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ABSTRACT
Many health problems, especially those associated with older age, can have an impact on an individual's mobility. This paper addresses how specific functional limitations and medical conditions may be associated with driving status, while controlling for age and gender. This paper uses baseline data (N=2025) from a longitudinal survey of adults, ages 55 and older, the Study of Physical Performance and Age-Related Changes in Sonomans (SPPARCS). For the 35 selected medical conditions and functional limitations, this report presents the prevalence, the relative "risk" ratio (i.e., the risk that an individual with that condition no longer drives), and the attributable risk (i.e., the percent of ex-drivers with each condition). Compared to current drivers, ex-drivers had higher rates of physical limitations (ability to ascend one flight of stairs or walk three blocks), cognitive impairment, vision problems and stroke. The conditions with the highest relative risk included personal mobility limitations (such as the ability to transfer onto or from bed and the ability to use the lavatory) and decreased peripheral vision. The relative risks of medical conditions' effects on driving status offer a perspective on individuals' mobility choices, and the attributable risks offer a perspective on the most important causes of driving cessation in the elderly population.

INTRODUCTION

In the U.S., driving one's personal vehicle is heavily relied upon for the access to employment, goods, services, and social contacts. Many older adults reduce or modify their driving behavior or stop driving all together. Increased age is associated with reduced and modified driving behavior. (*1*) (*2*) (*3*) (*4*) (*5*)

After years of relying on personal driving, many older Americans are faced with decisions about whether or not to continue driving. The effects of discontinued driving on personal lives are immense. Research indicates that these older adults experience decreased activity, mobility, and independence and increased depressive symptoms. (*6*) (*7*) (*8*) (*9*)

Studies have reported the association between driving status and various medical conditions, functional limitations, and physical symptoms. (*1*) (*4*) (*5*) Factors examined include cardiovascular diseases and symptoms, musculoskeletal disorders, and various conditions and symptoms related to impaired vision. In general, researchers tend to find associations in the positive direction; that is, older adults with various medical conditions, functional limitations, or symptoms tend to alter their driving patterns, to drive less, or to not drive at all. However, the studies differ widely in design, definition of driving status, type of population examined, and other factors. They also differ in whether age, gender, and other factors have been controlled for in the analysis.

Needed is a better understanding of the barriers to driving associated with medical conditions and functional disabilities. Moreover, research could contribute to the development of strategies to extend safe driving years for older adults. Identifying factors associated with driving cessation among older adults would assist both in identifying those most at risk for driving cessation and in developing appropriate measures to extend safe driving.

Towards these ends, this study analyzes the association between the decision to not drive and 35 medical conditions and functional limitations. These conditions include functional limitations such as the inability to climb one flight of stairs; medical conditions such as high blood pressure; vision conditions such as macular degeneration; and cognitive impairment. We combine the prevalence and the ex-driver status of these conditions to report how many ex-drivers experience these conditions. By combining prevalence and risk measures, attributable risk measures allow researchers to identify the most important conditions that lead to driving cessation.

METHODS

Subjects

As part of the Study of Physical Performance and Age-Related Changes in Sonomans (SPPARCS), the subjects were adults ages 55 years and older who were living in the city and surrounding area of Sonoma, 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 for persons in Sonoma, aged 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%) (Table 1). The sample was also somewhat more affluent and educated. 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 (1990 census) under represents only persons with annual incomes less than $10,000. The modal income category of our sample ($25,000-$49,000) is the same for the entire state of California. There also is very 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 for the present analysis are from the baseline evaluation of the cohort. The sample ($N = 2025$) was restricted to those who were current or ex-drivers. Driving status was based on subject self report as current driver, former driver, or never driver. Current drivers were participants who had a driver's license and reported driving trips in the previous 30 days.

Seven groups of health and functional limitations were included in the analysis. They are described below.

