

Original Investigation

Visual Function, Social Position, and Health and Life Chances The UK Biobank Study

Phillippa M. Cumberland, MSc; Jugnoo S. Rahi, PhD, FRCOphth; for the UK Biobank Eye and Vision Consortium

IMPORTANCE The adverse impact of visual impairment and blindness and correlations with socioeconomic position are known. Understanding of the effect of the substantially more common near-normal vision (mild impairment) and associations with social position as well as health and life chances is limited.

OBJECTIVE To investigate the association of visual health (across the full acuity spectrum) with social determinants of general health and the association between visual health and health and social outcomes.


DESIGN, SETTING, AND PARTICIPANTS A cross-sectional epidemiologic study was conducted using UK Biobank data from 6 regional centers in England and Wales. A total of 112 314 volunteers (aged 40-73 years) were assessed in June 2009 and July 2010. Data analysis was performed from May 20, 2013, to November 19, 2014.

MAIN OUTCOMES AND MEASURES Habitual (correction if prescribed) distance visual acuity was used to assign participants to 1 of 8 categories from bilateral normal visual acuity (logMAR, 0.2 or better; Snellen equivalent, 6/9.5 or better) to visual impairment or blindness (logMAR, 0.5 or worse; Snellen equivalent, 6/19 or worse) using World Health Organization and *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* taxonomy. Relationships between vision, key social determinants and health and social outcomes (including the main factors that define an individual's life—the social, economic, educational, and employment opportunities and outcomes experienced by individuals during their life course) were examined using multivariable regression.

RESULTS Of the of 112 314 participants, 61 169 were female (54.5%); mean (SD) age was 56.8 (8.1) years. A total of 759 (0.7%) of the participants had visual impairment or blindness, and an additional 25 678 (22.9%) had reduced vision in 1 or both eyes. Key markers of social position were independently associated with vision in a gradient across acuity categories; in a gradient of increasing severity, all-cause impaired visual function was associated with adverse social outcomes and impaired general and mental health. These factors, including having no educational qualifications (risk ratio [RR], 1.86 [95% CI, 1.69-2.04]), having a higher deprivation score (RR, 1.08 [95% CI, 1.07-1.09]), and being in a minority ethnic group (eg, Asian) (RR, 2.05 [95% CI, 1.83-2.30]), were independently associated with being in the midrange vision category (at legal threshold for driving). This level of vision was associated with an increased risk of being unemployed (RR, 1.55 [95% CI, 1.31-1.84]), having a lower-status job (RR, 1.24 [95% CI, 1.09-1.41]), living alone (RR, 1.24 [95% CI, 1.10-1.39]), and having mental health problems (RR, 1.12 [95% CI, 1.04-1.20]).

CONCLUSIONS AND RELEVANCE Impaired vision in adults is common, and even near-normal vision, potentially unrecognized without assessment, has a tangible influence on quality of life. Because inequalities in visual health by social position mirror other health domains, inclusion of vision in generic initiatives addressing health inequalities could address the existing significant burden of underrecognized and/or latent visual disability. Longitudinal investigations are needed to elucidate pathophysiological pathways and target modifiable mechanisms.

JAMA Ophthalmol. doi:10.1001/jamaophthalmol.2016.1778
Published online July 28, 2016.

 [Supplemental content at jamaophthalmology.com](http://jamaophthalmology.com)

Author Affiliations: Author affiliations are listed at the end of this article.

Group Information: A complete list of UK Biobank Eye and Vision Consortium investigators is provided at the end of the article.

Corresponding Author: Jugnoo S. Rahi, PhD, FRCOphth, Life Course Epidemiology and Biostatistics Section, University College London Institute of Child Health, 30 Guilford St, London WC1N 1EH, England (j.rahi@ucl.ac.uk).

