Causes and Prevalence of Visual Impairment Among Adults in the United States

*The Eye Diseases Prevalence Research Group**

Objectives: To estimate the cause-specific prevalence and distribution of blindness and low vision in the United States by age, race/ethnicity, and gender, and to estimate the change in these prevalence figures over the next 20 years.

Methods: Summary prevalence estimates of blindness (both according to the US definition of ≤6/60 [≤20/200] best-corrected visual acuity in the better-seeing eye and the World Health Organization standard of <6/120 [<20/400]) and low vision (<6/12 [<20/40] best-corrected vision in the better-seeing eye) were prepared separately for black, Hispanic, and white persons in 5-year age intervals starting at 40 years. The estimated prevalences were based on recent population-based studies in the United States, Australia, and Europe. These estimates were applied to 2000 US Census data, and to projected US population figures for 2020, to estimate the number of Americans with visual impairment. Cause-specific prevalences of blindness and low vision were also estimated for the different racial/ethnic groups.

Results: Based on demographics from the 2000 US Census, an estimated 937 000 (0.78%) Americans older than 40 years were blind (US definition). An additional 2.4 million Americans (1.98%) had low vision. The leading cause of blindness among white persons was age-related macular degeneration (54.4% of the cases), while among black persons, cataract and glaucoma accounted for more than 60% of blindness. Cataract was the leading cause of low vision, responsible for approximately 50% of bilateral vision worse than 6/12 (20/40) among white, black, and Hispanic persons. The number of blind persons in the US is projected to increase by 70% to 1.6 million by 2020, with a similar rise projected for low vision.

Conclusions: Blindness or low vision affects approximately 1 in 28 Americans older than 40 years. The specific causes of visual impairment, and especially blindness, vary greatly by race/ethnicity. The prevalence of visual disabilities will increase markedly during the next 20 years, owing largely to the aging of the US population.

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BLINDNESS AND LOW VISION ARE widely recognized as important causes of impairment among Americans.[1-3] Because of the cost and logistical difficulty of carrying out an appropriate sampling scheme, few population-based studies of national scope have been carried out in the United States to estimate the prevalence of visual impairment. While The National Health and Nutrition Examination Survey (NHANES) has collected national data on vision disabilities,[4] the lack of photographic documentation of ocular conditions limits the ability to assess causal associations. In addition, these data were collected more than 30 years ago. The Visual Acuity Impairment Survey carried out by the National Eye Institute in the 1980s suffered similar limitations because of the absence of photographic documentation and the large proportion of persons who could not be examined.[5] Population-based studies of ocular disease that have been carried out in the United States[6-9] are potentially limited in their generalizability by local variations in the populations studied, accessibility of eye care, and patterns of surgical practice.

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Recognizing the need for national estimates of visual impairment, Prevent Blindness America (Schaumburg, Ill) and the National Eye Institute (Bethesda, Md) invited the principal investigators of several population-based vision studies to a meeting in Fort Lauderdale, Fla, in May 2001, to standardize disease definitions and methods of data reporting so that available data from many of these studies might be analyzed together. Age- and race/ethnicity-specific prevalences of blindness and low vision were calculated based on studies of best-corrected visual acuity from the United States; Western Europe; Barbados, West In-

Table 1. Studies Included in Estimates of Blindness and Low Vision Prevalence*

	BES	Barbados†‡	BDES‡	BMES	Proyecto VER	RS	SEE Project	Melbourne VIP‡§
Years study conducted	1985-1988	1988-1992	1988-1990	1992-1994	1999-2000	1990-1993	1993-1995	1991-1998
No. of participants‖	5308	4303	4866	3625	4766	6391	2519	4729
Age group, y								
40-49	22.1	29.1	16.9	NA	33.4	NA	NA	26.6
50-54	11.9	12.0	13.8	12.8	16.3	NA	NA	14.4
55-59	12.9	12.6	12.9	14.7	12.3	17.6	NA	13.7
60-64	14.3	11.9	13.9	17.6	10.9	21.0	NA	13.4
65-69	14.5	11.3	14.2	18.5	9.8	19.4	31.0	11.6
70-74	11.2	10.8	12.0	14.8	8.2	16.7	33.1	9.5
75-79	7.2	7.4	9.2	11.6	5.1	12.5	22.0	5.6
≥80	5.8	4.9	7.1	10.0	4.1	12.8	13.9	5.1
Gender								
Female	60.3	57.4	56.0	56.7	61.2	58.2	57.8	53.3
Male	39.7	42.6	44.0	43.3	39.8	41.8	42.2	46.7
Race/ethnicity								
Black	45.1	100.0	NA	NA	NA	NA	26.4	NA
Hispanic	NA	NA	NA	NA	100.0	NA	NA	NA
White	54.9	NA	100.0	100.0	NA	100.0	73.6	100.0
Crude prevalence								
Blindness (WHO standard)¶	0.47	1.65	0.35	0.39	0.23	0.39	0.28	0.19
Blindness (US definition)¶	0.81	3.02	0.47	0.66	0.29	0.61	0.83	0.34
Low vision¶	0.98	NA	2.34	2.92	1.93	3.15	3.37	0.97