Functional limitations included self-reported difficulty with or assistance needed for the following activities: walking up or down a flight of stairs, walking three neighborhood blocks, lifting a 10 pound object, walking across a room, eating, transferring from bed, using a lavatory, or dressing, and bathing.

Medical conditions included self reported diagnosed conditions such as cancer, diabetes, heart disease, high blood pressure, kidney disease, and stroke. Medical conditions also included use of a hearing device, experience with falls, and limitations related to arthritis.

Visual conditions and function included self-reports of diagnosed visual conditions: cataracts, glaucoma, diabetic eye disease, and macular degeneration. Impaired visual function was assessed by having a 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 administered by the research team 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.(*10*)

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 a modified Mini-Mental State Examination (MMSE). 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).

Analysis

First, the data were analyzed to measure the prevalence of various health and functional conditions. Next, we calculated the percentage of subjects with a specific condition who do not drive, and the percentage of participants without that condition that do not drive. We then calculated a ratio from these percentages. This ratio represents the risk to an individual that he or she will discontinue driving if afflicted with a certain medical condition. Finally, we report the attributable risk for each condition based on the overall prevalence of the condition and the likelihood ex-driver status. The attributable risk corresponds to the overall impact of a medical condition on the driving status of older adults in the sample. Our discussion includes relative and attributable risks where $p< 0.05$.

The population attributable risk (PAR) is the proportion of the outcome in the population (in this case, driving cessation) that can be attributable to the exposure (in this case, a specific medical or functional condition). The PAR can be calculated as a percentage (population attributable risk percent) as follows:

$$PAR\% = \frac{Ppop - Punex}{Ppop} x100,$$

where *Ppop* is the percentage of those in the total population reporting limitations in driving because of a medical condition and *Punex* is the percentage of those in the "unexposed" group (i.e., those *without* the specific medical condition) who report limitations in driving because of a specified medical condition.(*11*)

Our analysis controls for age and gender. This was done by including age and gender in the analyses with driving status as the outcome variables, and health condition, age, and gender, as predictor variables. Adjusted (for age and gender) driving status for those with and without the health condition was generated from the resulting multivariate model.

RESULTS

The sample of 2025 adults, which was restricted to current or ex-drivers, included 1,189 women and 836 men. In different age groups were 546 adults ages 55 to 64 years, 867 ages 65 to74 years of age, and 613 age 75 or older (Table 1). The sample was primarily white (96.8%), with a majority married (62.5%) and educated at least at the high school level (67%, 12 or more years of formal education) (Table 1). A total of 179 subjects reported that they were ex-drivers. Compared to current drivers, ex-drivers were more likely to be older, female, and widowed and to have less education (Table 1).

The results for the various functional and medical conditions are given in Table 2, and summarized by category below. Most risk ratios and attributable risks were associated with a $p \leq 0.05$ (Table 2); risk ratios that were not largely statistically significant are indicated by asterisks.

Functional Limitations
The two most prevalent functional limitations reported by the sample were walking up a flight of stairs (17.6%) and lifting ten pounds (16.8%). The least prevalent functional limitation was the ability to feed one's self (0.4%). The vast majority (>60%) of persons with difficulty walking across a room, feeding one's self, transferring to or from bed, using a lavatory, dressing, or bathing were ex-drivers. In contrast, less than 25% of persons with difficulty walking one flight of stairs, walking three blocks, and lifting ten pounds, were ex-drivers. Therefore, the risk ratio of the ability to feed one's self, dress, transfer from/to a bed was very high (i.e., 9.0 – 10.0, refer to Table 2). However, due to their small prevalence, these functional limitations had a low attributable risk. For example, persons unable to transfer to or from a bed represented 6.7% of ex-drivers. The most prevalent functional limitations corresponded to those limitations with the highest attributable risk. For example, 30.7% of ex-drivers were unable to lift ten pounds. The functional limitations with the highest attributable risk were walking a flight of stairs, lifting ten pounds, and walking three blocks.

