents the risk to an individual that he or she will discontinue driving with the presence of the particular health problem. The attributable risk corresponds to the overall impact of a health problem on driving status. The population attributable risk (PAR) is the proportion of the outcome in the population (i.e. driving cessation) that can be attributable to the exposure (i.e., a specific health problem). The PAR can be calculated as a percentage (population attributable risk percent) as follows:

$$PAR\% = \frac{ppop - punex}{ppop} \times 100$$

where *Ppop* is the percentage of those in the total population who were ex-drivers and *Punex* is the percentage of those in the “unexposed” group (i.e., those *without* the specific health problem) who were ex-drivers (Last, Spasoff & Harris, 2000). All analyses control for age, gender, and the presence of a problem in the other health categories (yes vs. no for each of the 4 categories: function limitation, health problem, vision, and cognition). All analyses were conducted using SAS 9.2 (SAS Institute, Cary, NC). Statistical significance was evaluated at 0.05 level. However, given the smaller number of ex-drivers at follow-up, relationships with marginal significance are also discussed.

3. Results

Table 1. shows the participant characteristics. The sample was primarily white and a majority were married (63%) and had an education beyond high school (71%) at 5 year follow-up. Six percent of participants were ex-drivers (n=79). Ex-drivers tended to be older (90% vs. 40% current drivers age 75+ at follow-up) and female.

Table 2 provides (a) the prevalence of each of the health measures, (b) percent of ex-drivers with and without the specific health problem, (c) the risk ratio of these percents, and (d) the attributable risk. Results from Table 2. are summarized by category below.

3.1 Functional limitations

Impairment with self care ADLs had high risk ratios (3.9–5.7). However, due to the small prevalence, these had lower attributable risks. The functional limitations with both the highest prevalence and the highest attributable risk were mobility and exercise ADLs "Walking 3 blocks" (risk ratio = 4.4 and attributable risk = 20.5%) and "walking a flight of stairs" (risk ratio = 4.5 and attributable risk = 29.5%).

3.2 Health conditions

The most common health conditions were high blood pressure (39.3%), heart disease (24.1%), and arthritis (20%). Controlling for age, gender, and presence of other types of health problems, experience with falls was the only health condition that was a significant predictor of driving cessation. Experience with falls, was common (19.7%), associated with a moderate risk for driving cessation (2.1) and a high attributable risk (18.4%) relative to the other health conditions.

3.3 Visual conditions and function

The majority of participants had, or once had, a driver's license restriction to wear corrective lenses (57.3%) and nearly half had visual function outside the normal limits as measured by the SKILL card test (48.7 %). SKILL card vision, cataracts, and macular degeneration were the only significant predictors of driving cessation at 5 year follow-up. Macular degeneration was uncommon in this population (3.8%) and had a small attributable risk (4.5%). SKILL card vision was associated with a notable attributable risk (31.8%).

3.4 Vision problems

The most common vision problems were glare (26.1%), reading street signs at night (16.7%), and trouble focusing (16.2%).Many vision problems were significant predictors of driving cessation and were associated with moderate risk ratios (1.7–2.5) and relatively modest attributable risks (3.8%–10.0%).

3.5 Physical symptoms affecting the eye

Runny or itchy eyes, watering eyes, and dry eyes were all fairly common in the sample (31.7%, 26.3%, and 14.0% respectively). However, none of these symptoms were associated with driving cessation at follow-up.

3.6 Cognitive function

Cognitive impairment was detected in 16.1% of participants. Participants with cognitive impairment were 1.9 times more likely to be ex-drivers and the attributable risk was 12.6%.

4. Discussion

This study evaluated driving cessation as function of a range of health problems in an older adult cohort in California, USA. This paper provided two measures to identify health problems which have the greatest individual and population impact on driving cessation. Some limitations in health status may be compensated for with vehicle and environmental countermeasures while other impairments could be addressed with health prevention and treatment (e.g. cataract surgery). In order to effectively address healthy aging and mobility transitions, it is important to consider the implications of targeting the health problems of individuals or of the populations who are most impacted (Rose, 1985). By identifying those who are at high risk for driving cessation, the concerns of those who are in critical need of transportation alternatives may be addressed. However, by identifying a larger proportion of the population at lower risk can also be beneficial. Efforts aimed at this portion of the population could focus on extending safe driving and planning for mobility transitions.

