Age-Related Eye Diseases and Visual Impairment Among U.S. Adults

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Abstract

Background—Visual impairment is a common health-related disability in the U.S. The association between clinical measurements of age-related eye diseases and visual impairment in data from a national survey has not been reported.

Purpose—To examine common eye conditions and other correlates associated with visual impairment in the U.S.

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Methods—Data from the 2005–2008 National Health and Nutrition Examination Survey of 5222 Americans aged   40 years were analyzed in 2012 for visual impairment (presenting distance visual acuity worse than 20/40 in the better-seeing eye), and visual impairment not due to refractive error (distance visual acuity worse than 20/40 after refraction). Diabetic retinopathy (DR) and age-related macular degeneration (AMD) were assessed from retinal fundus images; glaucoma was assessed from two successive frequency-doubling tests and a cup-to-disc ratio measurement.

Results—Prevalence of visual impairment and of visual impairment not due to refractive error was 7.5% (95% CI=6.9%, 8.1%) and 2.0% (1.7%, 2.3%), respectively. The prevalence of visual impairment not due to refractive error was significantly higher among people with AMD (2.2%) compared to those without AMD (0.8%), or with DR (3.5%) compared to those without DR (1.2%). Independent predictive factors of visual impairment not due to refractive error were AMD (OR=4.52, 95% CI=2.50, 8.17); increasing age (OR=1.09 per year, 95% CI=1.06, 1.13); and less than a high school education (OR=2.99, 95% CI=1.18, 7.55).

Conclusions—Visual impairment is a public health problem in the U.S. Visual impairment in two thirds of adults could be eliminated with refractive correction. Screening of the older population may identify adults at increased risk of visual impairment due to eye diseases.

Introduction

Visual impairment, *a reduction in the clarity with which a person can see objects*, is a major public health problem. Visual impairment is associated with diminished quality of life because people with visual impairment often report difficulty performing everyday activities such as reading, meal preparation, and driving a car.[1–4] Moreover, visual impairment is associated with an increased risk of falls, fall-related injuries, depression, social isolation, and poorer overall health. Vision problems create a substantial burden on individuals and society. The estimated total annual cost of visual impairment and blindness among individuals aged   40 years in the U.S. is $5.5 billion.[7–9]

Extrapolating from data pooled from a collection of previously completed population-based studies, the Eye Diseases Prevalence Research Group estimated approximately 3.4 million U.S. adults aged   40 years had visual impairment. This figure was projected to reach 5.5 million by 2020.[10] An analysis of visual acuity data collected from the National Health and Nutrition Examination Survey (NHANES) in 1999–2002 reported uncorrected refractive error as the primary cause of visual impairment defined as *visual acuity of worse than 20/40 in the eye with the better vision*.[11]

Given the aging population, increased prevalence of chronic diseases such as diabetes, and the percentage of the population using electronic devices such as computers and smartphones, it is possible that the prevalence of visual impairment may have changed since the earlier reports.[12–15] Further, it has been estimated that at least half of all cases of legal blindness could be prevented by early detection and timely treatment of associated conditions.[16] From 2005 to 2008, the NHANES collected visual acuity data, supplementing earlier data collection with fundus photography to assess retinal diseases and frequency-doubling technology (FDT) to evaluate visual field loss. The present study evaluates, for the

first time in a national survey, the common eye conditions and other correlates associated with visual impairment, using the most recent data available from NHANES.

Methods

Data and Study Population

Data were obtained from the 2005–2008 NHANES, a complex, multistage probability survey of a sample of the U.S. civilian, non-institutionalized population, conducted by the National Center for Health Statistics (NCHS) of the CDC. A detailed description of the design and data collection of the NHANES survey has been published elsewhere.[17]

Participants selected for the survey were interviewed in their homes, where self-reported demographic, socioeconomic, and some health-related data were collected. Participants were then offered a physical examination, to be conducted in a specially designed and equipped Mobile Examination Center (MEC). The MEC examination included visual acuity testing and autorefraction for participants aged 12 years and FDT and retinal photography for participants aged 40 years, as described elsewhere.[10,18,19]

The response rate for participants aged 40 years was 69.0% for the NHANES sample invited to the MEC in 2005–2008.[20] Of the 7081 participants aged 40 years who participated in NHANES, 6797 reported to the MEC for a health examination. All NHANES physical exam participants were eligible for the vision examination except those who were blind (had no light perception); had an eye infection; or wore eye patches on both eyes (*n*=6). Among the participants who had the exam, complete visual acuity data were obtained for 6364 (93.6%); of these, 5408 (85.0%) received both the retinal imaging and FDT exam components. Complete gradable photographs for either their right or left eye were available from 5222 survey participants (Figure 1).