Abbreviations: Barbados, Barbados Eye Study, Barbados, West Indies; BDES, Beaver Dam Eye Study, Beaver Dam, Wis; BES, Baltimore Eye Survey, Baltimore, Md; BMES, Blue Mountains Eye Study, Sydney, New South Wales, Australia; Melbourne VIP, Vision Impairment Project, Melbourne, Victoria, Australia; NA, not applicable; Proyecto VER, Vision Evaluation Research, Nogales and Tucson, Ariz; RS, Rotterdam Study, Rotterdam, the Netherlands; SEE Project, Salisbury Eye Evaluation Project, Salisbury, Md; WHO, World Health Organization.

*Data are given as percentage of subjects unless otherwise indicated.

†Only data for cause-specific blindness were used; data for the prevalence of visual disability were not used in our estimates.

‡Did not attempt to attribute specific causes for low vision; note that RS did provide data on the prevalence of low vision due to age-related macular degeneration.

§Did not attempt to attribute specific causes for blindness; did provide data on prevalence of blindness due to age-related macular degeneration.

‖Note that the number of participants reported for each study in this table reflects the number contributing to our estimates in the current article and not necessarily to the total number of participants in the original study as published.

¶Blindness as defined by the WHO standard is the best-corrected visual acuity of less than 6/120 (<20/400) in the better-seeing eye; blindness as defined by the US definition is the best-corrected visual acuity of 6/60 or worse (≤20/200) in the better-seeing eye; low vision is defined as the best-corrected visual acuity less than 6/12 (<20/40) in the better-seeing eye (excluding those who were categorized as being blind by the US definition).

dies; and Australia. These estimates were then applied to the population structure of the United States as reported in the 2000 census,[10] to estimate the number of visually impaired persons nationally. Projections of prevalence and number of visually impaired persons in 2020 were also made based on census projections for the US population in that year. These results represent the most robust and up-to-date estimates available of the burden of visual impairment facing the United States.

METHODS

INCLUSION OF STUDIES

A decision was made in principle to include all population-based studies of blindness and low vision conducted in North America, Western Europe, and Australia and published in English after 1990 and up to the start of the current project (May 2001) (**Table 1** and **Figure 1**). The cutoff year of 1990 was chosen both owing to the scarcity of scientifically valid studies prior to this time and to minimize potential inaccuracies caused by secular trends in treatment and surgical practice over time. While studies from Western Europe and Australia were included in estimates for European-derived persons, potentially relevant studies from Africa[11] and Barbados[12] were excluded from prevalence estimates for African-derived persons because of concerns over the potential effect of rates of medical and surgical treatment being significantly different from those in the United States. Data from Barbados were evaluated; but since the prevalence was substantially higher than in studies of black persons in the United States, these data were excluded from the estimation of prevalence; however, they were used in the estimation of causes of blindness among black persons.

STANDARDIZATION AMONG STUDIES

Principal investigators from studies listed in Table 1 were asked to furnish data tables listing the prevalence of blindness and low vision in the better-seeing eye by 5-year age interval, gender, and (where relevant) race/ethnicity. Data were requested for both the World Health Organization (WHO) (<6/120 [<20/400]) and US (≤6/60 [≤20/200]) definitions of blindness, while low vision was defined as worse than 6/12 (<20/40) in the better-seeing eye, excluding those who were categorized as being blind by US definition. All measurements related to best-corrected visual acuity. Where not otherwise specified, all estimates for blindness are reported using the US definition, 6/60 (20/200) or worse in the better-seeing eye.

Investigators were asked to attribute a cause to the blindness and low vision for all persons with bilateral blindness or low vision. However, no specific causes of low vision were at-

tributed by either the Beaver Dam Eye Study, Beaver Dam, Wis, or the Melbourne Visual Impairment Project, Melbourne, Victoria, Australia. If it was felt that more than one disease entity was responsible for visual impairment in a subject, then a subjective decision was made in assigning the primary cause. This was possible for all subjects, with the exception of 2 participants in the Blue Mountains Eye Study, Sydney, New South Wales, Australia, both of whom received the diagnoses of cataract and glaucoma.

AGE-SPECIFIC PREVALENCE ESTIMATES

The age-specific prevalence proportions for blindness and low vision were derived by pooling the race/ethnicity- and age-specific prevalences from all contributing studies using minimum variance linear estimation. Stratum-specific proportions from each study were transformed using a logarithm odds transformation and proportion variances were calculated assuming a binomial distribution. The low numbers of cases in some 5-year age and gender intervals were insufficient to provide robust, pooled, gender-specific estimates, so these estimates were collapsed over gender. To determine the effects of age, sex, and race/ethnicity on the prevalence of disease and to produce a smoothed function over the age intervals for estimating the prevalence of the disease, logistic regression models were fit to the pooled prevalence proportions using the midpoint of each age interval as the independent variable. Models were fit separately for black, white, and Hispanic persons. For purposes of calculating the overall US prevalence, the estimates for other racial/ethnic groups were modeled using the average of the pooled age-specific estimates for these 3 groups.