People value good eyesight. Blindness is known to have a broad-ranging adverse influence on affected individuals, their families, and the societies in which they live and is exemplified by its association with impaired quality of life, worse general and mental health, curtailed life chances, and increased all-cause mortality.¹⁻⁴ It is therefore unsurprising that international policies and research relating to ophthalmology and visual sciences have prioritized this end of the spectrum of impaired vision.⁵⁻⁸ An unintended consequence of this prioritization is that less attention has been focused on the much larger population with mildly impaired or near-normal vision that also may affect activities of daily living.⁹ Equally, this prioritization has created an underpinning conceptual framework for policy and research centered on the notion of visual impairment (VI) rather than on the concept of visual health (ie, the full continuum of visual function). This narrow focus contrasts with the broader health literature. Consequently, although socioeconomic correlates of VI and blindness are known, neither the social determinants of visual health per se nor the social determinants of inequalities in visual health have received the same attention as other health states.¹⁰⁻¹³ Hence, evidence necessary for policy and service planning about the association between health and social outcomes and visual health is incomplete.

One obstacle to such research has been the unavailability of population samples of sufficient size and detail to enable robust interrogation of the full spectrum of visual function. We report what we believe to be a novel investigation of visual health in a contemporary adult population drawing on UK Biobank,¹⁴ the largest prospective investigation of lifestyle and environmental determinants of health and disease. We hypothesized that key social determinants of health are associated with visual health and that visual health is associated with key general health and social outcomes. We further hypothesized that meaningful gradients of inequality exist in these associations.

Methods

Between February 2006 and July 2010, UK Biobank assessed 502 682 persons aged 40 to 73 years (identified from the electoral register) following individual written informed consent for participation; there was no financial compensation.¹⁴ Diverse detailed data were collected through physical assessments, biological samples, and self-report on health and disease, including eyes and vision, using validated instruments. In 2009, an ophthalmic assessment was added to the main protocol and undertaken by 117 907 participants (23.5%) at 5 recruitment centers in England and 1 in Wales. This assessment comprised habitual distance visual acuity, refraction without cycloplegia (Tomey RC-5000 auto refkeratometer; Tomey Corporation), intraocular pressure measurement, fundus photography, and optical coherence tomography. The present study was conducted from June 2009 to July 2010.

UK Biobank has received approval from the North West Multi-Centre Research Ethics committee, which covers the United Kingdom. UK Biobank also obtained approval in England and Wales from the Patient Information Advisory Group for gaining access to information that would allow it to invite

Key Points

Question How is visual function across the full acuity spectrum ranging from near-normal vision to blindness associated with social position and health and social outcomes?

Findings In this study of a large national sample of UK adults with abnormal vision in 1 or both eyes, key indicators of social position were independently associated with abnormal vision across the full acuity spectrum, and impaired visual health was independently associated with adverse health and social outcomes in a gradient starting from near-normal vision.

Meaning The findings of this study indicate a significant burden of underrecognized and/or latent visual disability that might be addressed by including visual health within initiatives addressing general health inequalities.

people to participate. The Patient Information Advisory Group has since been replaced by the National Information Governance Board for Health & Social Care. In Scotland, UK Biobank has received approval from the Community Health Index Advisory Group. The present study was approved by the National Information Governance Board for Health & Social Care, which allows access to information for inviting individuals to participate.

Classification of Visual Function

Distance visual acuity is the standard clinical measure of visual function and the basis of international taxonomies of VI. Within UK Biobank, habitual distance visual acuity in each eye (ie, tested with the individual wearing any prescribed, presently used optical correction) was measured to assess real-life visual function rather than best-corrected acuity as is often used in ophthalmic research. Individuals were assigned to 1 of 8 mutually exclusive visual function categories (Table 1)¹⁵ based on acuity in the better-seeing eye (ie, at the level of the person rather than the level of the eye), given our interest in investigating risk factors and outcomes measured at the level of the person. Within both the World Health Organization's classification (based on the better-seeing eye) and *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision*¹⁶ (which also classifies unilateral vision in the worst-seeing eye), all individuals with visual acuity of 0.5 logMAR (Snellen equivalent, 6/19) or better are grouped together as having mild or no VI rather than being delineated as, for example, those not meeting thresholds for driving. Thus, we extended prior modification by our group¹⁷ of the source World Health Organization classification comprising VI, severe VI (SVI), and blindness (blind) to allow our a priori analysis of the full spectrum of acuity as an ordered categorical variable by distinguishing normal vision from new categories of unilateral near-normal and bilateral near-normal vision and socially significant VI.