Visual Acuity Measures

Presenting visual acuity with the participant wearing usual distance vision correction (i.e., eyeglasses or contact lenses), if any, was measured in a dimmed room using an ARK-760 automated refractometer. After presenting visual acuity was measured, the participant removed any vision correction, and the autorefractor was used to measure the objective refraction (sphere, cylinder, and axis) for each eye. In eyes with presenting visual acuity of worse than 20/40, visual acuity was further assessed as aided with autorefraction results. Visual impairment was defined as presenting distance visual acuity in the better-seeing eye of worse than 20/40. Visual impairment not due to refractive error was defined as visual acuity of worse than 20/40 while aided with autorefraction.[11]

Ocular Condition Measures

An FDT examination and a retinal imaging examination were performed to assess visual field loss and retinal lesions and optic disc characteristics, respectively. FDT was performed twice on each eye using the Humphrey Matrix Visual Field Instrument and the N-30-5 FDT screening protocol, a 19-point supra-threshold screening test.[19] Retinal images were taken

using the Canon CR6-45NM Ophthalmic Digital Imaging System and the Canon EOS 10D digital camera.

The procedures for image capture and their assessment have been described in detail elsewhere.[21,22] In brief, two 45° nonmydriatic digital retinal images were taken per eye, one centered on the optic nerve (Field 1), and one centered on the fovea (Field 2). These were then graded in a masked fashion using a modification of the Wisconsin Age-Related Maculopathy Grading System for age-related macular degeneration (AMD) and Airlie House Classification scheme for diabetic retinopathy (DR).[22]

Participants were considered to have AMD based on the presence of lesions defining early AMD (e.g., large retinal soft drusen or any drusen with retinal pigmentary abnormalities) or late AMD (e.g., exudative AMD or geographic atrophy).[23] An eye was defined as having DR if the participant had both (1) diabetes (defined by self-report of a previous diagnosis made by a physician [excluding gestational diabetes]) or hemoglobin A1c of 6.5% or greater and (2) one or more retinal microaneurysms or retinal blot hemorrhages with or without more-severe retinal lesions.[16] Visual field loss was defined for each eye using the 2-2-1 algorithm: having at least two abnormal field results ($p < 1\%$ for two or more of the 19 tested locations) in each of the two frequency-doubling exams, with one common abnormal field.[19] Glaucoma was defined as visual field loss combined with a cup-to-disc ratio of 0.7.[24] A person was determined to have glaucoma if at least one eye had glaucoma.

Demographics and Health Conditions Measures

For the descriptive analysis, age was classified into five categories: 40–49 years, 50–59 years, 60–69 years, 70–79 years, and 80 years. Age in years was utilized as a continuous variable to compute age-adjusted rates and for the multivariate logistic regression analyses. Race/ethnicity was categorized as non-Hispanic white; non-Hispanic black; Mexican American; or Other. The latter group included other Hispanics, multiracial people, and other races/ethnicities not included in the preceding categories. Mexican American and other Hispanic ethnicities were separated in accordance with the recommendations of the survey sponsor, the NCHS, given changes in sampling methodology in 2007.[25]

Educational attainment was classified into three categories: less than a high school education, high school diploma, or more than a high school education.[26] Insurance coverage was defined as insured (including health insurance obtained through employment or through government programs, such as Medicare and Medicaid) or uninsured. Smoking status was classified as never smoker, past smoker, and current smoker. BMI was derived from height and weight measurements collected during the NHANES physical examination. A BMI of <25.0 was classified as normal, 25.0–29.9 as overweight, and 30.0 as obese.[27] Hypertension was defined by either systolic blood pressure of 140 mmHg, diastolic blood pressure of 90 mmHg, or taking antihypertensive medication. History of cardiovascular disease was defined by a self-report of having had a heart attack, congestive heart failure, or stroke.

Data Analysis

Statistical analyses were conducted using SAS version 9.2 and SUDAAN version 10.1 software to calculate national estimates of visual impairment and their SEs, while accounting for the complex survey sampling methods. The prevalences of visual impairment and visual impairment not due to refractive error were estimated by age. Using the 2000 Census population, the age-standardized prevalence of visual impairment, and of visual impairment not due to refractive error, was estimated by AMD, glaucoma, DR, gender, race/ethnicity, educational attainment, insurance coverage, BMI, smoking status, hypertension, and cardiovascular disease. Chi-square tests were used to identify associations between each of these factors and visual impairment.