Medical Conditions
The most common medical condition was high blood pressure (42.8%) although, because it had a low relative risk ratio, high blood pressure was associated with a low attributable risk. In addition, stroke was a fairly uncommon condition in the study group (7.2%); however, 30% of persons who had experienced a stroke were ex-drivers. Hence, strokes had a high relative-risk ratio (4.1) and the highest attributable risk of all the medical conditions studied here. 18% of ex-drivers were stroke victims. Falls, the only injury included, accounted for 13.4% of all ex-drivers and had a prevalence of 22.1%. Heart disease and cancer had low risk ratios and attributable risks (3.8% and 2.7% attributable risks, respectfully). Arthritis and use of a hearing device also had low risk ratios, but slightly higher attributable risks (6.2% and 8.4%, respectfully).

Visual Conditions
Cataracts were the most common visual condition surveyed (27.9%) Glaucoma was reported by 7.2% and macular degeneration by 5.2% of subjects. About 22.4% of subjects with macular degeneration were ex-drivers, making macular degeneration the visual condition with the highest risk ratio. However, the visual condition with the highest attributable risk was cataracts, which accounted for 13.9% of ex-drivers. Diabetic eye disease was a rarely occurring condition in this study group (0.7%), and was not significantly related to being an ex-driver.

Visual Functions
The majority of subjects had, or once had, a driver's license restriction to wear corrective lenses (57.9%), and the majority also performed poorly in low-contrast and low light situations as measured by the SKILL card test (51.9%). However, the SKILL card test was not significantly associated with driving status. Although drivers with corrective lenses had low risk ratios, this group accounted for a large percent of all ex-drivers (17% attributable risk).

Vision Problems
The most common vision problem was glare (27.7%) followed by trouble focusing (18.2%). Reading street signs at night was also a common problem (16.6%), but a higher percentage of current drivers reported this problem than ex-drivers. The resulting protective attributable risk (a negative value) may be deceiving since subjects who are fit enough to drive at night are more likely to report this problem than subjects who are unable, or who avoid, driving at night. All vision problems, except seeing road signs at night, had a high-risk ratio for cessation of driving. Participants whose vision limited their physical activity were 5.3 times less likely to drive than participants who did not report this problem. Also, the risk ratio for peripheral vision was 3.4 and for the inability to see steps while walking up or down stairs was 2.9. In terms of attributable risk, 24% of ex-drivers reported problems focusing their eyes, and 17.8% limited their driving due to vision problems. Other vision problems with high attributable risk were the ability to recognize objects at a distance (12.3%), the ability to see steps while ascending or descending stairs (13.4%) and glare (13.4%).

Physical Symptoms Affecting the Eye
Runny or itchy eyes, watering eyes, and dry eyes were all fairly common in the sample (31.4%, 27.9%, and 15.4%, respectfully). Watering eyes and dry eyes had risk ratios of 1.3, and runny or itchy eyes had a risk ratio of 1.2. Of these three conditions, watering eyes had the highest attributable risk (8.7%), and runny or itchy eyes had the second highest attributable risk (6.9%). The attributable risk for dry eyes was 5%.

Cognitive Function
The group with MMSE scores in the lowest quartile (26.5% of the population) included 33.3% of the ex-drivers. Overall, subjects with low cognitive function were 2.9 times more likely to be ex-drivers subjects with scores in the top three quartiles.

DISCUSSION
Our previous studies with SPPARCS data focused on factors that were reported by older adults to limit driving. (*8*) In this paper, we have focused on the association between a number of functional or health problems and being an ex-driver. The association was calculated two ways. First, the association of each health condition with driving status was calculated as the ratio of the percent of ex-drivers among those conditions, to the percent of ex-drivers without those conditions. This approach is the most relevant to evaluating *individuals* with a specific condition. Virtually all previous studies have presented results in the same way, i.e. as an association between a condition and driving status that compares people with and without a condition with respect to driving status. (*1*) (*4*) (*5*) However, in our study, the attributable risk for ex-drivers was calculated (i.e., the percent of ex-drivers who have or who are "accounted for" by the condition). The attributable risk is relevant to planning countermeasures in *populations* (*12*). By comparison, risk ratios exclude information about overall prevalence of a condition; as a result, they do not allow researchers to evaluate what conditions are most likely to put a person at risk for driving cessation. Our study offers these two risk measures while controlling for the effects of age and gender. The relevance of both measures for each of the types of vision-related conditions is discussed below.