ESTIMATES OF THE PREVALENCE OF VISUAL IMPAIRMENT IN THE UNITED STATES

The number of visually impaired persons in the United States in each race/ethnicity and age category was generated by applying the modeled prevalence for each year of age to the 2000 US census population and summing across the age range for each 5-year age category. Projected estimates were derived applying the modeled prevalence for each year of age by race/ethnicity to the 2000 US census middle-series projections for 2020. Constant age- and race/ethnicity-specific prevalences were assumed over this period for both blindness and low vision. Stratum-specific US prevalences were computed by dividing the total number of estimated cases for each stratum by the stratum-specific US population.

STATISTICAL TESTS

Age and race/ethnicity effects were tested using the model Wald χ^2 test statistics. Odds ratios for race/ethnicity were derived from logistic regression coefficients for the appropriate racial comparisons. Tests for gender differences were based on the observed age-, race/ethnicity-, and gender-specific prevalence from each study. Separate Mantel-Haenszel χ^2 tests for 2×2 tables of observed rates were carried out by race/ethnicity, controlling for both age and study effects.

RESULTS

In 2000, there were an estimated 937000 blind Americans who were older than 40 years (US definition), a prevalence of 0.78% (95% confidence interval [CI], 0.63%-0.94%). The number of persons with low vision was estimated to be an additional 2.4 million (1.98%; 95% CI, 1.74%-2.21%), for a total of 3.3 million Americans aged 40 years and older with visual impairment (**Table 2**).

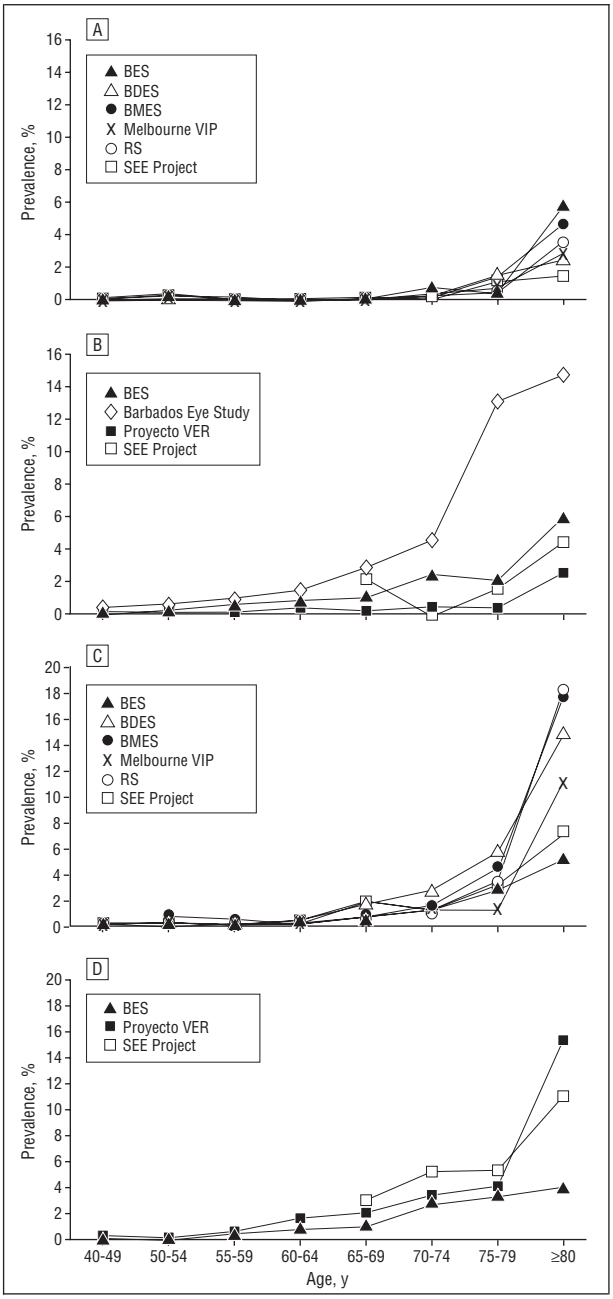

Figure 1. A, Prevalence of blindness (best-corrected visual acuity ≤6/60 [≤20/200] in the better-seeing eye) by age among white persons in 6 population-based studies. B, Prevalence of blindness (best-corrected visual acuity ≤6/60 [≤20/200] in the better-seeing eye) by age among black (Baltimore Eye Survey [BES], Baltimore, Md; Barbados Eye Study, Barbados, West Indies; and Salisbury Eye Evaluation [SEE] Project, Salisbury, Md) and Hispanic persons (Proyecto VER [Vision Evaluation Research], Nogales and Tucson, Ariz) in 4 population-based studies. C, Prevalence of low vision (best-corrected visual acuity <6/12 [<20/40] in the better-seeing eye) by age among white persons in 6 population-based studies. D, Prevalence of low vision (best-corrected visual acuity <6/12 in the better-seeing eye) by age among black (BES and SEE Project) and Hispanic persons (Proyecto VER) in 3 population-based studies. BMES indicates Blue Mountains Eye Study, Sydney, New South Wales, Australia; BDES, Beaver Dam Eye Study, Beaver Dam, Wis; VIP, Visual Impairment Project, Melbourne, Victoria, Australia; and RS, Rotterdam Study, Rotterdam, the Netherlands.