Multivariate logistic regression models were used to evaluate the relationship of visual impairment not due to refractive error with AMD, DR, and glaucoma, while adjusting for age (Model 1). Then a second logistic model (Model 2) was run by adding possible confounders such as demographic variables (gender, race/ethnicity, education, and insurance coverage) and health-related conditions (BMI, smoking status, hypertension, and cardiovascular disease).[10,16,21,28] ORs and their 95% CIs were calculated. In the logistic models, terms for age and age^2 were included to account for possible nonlinearity. The squared term (age^2) was dropped because it was not significant. Associations were considered significant if p<0.05. All analyses were conducted in 2012.

Results

The overall age-standardized prevalence of visual impairment was 7.5% (95% CI=6.9%, 8.1%) and visual impairment not due to refractive error was 2.0% (95% CI=1.7%, 2.3%) (Appendix A, available online at www.ajpmonline.org). The prevalence of visual impairment was associated with increasing age, with the highest rates found in people aged 80 years (26.3%, 95% CI=23.4%, 29.4%; Figure 2). After standardizing for age, the results showed a higher prevalence of visual impairment among people with DR (14.5%, 95% CI=10.4%, 19.8%) than those without DR (6.3%, 95% CI=5.6%, 7.0%). Almost three quarters of participants with visual impairment had refractive error as the cause of their inability to see with a visual acuity of 20/40 or better.

The remainder had visual impairment due to other nonrefractive conditions. The age-standardized prevalence of visual impairment not due to refractive error was almost thrice as high in those with AMD (2.2%, 95% CI=1.5%, 3.2%) compared with those without AMD (0.8%, 95% CI=0.6%, 1.1%). In addition, the prevalence of visual impairment not due to refractive error was also higher in people with DR than in those without DR (Appendix A, available online at www.ajpmonline.org). The presence of AMD, glaucoma, or DR or combination of these eye diseases was identified in a half of all participants whose visual impairment was not attributed to refractive error (Appendix B, available online at www.ajpmonline.org).

After adjusting for age, participants with AMD had greater odds of having visual impairment not due to refractive error than those without AMD (OR=4.03, 95% CI=2.23, 7.29; Table 1). Individuals with glaucoma or DR also had elevated odds of having visual

impairment not due to refractive error compared with those without the respective condition, although the risk of visual impairment associated with either glaucoma or DR was not significant (OR=3.18, 95% CI=0.88, 11.47, and OR=4.25, 95% CI=0.98, 14.43, respectively). In Model 2, after accounting for age, gender, race/ethnicity, and education, insurance coverage, BMI, smoking status, history of cardiovascular disease, and hypertension, the odds of having visual impairment among individuals with AMD increased to almost a fivefold higher risk, whereas the odds associated with glaucoma or DR were reduced.

Discussion

This study examined the age-related eye diseases and other correlates of visual impairment among U.S. adults aged 40 years participating in a national survey. It also determined how much visual impairment could be attributed to refractive error and how much to at least one of three major eye diseases that the study protocol allowed the current study to detect. Further, it found that nearly one in 13 adults (9.0 million) had visual impairment, of which an estimated 6.8 million cases were simply the result of not having refractive correction in the form of eyeglasses, contact lenses, or refractive surgery. The remaining 2.2 million people had visual impairment due to the nonrefractive causes such as AMD, glaucoma, or DR, which this study could detect, or other likely causes such as cataract, ocular injury, or eye diseases that, because of the study protocol used in NHANES, the current study was not able to detect. Hence, the present study's findings confirm earlier reports documenting uncorrected refractive error as the major cause of visual impairment in the U.S.[11,29]

In this study, the estimate of the prevalence of visual impairment among U. S. individuals aged 40 years in 2005–2008 is higher than the estimate for adults of comparable age reported from the earlier NHANES survey conducted in 1999–2002.[11] The reasons for the increase are unclear, although underutilization of eye care services is one likely explanation for the increase in prevalence of visual impairment. A study has shown that the main reasons for not seeking eye care were cost concerns, lack of health insurance, and the perception of not having a need for it.[30]

The present study, consistent with other studies, found visual impairment to be more prevalent in non-Hispanic blacks, Mexican Americans, those with less than a high school education, and those without health insurance.[31–35] The majority of the increase in visual impairment can be attributed to an increase in the rate of uncorrected refractive error. This estimate in this study that 2.2 million adults in the U.S. have visual impairment due to an eye disease is only two thirds of the estimate obtained from the meta-analysis performed in 2004 and is also less than the prevalence estimated from the 1999–2002 NHANES. Although it is possible that early detection of eye disease and improvements in therapeutic intervention of eye disease may explain, in part, the reduction in estimates of visual impairment attributable to eye disease over time, the authors cannot speculate about the extent to which this may be the case.