It has been established that cognitive, physical, and visual function are necessary for driving tasks; however the specific dimensions of each of these and the relative importance is still debated (Ackerman, Edwards, Ross, Ball, & Lunsman, 2008; Edwards, Ross, Ackerman, Small, Ball, Bradley, & Dodson, 2008). In this longitudinal study cognition, vision, experience with falls, and physical function were significant predictors of driving cessation at 5 year follow- up after controlling for age, gender, and the presence of presence of a problem in the other health categories. Functional limitations had the highest risk ratios while problems related to vision had the highest attributable risks.

4.1 Functional limitations

Functional limitations had the highest association with driving status compared to other health problems. This is consistent with previous research which indicates that functional impairments were significantly associated with risk for driving cessation after controlling for age (Brayne et al., 2000; Campbell et al., 1993; Foley et al., 2000; Freeman et al., 2005; Gallo et al., 1999). However, the functional measures assessed here vary by population impact. This may highlight the importance of promoting a certain level of physical functioning in the older adult population. It also is an important consideration for modifying vehicles to accommodate physical disabilities and license requirements for modified vehicles (Dobbs, 2005). This mobility measure may also be an important consideration in licensing in general. However, the research on musculoskeletal impairments and traffic crashes is relatively small (Dobbs, 2005).

4.2 Health conditions

Of the health conditions examined in this study, only falls was associated with driving cessation. Consistent with previous studies which examined arthritis, heart disease, and high blood pressure findings indicated relatively low or no associations between these medical conditions and driving status after controlling for age (Freund & Szinovacz, 2002; Gallo et al., 1999; Gilhotra et al., 2001). In other studies stroke show a relatively high association with driving cessation after controlling for age (Campbell et al., 1993; Freund & Szinovacz, 2002; Gilhotra et al., 2001). In this study, functional limitations were more important to driving cessation. However, heart attacks, stroke, hip fracture, and cancer can lead to physical disability (Guralnik, Ferrucci, Balfour, Volpato, & Di Iorio, 2001).

Some health conditions can have acute and chronic effects (Dobbs, 2005). A stroke, can quickly change one's cognitive and physical capacities. Falls are somewhat common among older adults and can result in injuries and fears about physical capacity. Identifying remedial factors might have an impact on driving status on a population basis. There are a number of preventive strategies for strokes and falls that could include preventive care visits, physical activity, and medication. In terms of the broader impact of medical conditions, heart disease is a concern for traffic crashes where drivers may suddenly fall ill at the wheel (Dobbs, 2005).

4.3 Vision and Cognition

Consistent with previous findings, visual impairment was associated with a risk for driving cessation after controlling for age (Campbell et al., 1993; Foley et al., 2000; Forrest et al., 1997; Freeman et al., 2005; Freund & Szinovacz, 2002; Gallo et al., 1999; Gilhotra et al., 2001). Cognitive impairment was also associated with driving cessation and this finding is consistent with previous studies that also indicated a high risk after controlling for age (Brayne et al., 2000; Foley et al., 2000). While vision is frequently associated with driving cessation, some longitudinal studies suggest that cognition is a better predictor of driving cessation (Anstey, Windsor, Luszcz, & Andrews, 2006; Edwards, Ross, Ackerman, Small, Ball, Bradley, & Dodson, 2008). However, remedial measures to reduce vision problems may have a higher population impact. This is not to suggest that we focus on vision in isolation or exclusively as there is research to suggest the relationship between vision and driving cessation may be mediated by cognitive performance (Ackerman, Edwards, Ross, Ball, & Lunsman, 2008). Rather, that vision is one capacity necessary for driving and older adults may comfortably manage some visual impairments with treatment (e.g. cataract surgery), glasses, and other improvements to the driving environment. It is interesting to note that, "problems reading street signs at night" was not associated with driving cessation. It may be that older adults in this sample have already reduced their night time driving. There is research to suggest that older adults self-regulate difficult driving situations and that this strategy may vary by gender and context (Kostyniuk & Molnar, 2008; Molnar, Eby, Charlton, Langford, Koppel, Marshall, & Man-Son-Hing, 2013). Older adults may also limit or avoid driving due to non-traffic safety concerns, such as, crime or because they have a reduced need to drive (Ragland, Satariano, & MacLeod, 2004).

