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Use of and disparities in access to adaptive devices among U.S. adults with age-related eye diseases

Diane M. Gibson
CUNY Bernard M Baruch College

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Diane M. Gibson

Marxe School of Public and International Affairs, Baruch College, City University of New York, 135 East 22nd Street, Box D-901, New York, NY 10010, United States of America

ABSTRACT

This paper examines adaptive device use among two samples of U.S. adults aged 40 years and older with age-related macular degeneration, diabetic retinopathy, glaucoma or cataracts from the 2008 and 2016 waves of the nationally-representative cross-sectional National Health Interview Survey (n = 2875 and n = 6233 respectively). Individuals who replied affirmatively to the question, "do you use any adaptive devices such as telescopic or other prescriptive lenses, magnifiers, large print or talking materials, CCTV, white cane or guide dogs?" were defined as adaptive device users. Descriptive statistics and logistic regression models of adaptive device use were estimated. The main regression models used 2008 data and included explanatory variables for vision-related limitations, other functional limitations, sociodemographic characteristics and the local availability of ophthalmologists and optometrists. 6.1% of the 2008 sample and 4.2% of the 2016 sample used adaptive devices, these percentages were significantly different. 31.4% of the 2008 sample and 24.0% of 2016 sample with multiple vision-related limitations used adaptive devices, these percentages were not significantly different. Based on previous research, adaptive device use among the subgroups with multiple vision-related limitations would be expected to improve functional ability. In the regression models, the likelihood of adaptive device use increased significantly with the number of vision-related limitations, family income and local ophthalmologist availability. The regression results provide evidence of socioeconomic and geographic disparities in adaptive device use in the U.S. Together the descriptive statistics and regression results suggest that public health strategies to increase access to adaptive devices are needed.

1. Introduction

Age-related eye diseases such as age-related macular degeneration (ARMD), diabetic retinopathy, glaucoma and cataracts are leading causes of visual impairment in the United States (Chou et al., 2013; Eye Disease Prevalence Research Group, 2004). Visual impairment is associated with a wide array of adverse outcomes including increased difficulty with daily activities, an increased likelihood of depression and social isolation, and decreased life expectancy (Agency for Healthcare Research and Quality, 2004; National Academies of Sciences, Engineering and Medicine, 2016). Vision rehabilitation is intended to help visually impaired individuals optimize the use of remaining vision. The vision rehabilitation process typically includes the prescription of vision assistive equipment (also known as "adaptive devices" or "low-vision aids") and the provision of other vision rehabilitation services such as training in the use of adaptive devices, orientation and mobility training, psychological counseling and occupational therapy (Agency

for Healthcare Research and Quality, 2004; Binns et al., 2012; Morse et al., 2010; National Academies of Sciences, Engineering and Medicine, 2016; Owsley et al., 2009).

A 2012 systematic review of English-language studies on the effectiveness of vision rehabilitation services concluded that there was good evidence that the receipt of vision rehabilitation services improved outcomes related to clinical and functional ability and that the use of low-vision aids improved reading ability (Binns et al., 2012). A more recent randomized clinical trial that used a sample of U.S. veterans with macular disease who were visually impaired found that the receipt of adaptive devices that were prescribed and dispensed by an optometrist improved functional ability in reading, visual information processing and visual motor skills (Stelmack et al., 2017).

Goals of the Healthy People 2020 initiative of the U.S. Department of Health and Human Services include increasing the receipt of vision rehabilitation services and the use of adaptive devices by individuals with a visual impairment (U.S. Department of Health and Human

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Table 1

Vision-related characteristics of the 2008 and 2016 Samples of U.S. adults with age-related eye diseases, 2008 and 2016 National Health Interview Surveys.

	2008 NHIS sample of adults with an age-related eye disease n = 2875 Weighted percentage (95% CI)	2016 NHIS sample of adults with an age-related eye disease n = 6233 Weighted percentage (95% CI)
Used adaptive devices, %	6.2 (5.1,7.3)	4.2 (3.6, 4.8)
Age-related eye diseases		
ARMD, %	11.9 (10.6, 13.3)	10.6 (9.6, 11.7)
Diabetic retinopathy, %	5.0 (4.1, 6.0)	5.1 (4.3, 5.9)
Glaucoma, %	16.4 (14.7, 18.0)	16.3 (15.1, 17.6)
Cataracts, %	85.3 (83.8, 86.8)	88.7 (87.6, 89.7)
More than one age-related eye disease, %	17.0 (15.3, 18.7)	18.1 (16.9, 19.3)
Lost vision due to an age-related eye disease, %	30.1 (28.1, 32.1)	28.0 (26.5, 29.4)
Even when wearing glasses or contacts it is difficult to		
Read, %	17.5 (15.9, 19.1)	16.6 (15.4, 17.8)
See in dim light, %	11.5 (10.1, 12.9)	11.7 (10.6, 12.8)
Drive, %	4.4 (3.5, 5.3)	3.5 (2.9, 4.1)
See peripherally, %	7.6 (6.5, 8.7)	6.4 (5.6, 7.2)
Combination of vision-related difficulties		
None, %	77.3 (75.7 79.2)	76.4 (75.0, 77.8)
Reading only difficulty, %	8.5 (7.3, 9.8)	8.5 (7.7, 9.4)
Difficulty other than reading only difficulty, %	4.1 (3.4, 5.0)	5.9 (5.2, 6.7)
Multiple difficulties, %	10.1 (8.9, 11.5)	9.2 (8.3, 10.2)
Combination of vision-related difficulties and adaptive device use among those with		
No vision-related limitations, % used adaptive devices	2.3 (1.7, 3.1)	1.5 (1.1, 2.0)
Reading only difficulty, % used adaptive devices	10.0 (6.2, 15.7)	6.9 (4.7, 9.9)
Difficulty other than reading only difficulty, % used adaptive devices	10.4 (5.4, 18.9)	4.9 (2.4, 9.5)
Multiple difficulties, % used adaptive devices	31.4 (24.9, 38.7)	24.0 (20.1, 28.4)
Type of age-related eye disease and adaptive device use among those with		
ARMD, % used adaptive devices	16.9 (12.8, 22.0)	11.9 (9.2, 15.2)
ARMD and multiple limitations, % used adaptive devices	44.8 (32.6, 57.6)	38.0 (28.3, 48.8)
Diabetic retinopathy, % used adaptive devices	17.1 (10.5, 26.7)	9.6 (6.4, 14.1)
Diabetic retinopathy and multiple limitations, % used adaptive devices	48.7 (28.6, 69.2)	23.5 (14.3, 35.9)
Glaucoma, % used adaptive devices	6.1 (4.1, 8.8)	5.9 (4.5, 7.8)
Glaucoma and multiple limitations, % used adaptive devices	33.2 (8.7, 32.2)	21.2 (14.6, 29.8)
Cataracts, % used adaptive devices	6.2 (5.1, 7.5)	4.1 (3.5, 4.8)
Cataracts and multiple limitations, % used adaptive devices	17.5 (26.2, 41.1)	24.0 (19.8, 28.7)