The leading cause of blindness among white Americans in 2000 was age-related macular degeneration (AMD),

Table 2. Estimated Prevalence of Blindness and Low Vision in the United States, by Age and Race/Ethnicity*

Variable	No. of Persons (in Thousands)			Total US Population	
	White	Black	Hispanic	No. of Persons (in Thousands) (95% CI)	Prevalence per 100 Individuals (95% CI)
Blindness by WHO Standard†‡					
Age, y					
40-49	35	6	2	45 (36-55)	0.11 (0.08-0.13)
50-54	10	4	1	17 (14-19)	0.10 (0.08-0.11)
55-59	8	4	1	15 (13-17)	0.11 (0.10-0.13)
60-64	8	5	1	16 (14-18)	0.15 (0.13-0.17)
65-69	11	6	2	20 (18-23)	0.21 (0.18-0.24)
70-74	19	7	2	30 (26-34)	0.34 (0.29-0.38)
75-79	35	7	2	46 (41-52)	0.63 (0.55-0.70)
≥80	409	16	5	435 (360-511)	4.74 (3.92-5.56)
Subtotal	**535**	**55**	**16**	624 (548-701)	0.52 (0.46-0.59)
Blindness by US Definition§					
Age, y					
40-49	37	9	2	51 (36-66)	0.12 (0.08-0.15)
50-54	13	6	1	23 (19-27)	0.13 (0.11-0.15)
55-59	12	7	2	22 (19-26)	0.16 (0.14-0.19)
60-64	13	8	2	25 (22-29)	0.24 (0.20-0.27)
65-69	18	11	2	34 (29-39)	0.36 (0.30-0.41)
70-74	31	14	3	52 (44-60)	0.59 (0.50-0.68)
75-79	59	16	3	82 (69-95)	1.10 (0.93-1.27)
≥80	591	42	7	648 (464-832)	7.05 (5.05-9.06)
Subtotal	**774**	**113**	**22**	937 (751-1122)	0.78 (0.63-0.94)
Low Vision‖					
Age, y					
40-49	62	2	11	80 (64-96)	0.19 (0.15-0.23)
50-54	35	3	7	48 (42-53)	0.27 (0.24-0.30)
55-59	37	5	8	54 (48-59)	0.40 (0.36-0.44)
60-64	46	9	10	70 (62-77)	0.65 (0.58-0.71)
65-69	71	15	13	106 (95-117)	1.11 (0.99-1.23)
70-74	128	23	18	179 (161-197)	2.02 (1.81-2.22)
75-79	229	29	21	292 (261-323)	3.93 (3.51-4.35)
≥80	1370	68	58	1532 (1259-1805)	16.68 (13.70-19.65)
Subtotal	**1978**	**154**	**146**	2361 (2083-2636)	1.98 (1.74-2.21)
All Vision Impaired					
Age, y					
40-49	99	11	13	131 (108-153)	0.31 (0.25-0.36)
50-54	48	9	8	71 (64-77)	0.40 (0.36-0.44)
55-59	49	12	10	76 (69-83)	0.56 (0.51-0.61)
60-64	59	17	12	95 (87-104)	0.88 (0.80-0.96)
65-69	89	26	15	140 (128-152)	1.47 (1.34-1.60)
70-74	159	37	21	231 (211-250)	2.60 (2.38-2.83)
75-79	288	45	24	374 (340-407)	5.03 (4.58-5.49)
≥80	1961	110	65	2180 (1850-2509)	23.73 (20.14-27.32)
Total	**2752**	**267**	**168**	3298 (2963-3629)	2.76 (2.48-3.04)

Abbreviations: CI, confidence interval; WHO, World Health Organization.

*All estimates are based on the 2000 US Census population.

†Estimates for the prevalence of vision impairment in the total US population include estimates for other races/ethnicities (ie, Asian, Native American, Alaska Native, Native Hawaiian and other Pacific Islander, and any other race/ethnicity) and those designating more than 1 race/ethnicity on the 2000 US Census form. These estimates were derived from models using an unweighted average of the pooled age- and gender-specific rates for white, black, and Hispanic participants. The age- and gender-specific estimates for the prevalence of vision impairment derived in this way are available at: http://www.nei.nih.gov/eyedata/.

‡Blindness as defined by the WHO standard is the best-corrected visual acuity of less than 6/120 (<20/400) in the better-seeing eye.