4.4 Study limitations and future research

There are limitations to this study that should be considered. While the analyses controlled for the simultaneous presence of other types of health problems, the severity of each type was not considered. Future studies should aim to better understand the patterns of decline in health and function that lead to driving cessation. For example, there is research to suggest that cognition is a predictor of progressive functional disability (Guralnik, Ferrucci, Balfour, Volpato, & Di Iorio, 2001). It is likely that health problems interact and that preventive strategies for one problem could have a positive impact on other dimensions of health and well-being.

In addition, this analysis did not consider the use of medication or other aids. Some medications may enable safe driving while others may interfere with safe driving. Further, people may compensate for impairments by using aids, such as, visors to reduce glare or special mirrors to reduce blind spots. These compensations are not accounted for in the analyses. Future research should focus on understanding the prevalence and impact of medications on safe driving among older adults. Research could also focus on the use of driving aids and the impact on perceptions of driving ability and observed driving performance.

Finally, this study population may not be generalizable to other current and future cohorts. The number of ex-drivers was fairly small and loss to follow-up was observed. In addition, future generations of older adults may drive longer and include a greater number of women drivers. These analyses did not account for other factors related to driving cessation, such as, need to drive and self-efficacy.

5. Conclusion

Among older adults, the association between vision impairments, physical limitations, and cognitive impairments and driving cessation has previously been observed. However, few have examined this longitudinally and few have examined the attributable risk. From a public health perspective the attributable risk can offer an important perspective for planning interventions in a population. This is particularly important as we prepare for the increasing number of older adults who will face important decisions about their driving behavior. In fact, intervening when the individual impact is lower but the population impact is relatively high, may be financially advantageous for some public health problems (Ahern, Jones, Bakshis, & Galea, 2008).

At every stage of life, function and quality of life can be affected by intervention and declines in health can potentially be compensated with vehicle and environmental design and clinical treatment. Vehicle and street lighting that reduces glare, vehicle windscreen clarity, and cataract surgery are examples of strategies to extend safe driving for those with vision problems (Satariano, MacLeod, Cohn, & Ragland, 2004). Strategies that affect a large segment of the older adult population may have longer-term social and health implications, such as, access to preventive health visits and social contacts. This can contribute to healthy years and well-being and potentially delay institutionalization. Further, environmentally-based improvements could have co-benefits for other community members. For example, neighborhood improvements to support physical activity or intelligent transportation system countermeasures to improve safety. In a world with limited resources it is important to consider the implications of targeting individuals or populations who are most impacted (Ahern, Jones, Bakshis, & Galea, 2008).

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Highlights

- We assess the impact of several health problems on driving status among older adults.
- We calculate a relative risk ratio which is relevant for evaluating individuals.
- We calculate a population attributable risk which is relevant for populations.
- The population impact and long term outcomes are important considerations.