Abbreviations: ARMD, age-related macular degeneration; CI, confidence interval; NHIS, National Health Interview Survey.

Services, 2010). These goals are based on data from the 2008 National Health Interview Survey (NHIS). This paper uses data from the 2008 and 2016 waves of the NHIS to examine the use of adaptive devices among adults aged 40 years and older with age-related eye diseases. Although these waves of the NHIS asked whether vision rehabilitation services were used at the time of the survey, vision rehabilitation is not considered in this paper because < 1% of the 2008 and 2016 samples with an age-related eye disease reported using vision rehabilitation services at the time of the survey (n = 30 and n = 41 respectively) and the sample size is not sufficient for an analysis of the characteristics associated with the receipt of vision rehabilitations services. The discussion of previous research that follows focuses on the use of adaptive devices.

Three previous studies examined the rate of adaptive device use among individuals with ARMD or diabetic retinopathy in the U.S. (Casten et al., 2005; Schmier et al., 2009; Schmier et al., 2006). These studies used samples of individuals who were patients at an ophthalmology clinic or participants in an ARMD support group. Two of the studies did not put a restriction on the age of the individuals in the sample (Schmier et al., 2009; Schmier et al., 2006) and one study limited its sample to individuals aged 65 years and older (Casten et al., 2005). These studies considered a similar set of devices (for example: white canes, magnifying glasses, telescopic glasses, glasses with special filters, hand-held magnifiers, hand-held telescopes and guide dogs) and examined the use of each type of device separately. All three studies found that magnifiers and telescopes were used most frequently (around 45% of the samples without age restrictions and 81% of the older sample used these devices). All three of these studies found that

the use of each type of adaptive device increased as visual acuity decreased. These studies did not consider whether adaptive device use varied with other individual characteristics. In the one prior study outside of the U.S., Becker et al. (2005) found that 87% of a sample of Germans aged 65 years and older who were patients at an ophthalmology clinic and had visual impairment due to ARMD used at least one type of adaptive device.

This paper adds to the previous research by examining the use of adaptive devices among two samples of U.S. adults with ARMD, diabetic retinopathy, glaucoma or cataracts from two waves of a nationally representative survey. It also adds to the prior research by considering whether a large set of individual and contextual characteristics was associated with the use of adaptive devices.

2. Methods

2.1. Sample

The empirical analyses used data on adults aged 40 years and older from the 2008 and 2016 waves of the NHIS. The NHIS is an annual cross-sectional survey and NHIS samples are designed to be nationally representative of the U.S. non-institutionalized civilian population. These waves were chosen for this study because they included supplemental vision health questions for the individual who was the NHIS "sample adult." In this paper, age-related eye diseases were defined to include ARMD, diabetic retinopathy, glaucoma and cataracts. The 2008 NHIS Sample Adult File contains observations on 3059 individuals aged 40 years and older who self-reported having an age-related eye disease;

Table 2
Characteristics of the 2008 Sample of U.S. adults with age-related eye diseases and characteristics of subsamples defined by adaptive device use, 2008 National Health Interview Survey.