§Blindness as defined by the US definition is the best-corrected visual acuity of 6/60 or worse (≤20/200) in the better-seeing eye.

‖Low vision is defined as the best-corrected visual acuity less than 6/12 (<20/40) in the better-seeing eye (excluding those who were categorized as being blind by the US definition).

accounting for 54% of all blindness, as opposed to 9% for cataract, the next most common cause (**Figure 2**). Age-related macular degeneration was also the leading cause of blindness in all 6 population-based studies of European-derived populations on which the current article is based. The leading causes of blindness among black persons were more evenly distributed than among white persons, with cataract and open-angle glaucoma (OAG) accounting for slightly over 60% of the cases. Among Hispanic persons, OAG was the most common cause of blindness (28.6% of the cases), although this is based on a total of only 4 persons bilaterally blind from glaucoma.

Cataract was the most frequently reported condition in persons with low vision, associated with approxi-

mately 50% of low vision cases among black, white, and Hispanic persons. This was more than twice the proportion of any other condition (**Figure 3**).

Both low vision and blindness increased significantly with age for all races/ethnicities ($P<.001$ for all races/ethnicities for both blindness and low vision) (**Table 3**). Although limited data did not permit us to make robust estimates in the age range beyond 85 years, a highly significant quadratic term in our models, together with a rapid apparent increase in estimated blindness prevalence above the age of 85 years, suggests that blindness prevalence rises rapidly among the oldest segment of the population.

Age-specific blindness prevalence was higher for black persons compared with white persons (odds ratio [OR] = 2.77; 95% CI, 1.56-4.92) or Hispanic persons (OR = 3.13; 95% CI, 2.29-4.29), while the prevalence of low vision among Hispanic persons was higher than that for white persons OR = 1.39; 95% CI, 1.24-1.56) and black persons (OR = 1.90; 95% CI, 1.28-2.83) (Table 3).

Men had a significantly higher age-adjusted prevalence of blindness than women among black persons ($P=.002$), but not among white ($P=.20$) or Hispanic persons ($P=.64$). The age-adjusted prevalence of low vision was significantly higher for women among white persons ($P=.01$) but did not differ significantly by gender among black ($P=.96$) or Hispanic persons ($P=.11$). (**Table 4**).

It was estimated that the number of blind persons older than 40 years in the United States would increase by approximately 70% to 1.6 million (prevalence of 1.1%) by 2020. The number of persons with low vision was projected to be 3.9 million (2.5%), for a total of 5.5 million visually impaired Americans (3.6%).

Estimates of the prevalence of visual impairment among Australians older than 40 years in 2000 were as follows: low vision 143 000 (1.8%), blindness (US definition of ≤6/60 [≤20/200] best-corrected visual acuity in the better-seeing eye) 55 000 (0.7%), and blindness (WHO standard of <6/120 [<20/400] best-corrected visual acuity in the better-seeing eye) 35 000 (0.4%). The corresponding figures for Western Europe were low vision, 3.64 million (2.0%); blindness (US definition); 1.38 million (0.7%); and blindness (WHO standard), 879 000 (0.5%). These estimates were derived by applying the age-specific modeled prevalence rates for white persons to the populations of Australia and Western Europe in each 5-year age interval.

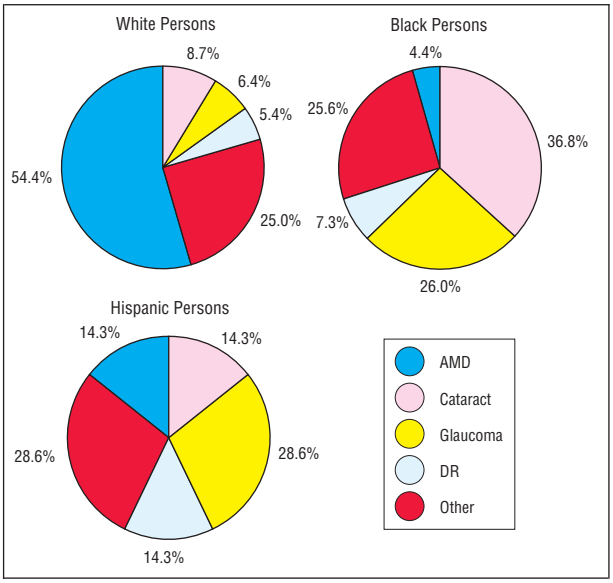

Figure 2. Causes of blindness (best-corrected visual acuity <6/60 [<20/200] in the better-seeing eye) by race/ethnicity. AMD indicates age-related macular degeneration; DR, diabetic retinopathy.