Table 1

Demographic Characteristics by Driving Status, SPPARCS, 1998–1999

	Current Drivers		Ex-Drivers	
Age	**n**	**%**	**n**	**%**
55–64	231	19.3	2	2.5
65–74	493	41.1	6	7.6
75+	476	39.7	71	89.9
Gender				
Female	693	57.7	54	68.3
Male	507	42.3	25	31.7
Education [a]				
≤12 years	337	28.1	32	40.5
>12 years	863	71.9	47	59.5
Marital Status				
Married	766	64.4	34	43.6
Divorced/Separated	136	11.4	7	9.0
Widowed	247	20.8	33	42.3
Never Married	41	3.4	4	5.1
Total	1200	100.0	79	100.0

[a]Information was not available for all participants

Table 2

Health Problems and Driving Status, SPPARCS, 1993–1994 and 1998–1999

Health Problems at Baseline	Prevalence	Percent of Ex Drivers-		Risk Ratio (% with/ % without)	Attributable Risk
		with the condition	without the condition		
Functional Limitations					
Mobility and Exercise					
Walking 3 blocks	7.8	20.3	4.6	4.4	20.5***
Walking flight of stairs	12.0	18.5	4.1	4.5	29.5***
Transferring from bed	0.3	23.8	5.7	4.2	1.0*
Walking across a room	0.7	28.5	5.6	5.1	2.9**
Lifting 10 pounds	11.8	12.2	4.9	2.5	14.7***
Self Care					
Using lavatory	0.2	32.3	5.7	5.7	1.1**
Dressing	0.3	22.5	5.7	3.9	0.9
Bathing	0.2	38.1	5.7	6.6	0.9**
Medical Conditions					
Arthritis[a]	20.0	3.3	6.4	0.5	−10.4
Cancer	12.9	6.8	5.6	1.2	2.6
Falls	19.7	10.1	4.7	2.1	18.4***
Heart disease	24.1	7.3	5.3	1.4	8.2
High blood pressure	39.3	6.0	5.6	1.1	2.7
Kidney	2.4	3.9	5.8	0.7	−0.8
Stroke	4.3	7.9	5.7	1.4	1.6
Use of hearing device	9.5	7.3	5.6	1.3	2.8
Visual Conditions					
Cataracts	21.8	8.0	5.2	1.5	10.5*
Glaucoma	5.3	7.4	5.7	1.3	1.6

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Health Problems at Baseline	Prevalence	Percent of Ex Drivers-		Risk Ratio (% with/ % without)	Attributable Risk
		with the condition	without the condition		
Macular degeneration	3.8	12.7	5.6	2.3	4.5**
Visual Function					
License restriction/corrective lenses	55.3	6.7	4.7	1.4	19.2
SKILL card test	48.7	6.8	3.5	2.0	31.8***
Vision Problems					
Limits physical activity	2.4	9.9	5.7	1.7	1.6
Focusing[b]	16.2	8.8	5.2	1.7	10.0**
Recognizing objects at a distance[b]	8.1	12.3	5.3	2.3	9.5***
Seeing steps up/down stairs[b]	6.0	12.6	5.4	2.3	7.4***
Seeing due to glare from sun light[b]	26.1	7.7	5.1	1.5	11.4*
Reading street signs at night[b]	16.7	5.9	5.8	1.0	0.5
Peripheral vision[b]	2.5	14.2	5.6	2.5	3.8**
Judging distance[b]	7.0	9.0	5.6	1.6	4.1
Physical Symptoms Affecting the Eye					
Watering eyes	26.3	6.9	5.4	1.3	6.8
Dry eyes	14.0	3.0	6.3	0.5	−7.8
Runny or itchy eyes	31.7	5.1	6.1	0.8	−5.3
Cognitive function					
Cognitive Impairment	16.1	9.6	5.1	1.9	12.6***

[a]Condition limits activity

[b]Self-reported within the past month.

Analyses control for age, gender, baseline cognition, and the presence of baseline conditions in other health problem categories.

*** indicates $p < 0.01$;

** indicates $p < 0.05$;

* indicates $p < 0.10$.

No marker indicates a value without sufficient significance.