	Full sample of adults with an age-related eye disease n = 2875 Weighted percentage or mean (95% CI)	Adults with an age-related eye disease who DID NOT use adaptive devices n = 2700 Weighted percentage or mean (95% CI)	Adults with an age-related eye disease who DID use adaptive devices n = 175 Weighted percentage or mean (95% CI)
Used adaptive devices, %	6.2 (5.1, 7.3)		
Age-related eye diseases			
ARMD, %	12.0 (10.6, 13.3)	10.5 (9.2, 12.1)	33.9 (26.1, 41.5)
Diabetic retinopathy, %	5.0 (4.1, 6.0)	4.4 (3.6, 5.3)	14.8 (8.9, 23.4)
Glaucoma, %	16.4 (14.7, 18.0)	16.4 (14.8, 18.1)	16.7 (11.4, 23.9)
Cataracts, %	85.3 (83.8, 86.8)	85.2 (83.6, 86.7)	86.0 (78.9, 91.0)
Combination of age-related eye diseases			
ARMD only, %	4.6 (3.7, 5.6)	4.6 (3.7, 5.7)	4.5 (2.4, 8.2)
Diabetic retinopathy only, %	2.4 (1.7, 3.2)	2.3 (1.6, 3.2)	4.9 (2.0, 11.7)
Glaucoma only, %	7.1 (6.0, 8.2)	7.4 (6.3, 8.6)	2.9 (1.3, 6.6)
Cataracts only, %	68.9 (66.9, 70.9)	70.7 (68.7, 72.8)	40.9 (32.9, 49.4)
ARMD & cataracts, %	5.4 (4.4, 6.4)	4.2 (3.3, 5.3)	23.1 (16.6, 31.1)
Diabetic retinopathy & cataracts, %	1.8 (1.2, 2.4)	1.5 (1.1, 2.0)	7.3 (3.2, 15.6)
Glaucoma & cataracts, %	7.6 (6.4, 8.8)	7.4 (6.3, 8.7)	10.6 (6.2, 17.5)
Other combination of age-related eye diseases, %	2.2 (1.6, 2.7)	1.9 (1.5, 2.5)	5.8 (3.3, 9.9)
Lost vision due to an age-related eye disease, %	30.1 (28.1, 32.1)	27.3 (25.3, 29.3)	72.9 (64.5, 79.9)
Even when wearing glasses or contacts it is difficult to			
Read, %	17.5 (15.9, 19.1)	14.5 (13.0, 16.1)	63.4 (54.8, 71.3)
See in dim light, %	11.5 (10.1, 12.9)	9.1 (7.9, 10.5)	48.1 (39.5, 56.9)
Drive, %	4.4 (3.5, 5.3)	3.1 (2.4, 4.0)	24.7 (17.9, 33.0)
See peripherally, %	7.6 (6.5, 8.7)	5.6 (4.7, 6.8)	37.3 (29.0, 46.5)
Combination of vision-related difficulties			
None, %	77.3 (75.5, 79.0)	80.5 (78.8, 82.2)	28.4 (21.5, 36.6)
Reading only difficulty, %	8.5 (7.3, 9.8)	8.1 (7.0, 9.5)	13.6 (8.5, 21.1)
Seeing in dim light, driving, or seeing peripherally only difficulty, %	4.1 (3.4, 5.0)	3.9 (3.2, 4.8)	6.9 (3.5, 12.9)
Multiple difficulties, %	10.1 (8.9, 11.5)	7.4 (6.3, 8.7)	51.1 (42.1, 60.1)
Other functional limitations			
Difficulty walking or climbing, %	41.8 (39.7, 44.0)	40.0 (37.9, 42.2)	69.3 (60.6, 76.8)
Difficulty reaching or grasping, %	22.8 (20.7, 24.9)	21.7 (19.6, 23.8)	40.6 (32.1, 49.7)
Hearing difficulties, %	19.2 (17.5, 21.0)	18.7 (17.1, 20.6)	26.7 (19.9, 34.8)
Female, %	62.0 (59.9, 64.1)	61.7 (59.5, 63.9)	66.4 (58.1, 73.7)
Age, mean	70.5 (70.0, 71.1)	70.4 (69.8, 71.0)	72.5 (70.3, 74.8)
Age			
40–64, %	28.9 (26.8, 31.1)	29.1 (26.9, 31.3)	27.3 (19.8, 36.3)
65–84, %	59.1 (56.8, 61.4)	59.1 (57.3, 61.9)	51.4 (42.3, 60.4)
85+, %	12.0 (10.5, 13.4)	11.3 (10.0, 12.8)	21.3 (14.9, 29.6)
Education			
Less than High School, %	21.5 (19.8, 23.2)	21.1 (19.4, 22.9)	27.5 (20.2, 36.1)
High School or GED, %	32.1 (30.1, 34.1)	32.0 (30.0, 34.0)	33.7 (26.0, 42.3)
Some College, %	24.8 (22.9, 26.7)	24.9 (23.0, 27.0)	23.1 (16.7, 31.0)
College, %	21.1 (19.1, 23.0)	21.4 (19.5, 23.5)	15.5 (10.5, 22.2)
Missing, %	0.5 (0.2, 0.9)	0.6 (0.3, 1.0)	0.3 (0.04, 2.1)
Family income-to-poverty ratio			
≤1, %	8.4 (7.3, 9.6)	8.6 (7.5, 9.8)	6.9 (3.5, 13.0)
>1 and ≤2, %	17.2 (15.5, 19.0)	17.3 (15.5, 19.2)	16.6 (11.7, 23.0)
>2, %	57.9 (55.6, 60.2)	57.8 (55.4, 60.2)	58.9 (50.3, 67.0)
Missing, %	16.4 (14.7, 18.1)	16.3 (14.7, 18.1)	17.8 (12.4, 24.5)
Race/ethnicity			
Non-Hispanic White, %	80.8 (79.0, 82.5)	80.7 (78.8, 82.5)	82.3 (75.6, 87.5)
Non-Hispanic Black, %	8.9 (7.7, 10.0)	8.8 (7.7, 10.1)	9.7 (6.3, 14.6)
Hispanic, %	6.3 (5.4, 7.3)	6.5 (5.5, 7.6)	4.3 (2.3, 8.0)
Other, %	4.0 (3.1, 4.9)	4.0 (3.1, 4.9)	3.7 (1.4, 9.2)
Married, %	54.1 (51.9, 56.4)	54.3 (52.0, 56.6)	51.3 (42.7, 59.9)
Family size, mean	1.98 (1.93, 2.03)	1.99 (1.93, 2.04)	1.86 (1.71, 2.01)
Health insurance[a]			
No health insurance, %	3.1 (2.4, 4.0)	3.2 (2.4, 4.1)	2.3 (0.6, 7.9)
Public insurance only, not including Medicare, %	4.1 (3.3, 5.0)	4.2 (3.3, 5.2)	2.7 (1.2, 5.6)
Medicare only, %	19.8 (17.9, 21.8)	19.9 (17.9, 21.9)	18.7 (13.1, 26.0)
Medicare and other public ins., %	11.5 (10.2, 13.0)	11.3 (9.9, 12.7)	15.6 (10.2, 23.1)
Medicare and private ins., %	42.3 (40.1, 44.5)	42.0 (39.8, 44.2)	46.8 (37.8, 55.6)
Private insurance only, %	19.3 (17.4, 21.2)	19.1 (17.7, 21.6)	19.6 (17.7, 21.6)
Has a usual place for health care, %	97.3 (96.7, 98.0)	97.4 (96.6, 98.0)	97.4 (92.3, 99.2)
Ophthalmologists per 100,000 county residents[b], mean	5.6 (5.3, 6.0)	5.6 (5.3, 6.0)	6.1 (5.2, 7.0)
Optometrists per 100,000 county residents, mean	14.1 (13.6, 14.6)	14.2 (13.7, 14.7)	13.2 (12.1, 14.4)
Tract population density, mean	4007 (3627, 4387)	4045 (3639, 4452)	3425 (2479, 4371)