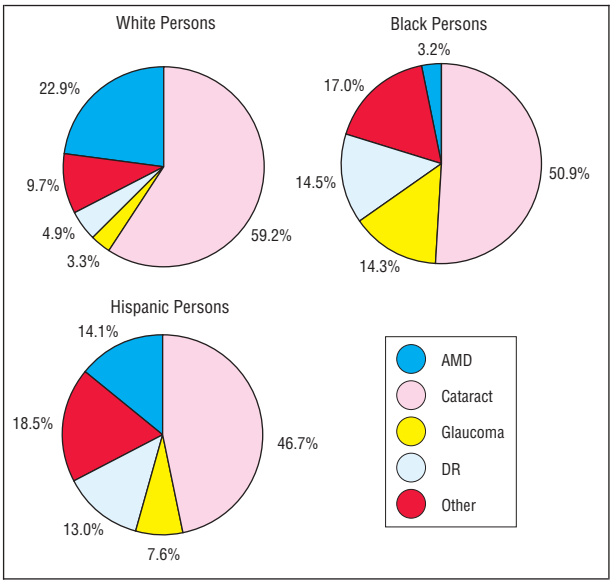

Figure 3. Causes of low vision (best-corrected visual acuity <6/12 [<20/40] in the better-seeing eye, excluding those who were categorized as being blind by the US definition) by race/ethnicity. AMD indicates age-related macular degeneration; DR, diabetic retinopathy.

COMMENT

Visual impairment is highly prevalent in the United States and is projected to increase rapidly as the population ages. Our results were consistent with those of the participating studies in demonstrating that the prevalence of visual impairment increases with increasing age. Diseases of aging are also the most common causes of blindness (AMD, cataract, and glaucoma) and of low vision (cataract).

Our finding of a higher age-adjusted blindness prevalence among black men as opposed to black women runs contrary to the results of a recent meta-analytic study that reported a significant age-adjusted excess of blindness among women in population-based studies throughout Africa, Asia, and the developed world.[13] Overall, blindness was significantly ($P=.004$) more common in white women than white men, but the difference was no longer significant after adjustment for age ($P>.10$). The lack of an increased burden of blindness among white women is counter to a recent report from a large, older, white population in England that women are at greater age-adjusted risk for blindness than men.[14] White women did appear to be at an increased risk of low vision in the current study.

Our decision not to include population studies of blindness carried out prior to 1990 has led to the exclusion of some important data, most notably from the Framingham Eye Study.[15] As noted earlier, it was felt that

Table 3. Prevalence of Blindness and Low Vision by Age and Race/Ethnicity*

Variable	Prevalence per 100 Individuals (95% CI)		
	White Persons	Black Persons	Hispanic Persons
Blindness by WHO Definition†			
Age, y			
40-49	0.11 (0.08-0.14)	0.13 (0.07-0.23)	0.04 (0.02-0.08)
50-54	0.08 (0.07-0.09)	0.22 (0.14-0.35)	0.08 (0.05-0.14)
55-59	0.08 (0.07-0.09)	0.32 (0.22-0.46)	0.13 (0.08-0.20)
60-64	0.10 (0.80-0.11)	0.45 (0.32-0.64)	0.20 (0.14-0.29)
65-69	0.14 (0.12-0.17)	0.65 (0.46-0.91)	0.31 (0.21-0.45)
70-74	0.25 (0.22-0.30)	0.93 (0.63-1.36)	0.48 (0.32-0.73)
75-79	0.55 (0.48-0.62)	1.32 (0.84-2.07)	0.75 (0.46-1.22)
≥80	4.27 (3.42-5.31)	2.67 (1.42-4.98)	1.80 (0.91-3.53)
Blindness by US Definition‡			
Age, y			
40-49	0.12 (0.08-0.17)	0.18 (0.13-0.24)	0.05 (0.03-0.08)
50-54	0.10 (0.08-0.13)	0.34 (0.26-0.43)	0.10 (0.08-0.15)
55-59	0.11 (0.09-0.14)	0.52 (0.42-0.65)	0.16 (0.12-0.22)
60-64	0.15 (0.11-0.19)	0.81 (0.67-0.98)	0.26 (0.20-0.33)
65-69	0.23 (0.18-0.30)	1.25 (1.04-1.51)	0.41 (0.32-0.52)
70-74	0.43 (0.34-0.54)	1.93 (1.56-2.38)	0.64 (0.48-0.84)
75-79	0.93 (0.75-1.14)	2.96 (2.30-3.80)	0.99 (0.72-1.38)
≥80	6.82 (4.85-9.52)	6.85 (4.85-9.58)	2.42 (1.53-3.79)
Low Vision§			
Age, y			
40-49	0.20 (0.15-0.25)	0.04 (0.02-0.07)	0.27 (0.19-0.38)
50-54	0.26 (0.22-0.30)	0.17 (0.12-0.23)	0.52 (0.42-0.64)
55-59	0.35 (0.30-0.40)	0.39 (0.29-0.54)	0.82 (0.68-1.0)
60-64	0.53 (0.46-0.62)	0.86 (0.62-1.18)	1.35 (1.10-1.64)
65-69	0.90 (0.78-1.04)	1.72 (1.27-2.33)	2.25 (1.85-2.72)
70-74	1.71 (1.50-1.95)	3.16 (2.41-4.13)	3.83 (3.22-4.56)
75-79	3.57 (3.13-4.08)	5.31 (3.99-7.04)	6.63 (5.56-7.87)
≥80	16.05 (12.95-19.73)	10.84 (5.89-19.11)	17.72 (13.02-23.66)