Appendix

Studies which have examined the association between health problems and driving status

Reference	Population	Driving	Health	Design	Analysis	Results	
Adler & Kuskowski, 2003.	N=43; age 60+; U.S. men with dementia; current and ex-drivers	self and collateral reported driving behavior (years, current, days per week)	cognition	longitudinal	univariate logistic regression	cognitive impairment	OR=1.3
Antsey et al. 2005	N=1,466; age 70+; Australian current and ex-drivers	Self-reported	Self-rated health, neurological, cardiovascular, 3+ medications, vision, hearing, grip, multiple measures of cognition	longitudinal	multivariate logistic regression	low grip strength, poorer cognitive, and poorer self-rated health	
Brayne et al., 2000.	N=404; age 85+; U.S. current, ex, and never drivers	self-reported driving behavior (ever, current, frequency, vehicle ownership)	angina, cognition, depression, hearing, ischaemic heart disease, near vision, physical function, stroke, transient ischaemic attacks	longitudinal	multivariate logistic regression controlling for age, gender, and education	cognitive impairment 3+ physical limits sensory impairment	OR=11.5 OR = 9.0 OR = 2.7
Campbell et al., 1993	N=1954; age 70–96; U.S. current and ex-drivers	self-reported driving behavior (ever drove regularly, current)	angina, arthritis, cognition, detatched retina, diabetes, dizziness, hearing, hypertension, macular degeneration, malignant neoplasm, mycocardial infarction, Parkinson's, physical function, stroke, syncope, vision	case control	multivariate logistic regression, population attributable risk fractions controlling for age and gender.	macular degeneration Parkinson's physical limit retinal hemorrhage stroke sequelae syncope	OR=4.3 PAR=14.1% OR=6.4 PAR=4.0% OR=3.4 PAR=25.6% OR=3.9 PAR=2.8% OR=3.0 PAR=3.3% OR=1.9 PAR=7.2%
Dellinger et al., 2001	N=141; age 55+; U.S. ex-drivers within the past 5 years	self-reported driving behavior (ever licensed, current, miles per week)	arthritis, heart, health (general), Parkinson's, vision	cross-sectional	multivariate logistic regression controlling for age, gender, previous weekly miles, and number of crashes within the past 5 years	The number of health problems *inversely* associated	

Reference	Population	Driving	Health	Design	Analysis	Results	
Edwards et al., 2008	N=1,656; age 65+; U.S. current drivers at baseline	Self-reported driving within the past 12 months and could currently drive if necessary	SF-36 physical functioning, physical performance, congestive heart failure, visual acuity, and cognition at baseline	longitudinal	Cox regression controlling for age and days/wk of driving at baseline	SF-36 Heart failure Physical performance Cognition	HR=0.78 HR=1.83 HR=1.23 HR=1.18
Foley et al., 2000	N=643; age 74–95; Japanese-American men who screened positive for possible incident dementia; current and ex-drivers	caregiver/family reported driving behavior (ever, current, if stopped when)	cognition, physical function, vision	longitudinal	multivariate logistic regression	cognitive impairment physical limits visual impairment	OR=4.9 ORs=2.2–3.9 OR=3.9
Forrest et al., 1997	N=1768; age 65+; U.S. women; current, ex, and never drivers	self-reported driving behavior (ever, current, frequency, miles per week, longest trip within the past year)	angina, arthritis, cancer, cataracts, cognition, depression, diabetes, glaucoma, hearing, hypertension, hyperthyroid disease, macular degeneration, myocardial infarction, osteoporosis, Parkinson's, seizures, stroke, vision	cross-sectional	multivariate logistic regression controlling for age, education, living arrangement, and resident type	angina diabetes fractures vision	OR=1.9 OR=2.5 OR=1.8 OR=1.8
Freeman et al., 2005	N=1824; age 65–84; U.S. current and ex-drivers	self-reported driving behavior (ever, miles within past year)	cognition, contrast sensitivity, depressive symptoms, diabetes, glare sensitivity, health (general), stroke, visual acuity, visual field	longitudinal	Cox regression controlling for age, sex, and race.	central visual field cognitive impairment contrast sensitivity contrast sensitivity loss diabetes health peripheral visual fields peripheral visual field loss stroke	HR=1.8 HR=1.9 HR=1.5 HR=1.7 HR=1.6 HR=1.8 HR=1.7 HR=1.9 HR=1.9