Table 2 (*continued*)

	Full sample of adults with an age-related eye disease n = 2875 Weighted percentage or mean (95% CI)	Adults with an age-related eye disease who DID NOT use adaptive devices n = 2700 Weighted percentage or mean (95% CI)	Adults with an age-related eye disease who DID use adaptive devices n = 175 Weighted percentage or mean (95% CI)
Tract median HH income, mean	54,233 (52,839, 55,627)	54,307 (52,866, 55,750)	53,112 (48,684, 57,539)
Region			
Northeast, %	18.6 (16.4, 20.7)	18.7 (16.6, 20.9)	17.5 (11.1, 26.6)
Midwest, %	24.9 (22.3, 27.6)	24.8 (22.3, 27.6)	25.9 (18.1, 35.6)
South, %	37.5 (34.8, 40.2)	37.3 (34.7, 40.0)	40.6 (31.8, 50.1)
West, %	19.0 (17.1, 20.9)	19.2 (17.3, 21.2)	16.0 (11.0, 22.6)

Notes

Abbreviations: ARMD, age-related macular degeneration; CI, confidence interval; ins., insurance; HH, household; NHIS, National Health Interview Survey.

Stata "svy" commands with the "subpop" option were used to estimate descriptive statistics that accounted for the complex design features of the NHIS and for the focus on the subsample of adults with an age-related eye disease. Taylor series linearization was used for variance estimation.

[a] The U.S. Medicare program provides health insurance to individuals aged 65 years and older and nonelderly people with a permanent disability. The U.S. Medicaid program provides health insurance to low-income individuals. Most individuals in the "public insurance only, not including Medicare" and "other public insurance" categories were participants in the Medicaid program.

[b] There are 50 states and 3141 counties in the U.S. The number of counties within U.S. states ranges from 3 (Delaware) to 243 (Texas).

individuals who self-reported that they were blind (n = 41) or who were missing information on key variables (n = 143) were excluded from the analyses, resulting in a 2008 sample of 2875 individuals. The 2016 NHIS Sample Adult File contains observations on 6439 individuals aged 40 years and older who self-reported having an age-related eye disease; individuals who were blind (n = 87) or missing information on key variables (n = 119) were excluded from the analyses, resulting in a 2016 sample of 6233 individuals. Individuals who were blind were excluded in order to focus on adaptive device use among individuals with or at high risk of low vision.

2.2. Outcome

2.2.1. Adaptive device use

Respondents were asked if they had trouble seeing even with glasses or contacts; those who replied affirmatively were asked, "Do you use any adaptive devices such as telescopic or other prescriptive lenses, magnifiers, large print or talking materials, CCTV, white cane or guide dogs?" Individuals who replied "yes" to the adaptive device question were defined as using adaptive devices and individuals who reported that they did not have trouble seeing even with glasses or contacts or who replied that they were not using adaptive devices were defined as not using adaptive devices.

2.3. Explanatory variables

2.3.1. Vision-related limitations

Respondents were asked if they experienced a set of vision-related limitations "even while wearing glasses or contacts." Two approaches were taken to characterizing an individual's vision-related limitations. The first approach used indicator variables for "difficulty reading" (difficulty reading or doing close work), "difficulty in dim light" (difficulty going down steps or curbs at night or in dim light), "difficulty driving" (difficulty driving during daytime in familiar places) and "difficulty peripherally" (difficulty noticing objects off to the side while walking). The second approach used indicator variables to characterize the combination of visual limitations experienced by an individual (reading only difficulty (yes/no), visual limitation other than reading only difficulty (yes/no), multiple types of visual limitations (yes/no), no visual limitations was the excluded category).

2.3.2. Other explanatory variables

Indicator variables were created to measure other functional limitations experienced by an individual. These variables were "difficulty walking or climbing" (difficulty walking 1/4 mile or climbing 10 steps),

"difficulty grasping or reaching" (difficulty grasping small objects or reaching overhead) and "hearing impairment" (hearing aid use or moderate or more severe difficulty hearing).

Demographic and socioeconomic explanatory variables were an individual's age (40–64 years, 65–84 years, 85 years and above), gender, educational attainment (less than high school, high school or Graduate Equivalency Degree, some college, college or more, missing education), total family income in the previous calendar year divided by the poverty threshold appropriate to the family's size (< 1, ≥ 1 and < 2, ≥ 2, missing) ("family income-to-poverty ratio"), race/ethnicity (white non-Hispanic, black non-Hispanic, Hispanic, other race/ethnicity), marital status (married, unmarried) and family size.

Explanatory variables measuring ability to access health care were an individual's health insurance status (see Tables 2 and 3 for insurance categories) and whether the individual reported having a place they usually go for routine or preventive care (yes/no). For 2008 NHIS respondents, restricted-access information on the county and census tract of residence of respondents in 2008 was used to add variables characterizing an individual's area of residence. Geocode information for 2016 NHIS respondents was not available at the time of this study. The contextual variables included the density of ophthalmologists per capita and the density of optometrists per capita in the respondent's county of residence. The county-level number of "patient care" ophthalmologists in 2008 and the number of optometrists in 2009 was drawn from the U.S. Department of Health and Human Services Area Health Resources File (AHRF). Optometrist data from 2008 were not available in the AHRF. Additional contextual variables were the region in which an individual resided (Northeast, Midwest, South, West) and the population density and median household income in an individual's census tract of residence. The 2006–2010 American Community Survey 5-Year Estimates was the source of county population and tract-level variables.

2.4. Statistical analysis

Stata version 15 was used to conduct the empirical analyses. Stata "svy" commands with the "subpop" option were used to estimate descriptive statistics and logistic regression models that accounted for the complex design features of the NHIS and for the focus on the subsample of adults with an age-related eye disease (Korn and Graubard, 1999). Associations were considered significant if the p-value was 0.05 or lower.