Abbreviations: CI, confidence interval; WHO, World Health Organization.
*All estimates are based on the 2000 US Census population.
†Blindness as defined by the WHO standard is the best-corrected visual acuity of less than 6/120 (<20/400) in the better-seeing eye.
‡Blindness as defined by the US definition is the best-corrected visual acuity of 6/60 or worse (≤20/200) in the better-seeing eye.
§Low vision is defined as the best-corrected visual acuity less than 6/12 (<20/40) in the better-seeing eye (excluding those who were categorized as being blind by the US definition).

differing methods and the likely influence of secular trends in diagnosis and treatment of eye disease, such as the widespread use of panretinal photocoagulation and automated perimetry, render these data of questionable usefulness for estimates of the causes and prevalence of visual impairment in 2000.

On the other hand, the decision to include data from Europe[16] and Australia[17,18] in calculating our estimates may equally well be questioned in the light of potential differences in access to eye care and treatment patterns between these countries and the United States. It is reassuring to note the high degree of similarity in age-specific blindness prevalence among the 6 studies of European-derived individuals on which our study estimates are based (Figure 1A). Differences in the observed age-specific prevalence of low vision among studies are more prominent. However, the Baltimore Eye Survey, Baltimore, Md, is at the lowest end of this range, and the Beaver Dam Eye Study toward the highest end (Figure 1C); these are both American studies.

Our estimates of the number of Americans with visual impairment are slightly lower than those given in NHANES I-A (NHANES Augmentation Study I), which reported that 7.7% of African American and 4.1% of non-Hispanic white subjects had binocular visual acuities of 6/15 (20/50) or worse.[19] However, the NHANES I-A results are for presenting rather than best-corrected visual acuity as in our analysis, and they included only persons aged 25 to 74 years. The proportion of persons older than 65 years with blindness and low vision in the United States seems to be somewhat lower than that reported among a population-based sample of similar-aged British persons.[20] Prevalence of visual impairment in the British sample (WHO low vision standard <6/18 [20/60]) was 3.1% for persons aged 65 through 74 years, as opposed to 1.47% for Americans aged 65 through 69 years, and 2.61% for those aged 70 through 74 years. Once again, however, the British study reported presenting as opposed to best-corrected visual acuity. Few national estimates exist for the prevalence of impaired best-corrected visual acuity, as was used in the current study, presumably because of the difficulty and expense involved.

Age-related macular degeneration has been reported to be the leading cause of blindness in most recent population-based studies of persons of European descent.[6-8,15-17] The substantially different distribution of

cause-specific blindness among African-derived populations is likely the result of a combination of different factors. These may include the comparatively low prevalence of neovascular AMD[21,22] and high prevalence of OAG[23] among black compared with white persons, and poorer access to and use of eye care among black persons leading to increased visual impairment due to cataract[24] and OAG.[25] The risk for development of diabetic retinopathy also seems to be higher among black persons who have diabetes mellitus.[26,27] This may be because of a combination of factors, including higher prevalence of hyperglycemia and hypertension, poor access to medical care, and reduced health literacy among black compared with white persons.[28] The higher burden of cataract, OAG, and diabetic retinopathy may also explain the higher age-specific prevalence of blindness among black compared white persons observed in our estimates.

Although our study gives estimates for the prevalence of visual impairment among Hispanic persons, these data are based on a single study, Proyecto VER (Vision Evaluation Research), based in Nogales and Tucson, Ariz.[9] These estimates may be susceptible to local patterns of medical and surgical practice, which are known to vary greatly by region[29] and patient insurance type.[30] Furthermore, the estimates for overall and cause-specific visual impairment in Hispanic persons are based on a few cases. This is most apparent for blindness estimates; OAG is indicated as the leading cause of blindness among Hispanic persons in our estimates (Figure 1) on the basis of 4 persons blind from glaucoma, compared with 2 each from diabetic retinopathy, cataract, and AMD in the Proyecto VER study.[9] Estimates of low vision among Hispanic persons are somewhat more robust; cataract is identified as the leading cause of low vision among Hispanic persons in our estimates, based on 43 persons with cataract from a total of 92 with visual acuity worse than 6/12 (<20/40).[9]

The projection of a large increase in the prevalence of blindness and low vision in the United States during the next 2 decades is driven largely by the fact that the prevalence of visual impairment increases sharply in persons older than 65 years. Persons aged 80 years and older made up only 7.7% of the population in our study but accounted for 69% of observed blindness. It is this group, the very old, who represent the fastest-growing segment of the US population. To avoid this increase in visual impairment will require broader dissemination of prevention strategies, such as regular eye examinations for persons with diabetes mellitus or those with a family history of OAG, smoking cessation to reduce risk of nuclear cataract,[31] appropriate vitamin and zinc supplements for selected persons at risk for vision-threatening AMD,[32] enhanced glycemic[33] and blood pressure control among persons with diabetes mellitus, and early detection and laser treatments for high-risk proliferative diabetic retinopathy[34] and clinically significant diabetic macular edema.[35] Further research is also needed to devise new and better preventive measures.