Reference	Population	Driving	Health	Design	Analysis	Results	
Freund & Szinovacz, 2002	N= 5460; age 70+; U.S. current and ex-drivers	self-reported driving behavior (current, distances)	arthritis, cognition, diabetes, heart disease, physical function, respiratory disease, stroke, vision	cross-sectional	multinomial logistic regression controlling for age, race, income, urban, and education by sex	arthritis cognition heart disease physical limits respiratory disease stroke with lasting problem vision	RRs=0.7–0.9 RR=0.9 RRs=1.1–1.2 RRs=1.4–1.6 RRs=0.9–1.4 RRs=4.0–10.9 RRs=1.9–2.4
Gallo et al., 1999	N=589; age 60+; U.S. current and ex-drivers (within the past 2 years)	self-reported driving behavior (years, currently drives at least once weekly, mileage in previous year)	arthritis, cognition, diabetes, heart disease, hearing, high blood pressure, physical function, psychological distress, stroke, vision	longitudinal	multivariate logistic regression controlling for age, gender, and race	arthritis cognitive impairment diabetes hearing heart disease high blood pressure physical limits psychological distress stroke vision	OR=1.1 ORs=1.1–1.8 OR=1.4 OR=0.8 OR=1.2 OR=1.1 ORs=1.5–2.2 OR=1.3 OR=1.3 OR=2.2
Gilhotra et al., 2001	N=2831; age 49+; Austrailian; current and ex-drivers	Self-reported driving behavior (ever, current)	arthritis, cardiovascular disease, diabetes, glaucoma, health, hearing, stroke, visual acuity, vision	Case control	Logistic regression controlling for age and sex	arthritis cardiovascular disease diabetes glaucoma poor health hearing impairment stroke difficulty seeing in the dark difficulty with glare poor visual acuity poor corrected visual acuity	OR=1.0 OR=1.6 OR=1.6 OR=2.2 OR=1.8 OR=1.6 OR=2.4 OR=1.9 OR=1.5 OR=2.5 OR=4.0
Hakamies-Blomqvist & Wahlstrom, 1998	N=3811; age 70; Finnish; current and ex-drivers	Driver license status	Depression, Diabetes, Glaucoma, Heart disease, Neurological diseases, Rheumatism	Case Control	One way analysis of the variance and chi-square statistic	depression, glaucoma, and neurological disorders	

Reference	Population	Driving	Health	Design	Analysis	Results	
Marottoli et al., 1993.	N = 595; age 65+; current and ex-drivers	self-reported driving behavior (ever, current, if stopped when, mileage, mileage compared to 5 previous)	amputation, angina, arthritis, cancer, cataracts, cirrhosis, diabetes, glaucoma, hearing, hip or other fracture, hypertension, myocardial infarction, Parkinson's, physical function, stroke, vision	longitudinal	multivariate logistic regression controlling for gender and housing stratum	cataracts Parkinson's or stroke physical activity physical limits	OR=2.3 OR=2.9 OR=0.7 OR=2.1 years
Siren et al., 2004	N=1198; age 70; Finnish women; current and ex-drivers	Driver license status	anemia, blood circulation, cancer, cataracts, chest pain, dementia, depression, diabetes, epilepsy, glaucoma, health, heart defect, heart infarction, high blood pressure, hyperthyroid, joint pain, lung diseases, multiple sclerosis, Parkinson's, short-term unconsciousness, stroke, vertigo, vitamin deficiency	Case control	logistic regression	depression, illnesses possibly impairing driving ability (chest pain, vertigo, heart defect, diabetes, heart infarction, Parkinson's disease, and epilepsy), and illnesses not impairing driving ability (pain in joints, high blood pressure, blood circulation problems in legs or feet, lung diseases, cancer, hyperthyroid or hypothyroid disease, anemia, and vitamin deficit).	

OR = Odds Ratio

HR = Hazard Ratio