Weighted descriptive statistics were estimated separately for the 2008 and 2016 samples and for subsamples defined by adaptive device use. Differences in proportions between the 2008 and 2016 samples were tested using Z-tests for the equality of two proportions from

Table 3

Multiple logistic regression models of adaptive device use among U.S. adults with age-related eye diseases, 2008 National Health Interview Survey, n = 2875.

	Model (1)		Model (2)	
	Odds ratio (95% CI)	Predictive margin (95% CI)	Odds ratio (95% CI)	Predictive margin (95% CI)
Even when wearing glasses or contacts it is difficult to				
Read				
Yes	4.82 (2.92, 7.97)	13.5 (9.6, 17.3)	–	–
No	1.00 (ref)	3.4 (2.4, 4.4)	–	–
See in dim light			–	–
Yes	2.13 (1.22, 3.73)	9.3 (6.3, 12.3)	–	–
No	1.00 (ref)	5.0 (3.7, 6.7)	–	–
Drive			–	–
Yes	1.69 (0.91, 3.17)	8.7 (5.0, 12.4)	–	–
No	1.00 (ref)	5.8 (4.7, 6.9)	–	–
See peripherally			–	–
Yes	1.88 (0.92, 3.85)	9.0 (4.7, 13.3)	–	–
No	1.00 (ref)	5.4 (4.3, 6.6)	–	–
Combination of vision-related difficulties				
None	–	–	1.00 (ref)	2.4 (1.6, 3.1)
Reading only difficulty	–	–	4.33 (2.26, 8.31)	9.4 (4.8, 13.9)
Seeing in dim light, driving, or seeing peripherally only difficulty	–	–	4.06 (1.88, 8.76)	8.8 (3.5, 14.2)
Multiple difficulties	–	–	17.97 (10.90, 29.69)	28.7 (22.0, 35.4)
Difficult to walk or climb				
Yes	1.54 (0.97, 2.42)	7.1 (5.6, 8.6)	1.58 (1.00, 2.51)	7.2 (5.7, 8.6)
No	1.00 (ref)	5.0 (3.6, 6.5)	1.00 (ref)	4.9 (3.5, 6.4)
Difficult to reach or grasp				
Yes	1.22 (0.77, 1.95)	6.9 (4.9, 8.8)	1.14 (0.72, 1.81)	6.6 (4.7, 8.6)
No	1.00 (ref)	5.9 (4.7, 7.0)	1.00 (ref)	6.0 (4.8, 7.1)
Hearing difficulties				
Yes	1.29 (0.83, 2.00)	7.2 (5.2, 9.2)	1.19 (0.77, 1.86)	6.9 (4.9, 8.8)
No	1.00 (ref)	5.9 (4.8, 7.0)	1.00 (ref)	6.0 (4.4, 7.8)
Gender				
Female	1.04 (0.66, 1.63)	6.3 (5.0, 7.5)	1.02 (0.66, 1.59)	6.2 (5.0, 7.4)
Male	1.00 (ref)	6.1 (4.4, 7.8)	1.00 (ref)	6.2 (4.5, 7.8)
Age				
40–64	1.00 (ref)	7.2 (3.8, 10.5)	1.00 (ref)	7.1 (3.9, 10.3)
65–84	0.74 (0.35, 1.57)	5.7 (4.4, 7.0)	0.74 (0.36, 1.49)	5.6 (4.4, 6.8)
85+	0.91 (0.37, 2.27)	6.7 (4.0, 9.4)	1.01 (0.42, 2.46)	7.2 (4.3, 10.0)
Education				
Less than High School	1.34 (0.70, 2.58)	6.5 (4.5, 8.4)	1.40 (0.75, 2.63)	6.7 (4.6, 8.7)
High School or GED	1.36 (0.74, 2.44)	6.5 (4.8, 8.3)	1.38 (0.79, 2.41)	6.6 (4.8, 8.3)
Some College	1.33 (0.72, 2.45)	6.4 (4.5, 8.3)	1.29 (0.72, 2.31)	6.2 (4.3, 8.1)
College	1.00 (ref)	5.1 (3.2, 7.1)	1.00 (ref)	5.1 (3.3, 6.9)
Missing	0.73 (0.11, 4.71)	4.0 (−1.9, 9.9)	0.75 (0.10, 5.56)	4.0 (−2.5, 10.6)
Family income-to-poverty ratio				
≤1	0.39 (0.16, 0.94)	3.4 (1.1, 5.6)	0.38 (0.16, 0.93)	3.3 (1.0, 5.6)
>1 and ≤42	0.70 (0.41, 1.19)	5.5 (3.6, 7.4)	0.67 (0.40, 1.12)	5.2 (3.5, 7.0)
>2	1.00 (ref)	7.1 (5.7, 8.6)	1.00 (ref)	7.2 (5.7, 8.7)
Missing	0.81 (0.48, 1.37)	6.1 (4.0, 8.2)	0.86 (0.51, 1.44)	6.4 (4.3, 8.5)
Race/ethnicity				
Non-Hispanic White	1.00 (ref)	6.2 (5.1, 7.3)	1.00 (ref)	6.3 (5.2, 7.3)
Non-Hispanic Black	1.30 (0.71, 2.41)	7.6 (4.4, 10.8)	1.22 (0.66, 2.27)	7.3 (4.1, 10.5)
Hispanic	0.58 (0.25, 1.35)	4.0 (1.4, 6.6)	0.54 (0.23, 1.23)	3.8 (1.3, 6.3)
Other	1.24 (0.35, 4.47)	7.3 (0.4, 14.2)	1.13 (0.31, 4.10)	6.9 (0.1, 13.6)
Married				
Yes	1.36 (0.80, 2.32)	7.0 (5.2, 8.7)	1.28 (0.78, 2.13)	6.8 (5.1, 8.5)
No	1.00 (ref)	5.5 (4.1, 6.9)	1.00 (ref)	5.6 (4.3, 7.0)
Family size	0.77 (0.56, 1.05)	NA	0.80 (0.60, 1.08)	NA
Health insurance				
No health insurance	1.00 (ref)	5.0 (−0.2, 10.1)	1.00 (ref)	5.1 (−0.2, 10.4)
Public insurance only, not including Medicare	0.52 (0.11, 2.67)	2.9 (0.01, 5.7)	0.57 (0.12, 2.73)	3.2 (0.3, 6.1)
Medicare only	1.38 (0.39, 6.41)	6.3 (3.8, 8.9)	1.34 (0.30, 6.07)	6.4 (3.9, 8.9)
Medicare and other public ins.	1.65 (0.39, 7.05)	7.3 (4.3, 10.3)	1.69 (0.41, 7.04)	7.7 (4.6, 10.7)
Medicare and private ins.	1.48 (0.35, 6.22)	6.7 (4.9, 8.5)	1.38 (0.34, 5.64)	6.5 (4.8, 8.3)
Private insurance only	1.07 (0.28, 4.06)	5.2 (2.4, 8.0)	1.03 (0.27, 3.88)	5.2 (2.5, 7.8)
Has a usual place for health care				
Yes	0.52 (0.14, 1.96)	6.1 (5.2, 7.1)	0.57 (0.14, 2.38)	6.2 (5.2, 7.1)
No	1.00 (ref)	9.9 (0.7, 19.2)	1.00 (ref)	9.3 (−0.2, 18.8)
Ophthalmologists per 100,000 county residents	1.06 (1.001, 1.12)	NA	1.06 (1.001, 1.11)	NA
Optometrists per 100,000 county residents	0.97 (0.94, 1.004)	NA	0.97 (0.95, 1.00)	NA
Tract population density	0.99 (0.99, 1.00)	NA	0.99 (0.99, 1.00)	NA
Tract median HH income	1.00 (0.99, 1.00)	NA	1.00 (0.99, 1.00)	NA
Region				
Northeast	1.00 (ref)	6.6 (4.3, 9.0)	1.00 (ref)	6.7 (4.2, 9.1)
Midwest	0.97 (0.52, 1.88)	6.6 (4.3, 8.8)	0.93 (0.48, 1.78)	6.3 (4.1, 8.5)
South	0.91 (0.50, 1.68)	6.2 (4.6, 7.8)	0.94 (0.51, 1.71)	6.4 (4.7, 8.0)