Of the three eye diseases NHANES measured, AMD had the largest impact on visual impairment among those with visual impairment not due to uncorrected refractive error.

AMD has been reported to be the primary cause of visual impairment in older U.S., European, and Australian populations.[29,36] However, nearly half of all people with visual impairment that is not due to refractive error in this sample had eye diseases that the NHANES protocol was not designed to detect because logistic limitations in time and scope precluded a complete dilated-eye examination. Specifically, neither lens opacity nor corneal disease was assessed. It is plausible that a sizable proportion of those with visual impairment that is not due to refractive error may have had cataracts.

Consistent with previous studies, the current study found that individuals with AMD were more likely to have visual impairment that is not due to refractive error than those without AMD.[10,37] Not surprisingly, age remained strongly related both to visual impairment and to visual impairment not due to refractive error.[32,38,39] Low education attainment also was associated with visual impairment regardless of underlying condition. Thus, the results from the current study corroborate previous studies reporting that individuals with visual impairment, regardless of age, were likely to be less educated.[40–42] Taken together, these studies suggest that targeted screening of the older population may help to identify those at increased risk of visual impairment so that refractive correction can be provided to those who would benefit and others with underlying eye conditions can be medically managed to prevent further loss of vision.

Limitations

This study has several limitations in addition to those stated above. NHANES, by design, does not include people who are institutionalized and as a result, the prevalence of visual impairment likely was underestimated. Because individuals without light perception were excluded from visual acuity testing, the current study was unable to generate estimates of blindness, and the estimates of visual impairment are artificially low. However, because cases of total blindness are relatively rare, the effects on statistical estimates are minimal. In addition, definition of glaucoma used was visual field loss combined with a cup-to-disc ratio 0.7; this does not allow for as precise a diagnosis of glaucoma as would be possible from a thorough clinical exam.[19] Finally, visual impairment can be produced by visual field constriction as well as visual acuity decrement. Because NHANES did not include data on visual field constriction, the current study could not account for this aspect. Thus, the prevalence of visual impairment might be underestimated.

Conclusion

Extrapolating from NHANES data to the entire U.S population, the present study estimates that nearly 9 million people aged 40 years are visually impaired. Of the ocular conditions assessed in NHANES, the condition most likely to result in visual impairment is uncorrected refractive error. Three of every four people could have their visual impairment alleviated solely with refractive correction, leaving only one in four people with visual impairment due to eye disease. The ocular disease most associated with visual impairment in the NHANES sample was AMD. Increasing age and low educational attainment were predictors of visual impairment. Screening of the elderly may identify adults at increased risk of visual impairment due to eye diseases. Increasing public awareness of vision health and the availability and affordability of eye healthcare services could help to reduce avoidable visual

impairment and better address the needs of those with underlying eye disease who might benefit from timely therapeutic intervention.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.
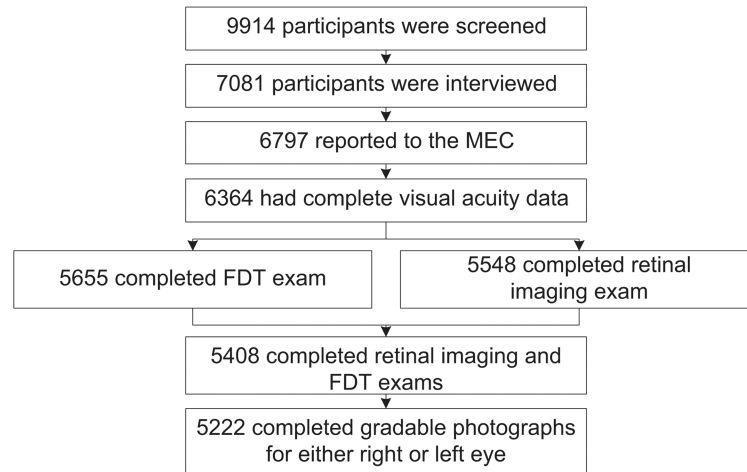
Acknowledgments