In general, symptoms manifested in typical daily activities such as climbing stairs, lifting weight, and distance vision are very prevalent in the senior population and correspond with a low risk of driving cessation. Regardless of low risk of driving cessation, due to their prevalence, these daily activity limitations have a high attributable risk. In contrast, specific, medically diagnosed conditions such as stroke, glaucoma, and the SKILL card test have a low prevalence, high risk of driving cessation, and, overall, a low attributable risk. The difference between risk ratios and attributable risk is very important. For intervention resource allocation, programs would prevent driving cessation on a larger scale by directing efforts towards conditions with high attributable risk.

Functional Limitations
Not surprisingly, the set of functional limitations studied here had the highest association with being an ex-driver compared to all other categories of health problems. The ratio of ex-drivers to current drivers ranges from 3.8 (limitations in lifting 10 lbs) to 10 (limitations in bathing). This finding is consistent with previous studies that have considered functional limitations and driving status.(*13*) While the association is not directly "causal," it likely reflects an overall decline in physical as well as cognitive functions. The implication for current drivers is that if they have one or more of these functional limitations, they might anticipate a future need for alternative, or dependent, transportation.

The relatively low prevalence of the some specific functional limitations means that the impact at the population level (i.e., the attributable risk) is not as high as might be expected based on the very strong impact in terms of association. For example, limitations on eating, transferring to and from bed, and using the lavatory all have low or very low attributable risk. (For example, attributable risk due to eating limitations is virtually "0"). Limitations in walking a flight of stairs, walking three blocks, or lifting 10 pounds each have a fairly high attributable risk both because of a relatively high prevalence and high association with being an ex-driver. The implications of these findings are that functional limitations "account for" a relatively high percentage of "ex-drivers" in this sample of older adults.

Medical Conditions
The association between each medical condition with driving status is relatively low; that is, they all have a ratio less than 2.0 (with the exception of stroke, which has a ratio of ex-driving status between those with and without a stroke of 4.1). The next highest conditions are "use of a hearing device" and "falls." Previous studies have found similar connections.(*13*) (*4*) However, each of these conditions (stroke, use of a hearing device, and falls) reflect factors that are potentially related to driving. Applying remedial measures in each of these cases may have a positive impact on driving. Of the medical conditions examined in this study, only strokes and falls have an appreciable association with attributable risk. Identifying remedial factors might have an impact on driving status on a population basis as well.

Visual Conditions, Vision Problems, and Physical Symptoms Affecting the Eye

Consistent with previous studies, most medical problems in these three related categories had a positive relationship with being an ex-driver. (*1*), (*2*), (*3*) Macular degeneration had the highest. Remedial measures for each of the conditions might increase the capacity for driving. Cataracts had the lowest association with ex-driving status; however, because of its relatively high prevalence, it had the highest attributable risk. Based on these findings, remedial measures aimed at correcting cataracts would have the highest population impact.

Two "visual function" indicators, "license restriction requiring corrective lenses," and poor performance on the SKILL test," had relatively small associations with being an ex-driver. However, because "license restriction requiring corrective lenses" has a high prevalence, this item also had a high attributable risk.

Most of the items in the category, "vision problems," had a substantial association with being an ex-driver, with one surprising exception: i.e., "problems reading street signs at night." It may be that older adults in this sample have already reduced their night time driving. The other findings are parallel to those found in other studies. (*1*), (*5*), (*13*) Clearly, addressing vision problems may have a positive effect on driving for affected individuals. Several of these conditions, because of a combination of high association and/or high prevalence, have a substantial attributable risk. It is clear that addressing these health problems could have a major impact at a population level.