Table 3 (*continued*)

	Model (1)		Model (2)	
	Odds ratio (95% CI)	Predictive margin (95% CI)	Odds ratio (95% CI)	Predictive margin (95% CI)
West	0.76 (0.40, 1.42)	5.4 (3.5, 7.2)	0.76 (0.41, 1.41)	5.4 (3.7, 7.1)

Notes

Abbreviations: ARMD, age-related macular degeneration; CI, confidence interval; HH, household; NA, not applicable, NHIS, National Health Interview Survey.

Stata "svy" commands with the "subpop" option were used to estimate logistic regression models that accounted for the complex design features of the NHIS and for the focus on the subsample of adults with an age-related eye disease. Taylor series linearization was used for variance estimation.

The predictive margin for a category of an explanatory variable is the average over the sample of the predicted probability of device use for each individual calculated as if the individual was in that category and the remainder of the explanatory variables were equal to the individual's actual values. Predictive margins are useful for gauging the magnitude of an association between an explanatory variable and a binary outcome variable because the difference in predictive margins between categories of an explanatory variable shows how much the predicted probability of the outcome changes as the explanatory variable changes. Predictive margins are presented on a scale from 0 to 100%.

independent samples. Differences in proportions between subsamples from the same survey year were tested using Pearson design-based F-tests.

The main logistic regressions models were estimated using 2008 data because it included contextual variables. Model (1) included indicator variables for each type of vision-related limitation and model (2) included the indicator variables for the combination of visual limitations experienced by an individual. Both models also included the variables for other functional limitations, sociodemographic characteristics, access to health care and contextual characteristics. Morse et al. (2010) excluded individuals with cataracts from their estimates of the prevalence of visual impairment and the need for vision assistive equipment in the U.S. Medicare population on the grounds that vision loss from cataracts is potentially reversible through surgery. In sensitivity analyses, models (1) and (2) were estimated excluding individuals who had cataracts but no other age-related eye diseases. The full set of models, excluding contextual variables, was also estimated using the 2016 sample. Odds ratios (ORs), predictive margins (PMs), and 95% confidence intervals (CIs) were calculated. The footnotes to Table 3 provide information about the calculation and interpretation of PMs. For each set of indicator variables (i.e., combinations of vision-related limitations), adjusted Wald tests were used to determine whether the ORs and PMs for the variables in the set were significantly different from each other.

3. Results

3.1. Descriptive statistics

Table 1 presents weighted vision-related descriptive statistics for the 2008 and 2016 samples. 6.2% of the 2008 sample and 4.2% of the 2016 sample used adaptive devices; these percentages were significantly different. Cataracts was the most common age-related eye disease in the 2008 and 2016 samples (85.3% and 88.7% of the respective samples). 17.0% of the 2008 sample and 18.1% of the 2016 sample had more than one age-related eye disease. The proportion of each sample with cataracts differed significantly between samples, but the proportions with other age-related eye diseases did not. Difficulty reading was the most common vision-related limitation in the 2008 and 2016 samples (17.5% and 16.6% of the respective samples). 10.1% of the 2008 sample and 9.2% of the 2016 sample had multiple vision-related limitations and 31.4% of the 2008 sample and 24.0% of the 2016 sample with multiple vision-related limitations used adaptive devices; these percentages did not differ significantly between samples. Among those with multiple vision-related limitations, the proportions of the 2008 and the 2016 samples that used adaptive devices differed significantly for those with diabetic retinopathy but not for those with ARMD, glaucoma or cataracts.