To specifically assess unrecognized or uncorrected refractive error as a potential cause of reduced habitual visual acuity in individuals without prescribed optical correction, we undertook subgroup analysis of associations between refractive error, self-report of optical correction, visual function, and sociodemographic and health variables. Spherical equivalent

Table 1. Distribution of Vision Function Categories by Age^a

| Descriptive Category in WHO Taxonomy ^b | Visual Function Category ^c | Participant Age, No. (%), y | | | |
|---|--|-----------------------------|---------------|---------------|---------------|
| | | 40-49 | 50-59 | 60-73 | Total |
| Mild or no visual impairment ^d | Bilateral normal 0-0.2 (Snellen equivalent, 6/6 to 6/9.5) | 21 934 (85.5) | 27 482 (77.5) | 36 461 (71.7) | 85 877 (76.5) |
| | Unilateral near normal 0-0.2 vs 0.21-0.3 (Snellen equivalent, 6/6-6/9.5 vs worse than 6/9.5-6/12) | 1390 (5.4) | 3063 (8.6) | 5474 (10.8) | 9927 (8.8) |
| | Bilateral near normal 0.21-0.3 (Snellen equivalent, worse than 6/9.5-6/12) | 150 (0.6) | 379 (1.1) | 828 (1.6) | 1357 (1.2) |
| VI and SVI (low vision) | Unilateral VI 0-0.3 vs 0.31 or worse (Snellen equivalent, 6/12 or better vs worse than 6/12) | 1788 (7.0) | 4037 (11.3) | 6652 (13.1) | 12 477 (11.1) |
| | Socially significant VI ¹ 0.31-0.49 (Snellen equivalent, worse than 6/12-6/18) in the better-seeing eye | 237 (0.9) | 599 (1.7) | 1081 (2.1) | 1917 (1.7) |
| Blindness | VI 0.5-1.0 (Snellen equivalent, 6/19 to 6/60) in the better-seeing eye | 136 (0.5) | 213 (0.6) | 378 (0.7) | 727 (0.6) |
| | SVI 1.1-1.3 (Snellen equivalent, worse than 6/60 to 3/60) in the better-seeing eye | 6 (0.02) | 11 (0.03) | 9 (0.02) | 26 (0.02) |
| Blindness | Blindness 1.31 or worse in both eyes (Snellen equivalent, worse than 3/60 in both eyes) | 4 (0.01) | 2 (0.01) | 0 | 6 (0.01) |
| | Total | 25 645 (22.8) | 35 786 (31.9) | 50 883 (45.3) | 112 314 (100) |

Abbreviations: SVI, severe visual impairment; VI, visual impairment; WHO, World Health Organization.

^a Distribution of vision function by sex was the same as the overall distribution.

^b Ratified taxonomies.¹⁵

^c Habitual logMAR visual acuity.

^d LogMAR, 0-0.49 in better-seeing eye (Snellen equivalent, 6/18 or better).

(SEQ) quantifies the refractive status of an eye in a single scale (algebraic sum in diopters [D], sphere +0.5 cylinder, and refraction measures). Using the mean SEQ of the 2 eyes, we categorized individuals as having emmetropia (SEQ, -0.99 to +0.99 D), myopia (SEQ, -1.0 D or less), or hypermetropia (SEQ, +1.0 D or more). The available demographic, socioeconomic, and health data and derived variables are reported in Table 2.

Eligibility and exclusion criteria applied to achieve the sample for analysis (eFigure 1 in the Supplement) included categorization or exclusion of individuals unable or unwilling to undergo acuity assessment, those ineligible for clinical reasons as prespecified in the UK Biobank protocol (<https://biobank.ctsu.ox.ac.uk/crystal/refer.cgi?id=100250>), and those lacking sufficient data on acuity for both eyes to allow categorization of visual status (eg, did not complete the test or tested in only 1 eye).

Statistical Analysis

Descriptive analysis of the distribution of visual function was based on all participants. Associations between visual function and sociodemographic factors were analyzed using the data set complete for visual function, demographic, socioeconomic, and health variables. Because of the small numbers within the groups (Table 1), the World Health Organization categories of VI (n = 727), SVI (n = 26), and blind (n = 6) (ie, logMAR 0.5 or worse; Snellen equivalent 6/19 or worse in the better-seeing eye) were combined.