Cognitive Function

Cognitive impairment measures evaluate patients with respect to the mental faculties of average adults; therefore, the prevalence of cognitive impairment is almost pre-determined simply by test-scoring methods (i.e., wherever the test developers draw the line between "average" and "impaired" performance). Regardless, attributable risk measures still help researchers decide if driving cessation can be attributed to (test-developer-defined) cognitive impairment. We only had available one direct measure of cognitive impairment, and it had a strong association with being an ex-driver. Because of a relatively high prevalence, it had a high attributable risk; in fact, cognitive impairment had the second highest attributable risk (after trouble "walking a flight of stairs") among all health conditions examined. This finding is consistent with previous studies that have identified cognitive impairment as an important factor in driving status. (*5*), (*13*)

Overall Relationship with Other Studies

Over the past decade, a number of studies have examined many of the health problems reported in the current study. (*1*), (*2*), (*3*), (*5*), (*13*) All previous studies focused on the association between various conditions and driving status, as opposed to the population impact as presented here. A number of previous studies reported prevalence of relevant conditions, but didn't translate this into population risk. (*1*), (*2*), (*3*), (*4*), (*5*) Therefore, our comparison with previous studies is limited to indications of association. In general, as we have indicated above, the associations we have found between various conditions and driving status are similar in general magnitude with other studies.

Future Research

It is clearly important to determine the relationship between the various health problems (i.e., functional limitations, vision symptoms and conditions, and medical conditions) that increase in frequency with age. There are limitations to this study that should be addressed in future studies.

First, the present study, as well as many of the previous studies, have been cross-sectional, making it more difficult to establish a causal pathway. In fact, even in current prospective studies, it is difficult to determine causality because the relative onsets of either the health problem or the decision to cease driving are difficult to establish. Therefore, future studies might need to devise ways to establish the time sequence of relevant events.

Second, at least some previous studies did not control for age per se in their analyses. In the current study, we included both age and gender in our models to control for potential confounding effects. We found (analyses not shown) that including these as control variables reduced the observed associations and subsequent attributable risk considerably. With respect to age, for example, this means that some portion of the "ex-driving" was due to other factors associated with age and not only the health problem under study. This of course, is extremely important in interpreting the results, and subsequent studies should control for age, gender, and other relevant factors.

Third, when studying a particular condition (e.g., heart disease), we did not control for the possible simultaneous presence of other conditions (e.g., stroke) or the effect of medications related to the conditions. Given the increasing level of co-morbidity (i.e., co-occurrence of multiple health problems) with increasing age, it is possible or even likely that there are confounding effects that have an impact the results. Other studies have also not accounted for the possible confounding effects of comorbidity. One reason is that when many factors are measured, it is unwieldy statistically to control for all of the factors, although various approaches can be taken. Future studies

should identify ways to address this issue, perhaps focusing on subsets of medical conditions/limitations, and conducting analyses within these subsets.

Fourth, various studies have used widely differing measures of driving status or driving limitations, making results somewhat difficult to compare. Standardized assessment driving status should be developed and used in future studies. Here we based driving status on participants' driving behavior in the past six months and their current license status. Driving limitations might be measured by the number of days driven, the number of trips or miles driven, and the avoidance of certain driving situations.