Table 2 presents weighted descriptive statistics for the full set of explanatory variables for the 2008 sample and for subsamples defined

by adaptive device use. The 2008 sample is highlighted because it is the primary focus of the regression analyses. Those who reported using adaptive devices were significantly more likely to have ARMD or diabetic retinopathy and were significantly more likely to have more than one age-related eye disease than those who did not. Additionally, those who used adaptive devices were significantly more likely to have a vision-related limitation or other functional limitation and were significantly more likely to have more than one vision-related limitation than those who did not use adaptive devices.

3.2. Regression analyses

Table 3 presents the results of the logistic regression models using the 2008 sample. In model (1), difficulty reading and difficulty seeing in dim light were each associated with a significantly higher likelihood of adaptive device use relative to not having these difficulties. The likelihood of adaptive device use differed significantly between the lowest and highest income categories. Additionally, greater county-level per capita availability of ophthalmologists was associated with a significantly higher likelihood of device use. The other explanatory variables in model (1) were not significantly associated with adaptive device use.

In model (2), having multiple vision-related limitations was associated with a significantly higher likelihood of adaptive device use relative to having one or no limitations and having one limitation was associated with a significantly higher likelihood of device use relative to having no limitations. As in model (1), income and local ophthalmologist availability were significant predictors of adaptive device use in model (2). The results of models (1) and (2) estimated with a subsample that excluded individuals with cataracts and no other age-related eye diseases were similar to those for the full age-related eye disease sample (results not shown).

In models (1) and (2) estimated using the 2016 sample, the likelihood of adaptive device use increased significantly with the number of vision-related limitations but not with family income (results not shown). When the models were estimated with a subsample that excluded individuals with cataracts but no other age-related eye diseases, the likelihood of adaptive device use increased substantially with income and significantly so when the sample was further limited to those with multiple vision-related limitations (results not shown).

4. Discussion

The rate of adaptive device use in the 2008 and 2016 samples and the subsamples of those with ARMD or diabetic retinopathy was substantially lower than that found in previous research (Becker et al., 2005; Casten et al., 2005; Schmier et al., 2009; Schmier et al., 2006). However, the prior research used samples of individuals with ARMD or diabetic retinopathy who were patients at an ophthalmology clinic or participated in an ARMD support group, and it is likely that individuals

in these samples had more severe visual impairment than the individuals in the NHIS samples. This hypothesis is supported by the finding that the rate of adaptive device use among individuals with ARMD or diabetic retinopathy and multiple vision-related limitations in the NHIS samples was similar to the previous studies that did not put a restriction on the age of the individuals in the sample (Schmier et al., 2009; Schmier et al., 2006). The difference in adaptive device use between the 2008 and 2016 samples, while statistically significant, is small in percentage point terms. The difference is driven primarily by the significantly higher prevalence of cataracts and the lower rate of adaptive device use among individuals with cataracts in the 2016 compared to the 2008 sample.

Two important public health questions are: How many visually impaired individuals in the U.S. could benefit from the use of adaptive devices? and How much of this need is unmet? It is difficult to answer these questions because the effects of a given vision condition on functional ability can vary across individuals and the effects of vision rehabilitation services and adaptive devices use can also vary across individuals (Agency for Healthcare Research and Quality, 2004; Binns et al., 2012; Morse et al., 2010; National Academies of Sciences, Engineering and Medicine, 2016). However, there is established evidence that use of adaptive devices by visually impaired individuals can improve functional reading ability and more recent evidence that use of adaptive devices can improve visual information processing and visual motor skills among individuals with macular disease (Binns et al., 2012; Stelmack et al., 2017). Therefore, the low rate of adaptive device use in both NHIS samples among those with an age-related eye disease who reported difficulty reading and other vision-related limitations adds support to the argument that public health strategies are needed to increase access to adaptive devices in the U.S. (National Academies of Sciences, Engineering and Medicine, 2016). More research is needed to determine whether adaptive device use could improve a wider range of functional abilities for a wider set of visually impaired individuals (Binns et al., 2012; National Academies of Sciences, Engineering and Medicine, 2016). Low vision rehabilitation is the primary means by which visually impaired individuals are prescribed appropriate adaptive devices and trained in their use. However, very few individuals in the NHIS samples reported receiving vision rehabilitation services at the time of the surveys. This suggests that improving access to low vision rehabilitation services is likely to increase access to adaptive devices and improve visual ability. The development and evaluation of public health strategies to achieve these goals are still in the early stages and best practices have yet to be established (National Academies of Sciences, Engineering and Medicine, 2016).

It should be a concern for public health if, among persons with identical vision-related limitations and other functional limitations, the use of adaptive devices differed with other individual or contextual characteristics. Using data from 2008, this paper found consistent disparities by family income and the local availability of ophthalmologists in adaptive device use among U.S. adults with age-related eye diseases. The models using 2016 data suggest a similar pattern with respect to family income among those with multiple vision-related limitations. However, the 2016 results should be interpreted with caution because the 2016 models did not include contextual variables.

The likelihood of adaptive device use was twice as high for the highest income category as it was for the lowest income category in the 2008 regression models. Medicare does not cover adaptive devices that contain lenses (Morse et al., 2010). Medicaid coverage of adaptive devices varies by state and is limited in those states that do have coverage (Kaiser Commission on Medicaid and the Uninsured, 2012; National Academies of Sciences, Engineering and Medicine, 2016). Private health insurance often has coverage restrictions as well (Institute of Medicine Committee on Disability in America, 2007; National Academies of Sciences, Engineering and Medicine, 2016). A potential explanation for the findings with respect to income is that lower-income individuals were more likely to forgo adaptive devices because of the difficulty of affording the out-of-pocket cost of these devices. Additionally, given that eye care providers are the primary source of referrals for vision rehabilitation services and that lower-income individuals tend to have more limited contact with eye care providers than higher-income individuals, differences in visits to eye care providers by income is another possible explanation for differences in adaptive device use by income (Owsley et al., 2009; Zhang et al., 2013; Zhang et al., 2012). There is a positive correlation between local eye care provider availability and household income in the U.S. (Gibson, 2015). However, given that the 2008 regression models include explanatory variables for local eye care provider availability, the findings suggest that lower income individuals are less likely to visit a given set of providers than higher income individuals.