To investigate the association of social determinants of general health with vision health (across the full acuity spectrum), multinomial analyses were undertaken with adjustment for confounders and comparison of each visual function category with the results of persons with bilateral normal vision. Robust SEs were used to account for clustering of individuals within test center.

Multivariable logistic and ordinal regression were used, as appropriate, to investigate associations between visual function and health and life chances (the social, economic, educational, and employment opportunities and outcomes experienced by individuals during their life course). Because the temporal relationship between impaired visual function, education, and social position is difficult to disentangle using the cross-sectional data available in UK Biobank, we undertook an additional subgroup analysis restricted to participants with higher educational attainment to investigate associations between visual function and social outcomes. Analyses were carried out using Stata, version 13 (StataCorp LP). Data analysis was performed from May 20, 2013, to November 19, 2014.

Results

Participation and Final Analysis Sample

A total of 112 314 individuals (95.3% of 117 907 with acuity measurement) could be reliably assigned to a visual function category (eFigure 1 in the Supplement). Of these, 61 169 participants (54.5%) were female, mean (SD) age was 56.8 (8.1) years, and 111 914 people (99.6%) lived in England. Five hundred sixty-four individuals were not tested (ineligible or other reason) and 1506 had both eyes tested, but the results were unreliable (eFigure 1 in the Supplement). There was insufficient information for visual acuity categorization for 3523 participants who had 1 eye tested. A total of 759 participants (0.7%) had visual impairment or blindness, and an additional 25 678 individuals (22.9%) had reduced vision in 1 or both eyes. Of 248 participants who self-reported VI in the untested eye, 195 people (78.6%) had good acuity (logMAR, 0.3 or better; Snellen equivalent, 6/12 or better) and 33 participants (13.3%) had reduced acuity (logMAR, worse than 0.3; Snellen equivalent, worse than

Table 2. Demographic, Socioeconomic, and Health Variables

| Variable | Original Variable | Derived Variable ^a |
|--|---|--|
| Age | Age at recruitment | Age groups: 40-49, 50-59, and 60-73 y |
| Sex | Male or female | |
| Townsend Index ¹⁸ | Based on 4 area-based census variables | Continuous scale, range -6 to +10 (higher scores indicate greater deprivation) |
| Disability allowance ^{19b} | Governmental financial assistance for disability based on medical assessment | Governmental financial support for those with chronic illness; either no allowance or attendance and/or disability allowance |
| Attendance allowance ^{19b} | Governmental financial assistance for personal home care for those >65 y based on medical assessment | |
| Ethnicity | Reported in 21 categories under 6 main headings: white, mixed, Asian or Asian British, black or black British, Chinese, or other | 6 Categories: white, mixed, Asian or Asian British, black or black British, Chinese, or other |
| Highest educational attainment ^c | No qualifications, O levels, A levels, or university/other professional qualification | |
| Accommodation type | House, apartment, or mobile/temporary accommodation ^d | Household structure: single-person, ≥2 individuals in household, sheltered accommodation, or care home |
| No. in household ^e | 1, 2 or ≥3 | |
| Mean total household income before tax, £ ^{e,f} | <18 000, 18 000-30 999, 31 000-51 999, 52 000-100 000, or >100 000 | Mean total income, <18 000 vs ≥18 000 |
| Employment status | Employed, unemployed, retired, home maker, unpaid work, student, or unable to work | |
| Occupation category | Categories for job code based on the 9 top hierarchy job codes, from managers and senior officials to elementary occupations ^g | |
| General health | Self-rating as excellent, good, fair, or poor | |
| Mental health | Response to, "Have you ever seen a GP/psychiatrist for nerves, anxiety, tension, or depression?" (yes or no) | |

Abbreviation: GP, general practitioner.

^a If original variable was recategorized; no listing indicates that the original variable was unchanged.

^b Data were not collected on UK certification for sight impairment/severe sight impairment, which enables government-provided financial assistance to those with severe sight loss. Thus, we used data collected on disability and attendance allowances, which provide governmental financial assistance for those with disability as assessed by a medical examination.¹⁹

^c O levels indicate state school examinations at age 16 years; A levels, state

school examinations at age 18 years.