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LIST OF TABLES AND FIGURES

TABLE 1 Demographic Characteristics Among Current and Ex Drivers Ages 55 or Older (SPPARCS Baseline Data, 1993-1994, N=2025)

	Current Drivers		Ex-Drivers	
Age	**n**	**%**	**n**	**%**
55-64	541	29.3	5	2.8
65-74	831	45.0	35	19.6
75+	474	25.7	139	77.7
Total	1846	100.0	179	100.0
Gender	**n**	**%**	**n**	**%**
Female	1068	57.9	121	67.6
Male	778	42.2	58	32.4
Total	1846	100.0	179	100.0
Education	**n**	**%**	**n**	**%**
≤12 years	585	31.7	82	46.1
>12 years	1258	68.3	96	53.9
Total	1843	100.0	178	100.0
Marital Status	**n**	**%**	**n**	**%**
Married	1182	64.0	84	46.9
Divorced/Separated	228	12.4	14	7.9
Widowed	365	19.8	70	39.1
Never Married	71	3.9	11	6.2
Total	1846	100.0	179	100.0

Table 2. Health Problems and Functional Limitation by Ex-Driver Status, Ages 55 and Older and Adjusted for Age and Gender (SPPARCS Baseline 1993-1994, N=2025)
No marker indicates $p < 0.001$; (*) indicates $p < 0.05$, (**) indicates a value without sufficient significance.

Health Problems and Functional Limitations	Prevalence	Percent of Ex Drivers-		Risk Ratio (% with/ % without)	Attributable Risk
		with the condition	without the condition		
Functional Limitations					
Walking flight of stairs	17.6	21.3	5.2	4.1	34.5
Walking 3 blocks	12.4	23.3	5.9	3.9	26.0
Lifting 10 pounds	16.8	19.2	5.1	3.8	30.7
Walking across a room	3.2	63.5	7.1	9.0	19.3
Feeding self	0.4	81.8	8.5	9.7	0.0
Transferring from bed	1.1	66.8	8.2	8.2	6.7
Using lavatory	1.2	69.2	8.1	8.6	7.0
Dressing	1.7	63.6	7.9	8.1	12.4
Bathing	2.5	72.0	7.2	10.0	15.2
Medical Conditions					
Arthritis[a]	22.1	10.5	8.1	1.3	6.2
Cancer	16.5	9.8	8.4	1.2	2.7(*)
Falls	22.1	12.9	7.6	1.7	13.4
Heart disease	26.5	9.8	8.5	1.2	3.8(*)
High blood pressure	42.8	9.5	8.4	1.1	5.6(*)
Kidney	2.2	11.8	8.4	1.4	0.8(**)
Stroke	7.2	29.5	7.2	4.1	17.9
Use of hearing device	11.8	14.2	8.0	1.8	8.4
Visual Conditions					
Cataracts	27.9	11.5	7.2	1.6	13.9
Diabetic eye disease	0.7	15.9	8.4	1.9	0.9(**)
Glaucoma	7.2	14.0	8.0	1.8	5.0
Macular degeneration	5.2	22.4	7.7	2.9	8.7
Visual Function					
License restriction/corrective lenses	57.9	2.3	1.7	1.4	17.0(*)
SKILL card test	51.9	5.4	4.9	1.1	5.7(**)
Vision Problems					
Limits physical activity	4.8	39.4	7.4	5.3	17.8
Focusing[b]	18.2	16.0	5.8	2.8	24.0
Recognizing objects at a distance[b]	10.7	16.1	6.7	2.4	12.3
Seeing steps up/down stairs[b]	8.0	22.4	7.6	2.9	13.4
Seeing due to glare from sunlight[b]	27.7	10.3	6.7	1.5	12.6
Reading street signs at night[b]	16.6	6.6	7.9	0.8	-2.7(**)
Peripheral vision[b]	3.5	24.1	7.1	3.4	6.7
Judging distance[b]	8.4	15.2	7.0	2.2	8.6
Physical Symptoms Affecting the Eye					
Watering eyes	27.9	9.4	7.0	1.3	8.7(*)
Dry eyes	15.4	9.8	7.3	1.3	5.0(*)
Runny or itchy eyes	31.4	8.8	7.1	1.2	6.9(*)
Cognitive function					
Cognitive Impairment	26.7	17.3	5.9	2.9	33.5

[a]Condition limits activity
[b]Self-reported within the past month