Living in a county with fewer ophthalmologists per capita was associated with a significantly lower likelihood of adaptive device use in the 2008 regression models. Owsley et al. (2009) surveyed entities that provided vision rehabilitation services and found that almost half of vision rehabilitation clients were referred for services by ophthalmologists and that referrals from other sources were substantially less common. Gibson (2016) found that greater local ophthalmologist availability was associated with a significantly increased likelihood of having had a recent dilated eye exam among a sample of individuals with ARMD, glaucoma, or cataracts and that the likelihood of having lost vision due to an age-related eye disease declined as local ophthalmologist availability increased. The combination of these findings and those of the current paper suggest that individuals with an age-related eye disease who lived in a county with greater ophthalmologist availability had more contact with ophthalmologists and as a result were more likely to be referred for and receive vision rehabilitation services and adaptive devices than individuals who lived in an area with lower ophthalmologist availability.

A limitation of the paper that has not already been mentioned is that information is not available from the NHIS surveys about the types of adaptive devices that individuals used, whether the devices used were the ones best suited to an individual's limitations, whether individuals had been prescribed devices but abandoned them, the extent to which individuals received training in and benefitted from the devices they were using, and the distance to and capacity of local eye care and vision rehabilitation service providers. An additional limitation is that adaptive device use and other individual characteristics were self-reported. Despite these limitations, the paper has a number of strengths. One is that it used two large samples of individuals with age-related eye diseases drawn from two separate waves of a nationally-representative survey. Another is that the empirical analyses included detailed measures of an individual's vision-related limitations and other individual characteristics and, for the 2008 sample, an extensive set of contextual variables.

The rate of adaptive device use among U.S. adults with age-related eye diseases was very low in the 2008 and 2016 samples, even among individuals with vision-related limitations for which adaptive devices have been found to improve functional ability. Furthermore, there were differences in the use of adaptive devices by income and the local availability of ophthalmologists, which provides additional evidence of disparities in vision-related outcomes in the U.S. (National Academies of Sciences, Engineering and Medicine, 2016; Zhang et al., 2013; Zhang et al., 2012). These findings support the need for public health strategies to increase access to adaptive devices in the U.S.

Acknowledgments

References

Agency for Healthcare Research and Quality, 2004. Vision Rehabilitation for Elderly Individuals With Low Vision or Blindness (Rockville, MD). .

Becker, S., Wahl, H., Schilling, O., Burmedi, D., 2005. Assistive device use in visually impaired older adults: role of control beliefs. Gerontologist 45 (6), 739–746.

Binns, A., Bunce, C., Dickinson, C., et al., 2012. How effective is low vision service provision? A systematic review. Surv. Ophthalmol. 57 (1), 34–65.

Casten, R., Maloney, E., Rovner, B., 2005. Knowledge and use of low vision services among persons with age-related macular degeneration. J. Vis. Impair. Blind 99 (11), 720–724.

Chou, C., Cotch, M., Vitale, S., et al., 2013. Age-related eye diseases and visual impairment among U.S. adults. Am. J. Prev. Med. 45 (1), 29–35.

Eye Diseases Prevalence Research Group, 2004. Causes and prevalence of visual impairment among adults in the United States. Arch. Ophthalmol. 122, 477–485.

Gibson, D., 2015. The geographic distribution of eye care providers in the United States: implications for a National Strategy to Improve Vision Health. Prev. Med. 73, 30–36.

Gibson, D., 2016. The local availability of eye care providers and the vision health of adults in the United States. Ophthalmic Epidemiol. 23 (4), 223–231.

Institute of Medicine Committee on Disability in America, 2007. The Future of Disability in America. The National Academies Press, Washington, DC.

Kaiser Commission on Medicaid and the Uninsured, 2012. Medicaid Benefits: Optometrist Services. Kaiser Family Foundation.

Korn, E.L., Graubard, B.I., 1999. Analysis of Health Surveys. Wiley, New York, NY.

Morse, A., Massof, R., Cole, R., et al., 2010. Medicare coverage for vision assistive equipment. Arch. Ophthalmol. 128 (10), 1350–1357.

National Academies of Sciences, Engineering, and Medicine, 2016. Making Eye Health a Population Health Imperative: Vision for Tomorrow. The National Academies Press, Washington, DC. https://doi.org/10.17226/23471.

Owsley, C., McGwin, G., Lee, P., et al., 2009. Characteristics of low-vision rehabilitation services in the United States. Arch. Ophthalmol. 127 (5), 681–689.

Schmier, J., Halpern, M., Covert, D., et al., 2006. Impact of visual impairment on service and device use by individuals with age-related macular degeneration. Disabil. Rehabil. 28 (21), 1331–1338.

Schmier, J., Covert, D., Matthews, P., et al., 2009. Impact of visual impairment on service and device use by individuals with diabetic retinopathy. Disabil. Rehabil. 31 (8), 659–665.

Stelmack, J., Tang, C., Wei, Y., et al., 2017. Outcomes of the veterans affairs low vision intervention trial II (LOVIT II): a randomized clinical trial. JAMA Ophthalmol. 135 (2), 96–104.

U.S. Department of Health and Human Services, 2010. Healthy People 2020: Healthy People in Healthy Communities. Office of Disease Prevention and Health Promotion, Publication B0132.

Zhang, X., Cotch, M., Ryskulova, A., et al., 2012. Vision health disparities in the United States by race/ethnicity, education, and economic status: findings from two nationally representative surveys. Am J. Ophthalmol. 154 (60), S53–S62, e51.

Zhang, X., Beckles, G., Chou, C., et al., 2013. Socioeconomic disparity in use of eye care services among U.S. adults with age-related eye diseases: National Health Interview Survey, 2002 and 2008. JAMA Ophthalmol. 131 (9), 1198–1206.