^d Trailer, sheltered accommodation, or residential care home.

^e Question not asked if accommodation type reported as sheltered accommodation or care home.

^f Average conversion rate from pounds to US dollars between June 2009 and July 2010 was £1 = \$1.5814.

^g From the standard occupation classification (2003) index (eTable 1 in the Supplement).²⁰

6/12). These individuals were more likely to be male and of poorer social position than were those included in the analysis sample. Based on UK Census 2011 data (<https://www.nomisweb.co.uk/census/2011>), although the ethnic composition of UK Biobank is comparable to that of the general UK population, the analysis sample was older (participation increased with age), had fewer men, was more affluent, and had higher levels of education. Thus, the distribution of visual function (Table 1) cannot be extrapolated as precise population prevalence estimates. The distribution of all demographic, socioeconomic, and health variables by visual function category is presented in eTable 2 in the Supplement.

Sociodemographic Factors Associated With Visual Function

As reported in Table 3, VI across the acuity spectrum was consistently and independently associated with increasing age, female sex, and a worse deprivation score. The risk of VI rose with decreasing levels of educational qualification. Individuals in any black or minority ethnic group were more likely to have impaired visual function compared with white persons. Gradients were observed in these associations with social determinants of health within each visual function category. Comparison of these associations across visual function categories showed some gradient effects. For example, the increased risk of VI for persons without educational qualifications ranged

from 1.29 (95% CI, 1.25-1.33) for unilateral near-normal vision to 1.99 (95% CI, 1.33-2.96) for bilateral SVI or blindness.

Refractive Error, Optical Correction, and Visual Function

Overall, 99 070 of 111 863 participants (88.6%) reported wearing eyeglasses or contact lenses for correction of distance, near vision, or both forms of VI. Of participants with no optical correction, 12 570 of 12 793 individuals (98.3%) had autorefractive error, which suggested that fewer than 11% of the sample had an uncorrected refractive error (ie, 1.2% of all participants). Specifically, 749 people (6.0%) had myopia (mean SEQ, lower than -1 D) and 595 individuals (4.7%) had hypermetropia (mean SEQ, higher than +1 D). Having a refractive error but no optical correction was associated independently with younger age, male sex, increasing deprivation, and nonwhite ethnicity.

Visual Function and Socioeconomic Outcomes

Reduced visual function was independently associated with increased risk of being unable to work and being unemployed; individuals in the most severe category (VI/SVI/blindness) had 3 times the risk of being unable to work and twice the risk of being unemployed. Even those with only mildly reduced vision in 1 eye were disadvantaged (Table 4 and eFigure 2 in the Supplement). Among participants with paid employment, impaired visual function was independently inversely associated with lower occu-

Table 3. Associations Between Sociodemographic Factors and Visual Function Category^a