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┌─────────────────────────────────────┐
│   9914 participants were screened    │
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┌─────────────────────────────────────┐
│  7081 participants were interviewed  │
└─────────────────────────────────────┘
                   ↓
┌─────────────────────────────────────┐
│       6797 reported to the MEC       │
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│  6364 had complete visual acuity data │
└─────────────────────────────────────┘
          ↓                  ↓
┌──────────────────┐  ┌──────────────────┐
│ 5655 completed   │  │ 5548 completed   │
│   FDT exam       │  │ retinal imaging  │
│                  │  │      exam        │
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│  5408 completed retinal imaging and  │
│             FDT exams                │
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┌─────────────────────────────────────┐
│ 5222 completed gradable photographs  │
│      for either right or left eye    │
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Figure 1.
Flow diagram of participants aged 40 years in National Health and Nutrition Examination Survey, 2005–2008, included in analysis

FDT, frequency-doubling technology; MEC, Mobile Examination Center
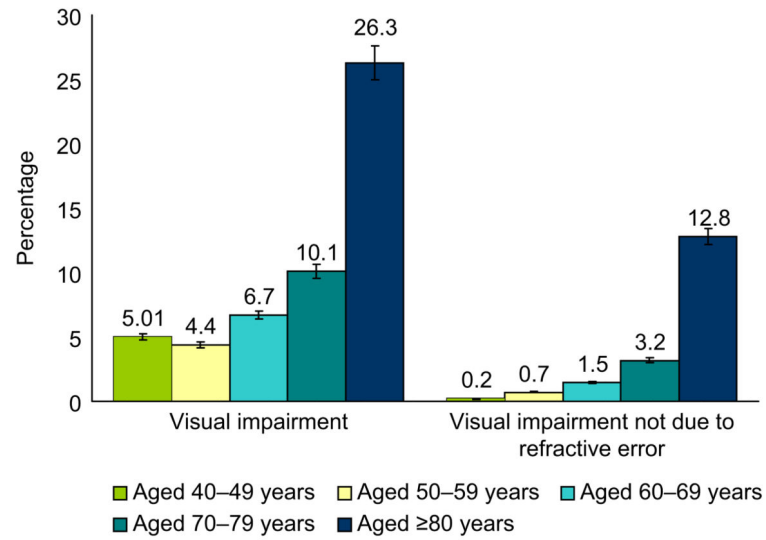
Figure 2.
Prevalence of presenting visual impairment, and visual impairment that is not due to refractive error, by age group among those aged 40 years
Note: $p < 0.001$ for association of increasing age with visual impairment and with visual impairment that is not due to refractive error. Error bars indicate 95% CI. Data source: National Health and Nutrition Examination Survey, 2005–2008

Table 1

Odds of visual impairment not due to refractive error among those aged   40 years, OR (95% CI)

	Model 1	Model 2
Age-related macular degeneration		
No	1	1
Yes	4.03 (2.23, 7.29)	4.52 (2.50, 8.17)
Glaucoma		
No	1	1
Yes	3.18 (0.88, 11.47)	2.46 (0.70, 8.67)
Diabetic retinopathy		
No	1	1
Yes	4.25 (0.98, 14.43)	2.55 (0.68, 9.51)
Age, per 1-year increase at ages >40 years	1.09 (1.06, 1.12)	1.09 (1.06, 1.13)
Gender		
Female		1
Male		1.60 (0.90, 2.86)
Race/ethnicity		
Non-Hispanic white		1
Non-Hispanic black		2.10 (0.83, 5.34)
Mexican-American		1.30 (0.40, 4.44)
Other		0.63 (0.18, 2.18)
Education		
>High school		1
High school		1.70 (0.57, 5.11)
<High school		2.99 (1.18, 7.55)
Insurance coverage[a]		
Uninsured		0.49 (0.16, 1.58)
Insured		1
BMI[b]		
Normal		1
Overweight		0.71 (0.34, 1.48)
Obese		1.27 (0.57, 2.82)
Smoking status		
Never smoker		1
Past smoker		0.71 (0.34, 1.48)
Current smoker		1.02 (0.35, 3.01)
Cardiovascular disease[c]		
No		1

	Model 1	Model 2
Yes		1.48 (0.63, 3.46)
Hypertension[d]		
No		1
Yes		1.73 (0.74, 4.09)

Note: Data source: National Health and Nutrition and Examination Survey (NHANES), 2005–2008. Visual impairment not due to refractive error is defined as visual impairment after autorefractive correction.

[a]Insurance coverage included health insurance obtained through employment or provided through government programs such as Medicare and Medicaid.

[b]BMI was classified as <25.0 for normal, 25.0–29.9 for overweight, and 30.0 for obese.

[c]Cardiovascular disease was defined as having self-reported heart attack, heart failure, or stroke.

[d]Hypertension was defined as having systolic blood pressure 140, diastolic blood pressure 90, or being on hypertension medication.