This study has important limitations. Our estimates for white persons rely in part on data from Australia and Europe, where clinical and surgical practices and access to care may differ from the United States. These factors might be expected to influence the prevalence and cause-specific distribution of visual impairment. In the case of Hispanic persons, an important and rapidly growing segment of the US population, estimates are based on data from a single study of persons of Mexican descent,[9] which are likely to be influenced by local factors such as number, distribution, and practice patterns of ophthalmologists. National estimates derived in this way may not be representative of the American Hispanic population as a whole, which comprises Cuban Americans, Puerto Ricans, and Central Americans in addition to Mexican Americans. Estimates for black persons are based on data from only 2 studies,[7,8] both from the same state, and may be similarly unstable. It is also unlikely that estimates derived from any existing studies will be fully relevant to important seg-

Table 4. Gender Difference in the Prevalence of Blindness and Low Vision*

Variable	Crude Prevalence		Crude Value		Age-Adjusted Value	
	Females	Males	OR	*P* Value	OR	*P* Value
Blindness†						
White persons						
BES	0.65	0.66	0.98	.97	0.70	.46
BDES	0.62	0.28	2.23	.08	1.76	.25
BMES	0.92	0.32	2.92	.03	2.44	.07
RS	0.82	0.31	2.68	.01	1.69	.19
SEE Project	0.48	0.62	0.77	.68	0.67	.52
Melbourne VIP	0.32	0.36	0.88	.79	0.77	.61
Pooled total‡	0.69	0.40	1.72	.004	1.29	.20
Black persons						
BES	0.67	1.56	0.42	.03	0.36	.02
SEE Project	0.97	2.76	0.35	.08	0.28	.045
Pooled total‡	0.74	1.89	0.40	.006	0.33	.002
Hispanic subjects						
Proyecto VER	0.27	0.32	0.85	.76	0.79	.64
Low vision§						
White persons						
BES	1.00	1.07	0.93	.85	0.72	.37
BDES	3.01	1.45	2.10	<.001	1.63	.03
BMES	3.55	2.10	1.71	.01	1.56	.045
RS	4.01	1.88	2.18	<.001	1.41	.05
SEE Project	2.49	2.97	0.83	.53	0.75	.30
Melbourne VIP	1.07	0.86	1.25	.46	1.06	.86
Pooled total‡	3.04	1.71	1.69	<.001	1.29	.01
Black persons						
BES	0.93	0.89	1.05	.92	1.07	.89
SEE Project	5.34	5.12	1.05	.90	0.95	.89
Pooled total‡	2.69	2.61	1.05	.87	0.99	.99
Hispanic persons						
Proyecto VER	2.26	1.40	1.63	.04	1.47	.11

Abbreviations: BDES, Beaver Dam Eye Study; BES, Baltimore Eye Survey; BMES, Blue Mountains Eye Study; OR, odds ratio; RS, Rotterdam Study; SEE, Salisbury Eye Evaluation; VER, Vision Evaluation Research; VIP, Visual Impairment Project.

*All estimates are based on the 2000 US Census population. Data are given as percentage of participants.

†Blindness as defined by the US definition is the best-corrected visual acuity of 6/60 or worse (≤20/200) in the better-seeing eye.

‡Total odds ratios are adjusted for the study effect.

§Low vision is defined as the best-corrected visual acuity less than 6/12 (<20/40) in the better-seeing eye (excluding those who were categorized as being blind by the US definition).

ments of the US population, such as the rural South and other ethnic minority groups such as Asians, Native Americans, and Native Hawaiians and other Pacific Islanders.

Diagnostic criteria for the various causes of blindness and low vision also differed among studies. Finally, and perhaps most importantly, the estimates reported here are based on best-corrected visual acuity. These figures do not reflect the burden of low vision and blindness due to uncorrected refractive error, potentially an important cause of visual impairment in the United States.[36,37] A recent report from the Melbourne Visual Impairment Project[17] suggests that almost 60% of visual impairment may be due to uncorrected refractive error. If such estimates may accurately be applied in the United States, the true number of visually impaired Americans might be as high as 8 million. Most of this blindness could be reversed with treatment or avoided by preventive efforts.

Nevertheless, these estimates of low vision and blindness prevalence among the US population are the first to take full advantage of the large number of population-based studies of vision carried out in the last decade. The estimates were derived from raw data provided directly by the study groups and were combined only after agreement had been reached on standard presentation of data. A recent review has cited differences in the definition of low vision and the age range of the oldest age category as the 2 most important sources of disagreement in estimates of visual impairment between studies.[38] Our approach has allowed such differences to be eliminated. Thus, the results of the current study provide useful estimates of the burden of visual impairment in the United States, its distribution by age, race/ethnicity, and sex, and its likely rapid future increase.

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