| Variable | Adjusted RR (95% CI) | | | | |
|-----------------------------------|--------------------------|------------------|------------------|-------------------------|------------------|
| | Unilateral | | Bilateral | | |
| | Near Normal ^b | VI ^c | Near Normal | Socially Significant VI | VI ^c |
| Sex | | | | | |
| Male | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Female | 1.10 (1.06-1.14) | 1.03 (1.00-1.05) | 1.18 (1.09-1.28) | 1.09 (1.01-1.16) | 1.15 (1.03-1.29) |
| Increasing age, y | 1.05 (1.04-1.05) | 1.04 (1.03-1.05) | 1.07 (1.06-1.08) | 1.05 (1.05-1.06) | 1.03 (1.01-1.04) |
| Age group, y | | | | | |
| 40-49 | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| 50-59 | 1.83 (1.73-1.93) | 1.86 (1.69-2.03) | 2.17 (2.03-2.32) | 2.26 (1.93-2.66) | 1.34 (1.06-1.70) |
| 60-73 | 2.48 (2.30-2.68) | 2.29 (1.97-2.67) | 3.53 (2.96-4.22) | 3.02 (2.72-3.36) | 1.81 (1.29-2.54) |
| Ethnicity | | | | | |
| White | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Mixed | 1.21 (1.00-1.46) | 1.02 (0.87-1.20) | 1.19 (0.57-2.41) | 0.90 (0.46-1.78) | 1.81 (1.27-2.59) |
| Asian/Asian British | 1.47 (1.27-1.71) | 1.32 (1.19-1.48) | 2.39 (1.71-3.15) | 2.05 (1.83-2.30) | 1.99 (1.39-2.85) |
| Black/black British | 1.47 (1.31-1.64) | 1.29 (1.18-1.41) | 2.27 (1.80-2.71) | 2.46 (2.13-2.85) | 1.82 (1.28-2.58) |
| Chinese | 1.63 (0.96-2.77) | 1.73 (1.16-2.59) | 2.46 (1.08-5.20) | 2.17 (1.44-3.28) | 1.26 (0.41-3.91) |
| Other | 1.45 (1.15-1.83) | 1.26 (1.12-1.42) | 2.06 (1.51-2.69) | 1.62 (0.97-2.71) | 2.47 (1.82-3.36) |
| Townsend Index ^d | 1.03 (1.02-1.04) | 1.04 (1.03-1.05) | 1.04 (1.02-1.06) | 1.08 (1.07-1.09) | 1.10 (1.07-1.14) |
| Qualifications^e | | | | | |
| Higher level | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| A level | 1.10 (1.07-1.13) | 1.10 (1.04-1.18) | 1.20 (1.06-1.37) | 1.14 (0.95-1.38) | 1.24 (0.84-1.83) |
| O level | 1.13 (1.09-1.16) | 1.09 (1.06-1.13) | 1.22 (1.11-1.33) | 1.28 (1.07-1.53) | 1.26 (1.14-1.38) |
| None | 1.34 (1.25-1.44) | 1.29 (1.25-1.33) | 1.81 (1.44-2.28) | 1.86 (1.69-2.04) | 1.99 (1.33-2.96) |

Abbreviations: RR, risk ratio; VI, visual impairment.

^a Comparing each visual function category with bilateral normal-acuity, logMAR 0.2 or better (Snellen equivalent, 6/9.5 or better) in 110 134 individuals.

^b Estimates adjusted for all factors in the table (age as continuous variable), and variance adjustment for test center.

^c Includes moderate VI, severe VI, and blindness.

^d Higher scores indicate greater deprivation.¹⁸

^e O levels indicate state school examinations at age 16 years; A levels, state school examinations at age 18 years.

Table 4. Associations Between Visual Function and Employment, Occupation Category, Household Income, and Household Structure

| Visual Function Category | Adjusted RR (95% CI) | | | | | |
|--------------------------|--------------------------------|------------------|--|---------------------------------|----------------------------------|--------------------------------------|
| | Employment Status ^a | | Lower-Grade Occupation Category ^b | Lowest Income Band ^c | Household Structure ^d | |
| | Unable to Work | Unemployed | | | Single Person | Sheltered Accommodation or Care Home |
| Bilateral normal | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Unilateral near normal | 1.22 (1.07-1.39) | 1.14 (1.02-1.27) | 1.05 (1.02-1.08) | 1.21 (1.13-1.29) | 1.08 (1.04-1.11) | 1.31 (1.01-1.71) |
| Unilateral VI | 1.39 (1.29-1.50) | 1.17 (1.13-1.21) | 1.06 (1.01-1.10) | 1.16 (1.11-1.22) | 1.13 (1.07-1.19) | 1.53 (1.15-2.05) |
| Bilateral near normal | 1.85 (1.35-2.54) | 1.10 (0.68-1.77) | 1.13 (1.01-1.27) | 1.42 (1.36-1.49) | 1.15 (0.96-1.37) | 1.51 (1.13-2.01) |
| SSVI | 1.65 (1.30-2.08) | 1.55 (1.31-1.84) | 1.24 (1.09-1.41) | 1.62 (1.35-1.95) | 1.24 (1.10-1.39) | 2.47 (1.72-3.55) |
| VI/SVI/blind | 3.48 (2.57-4.72) | 1.91 (1.33-2.76) | 1.35 (1.12-1.63) | 1.58 (1.27-1.97) | 1.28 (1.02-1.61) | 3.73 (2.03-6.84) |

Abbreviations: RR, risk ratio; SSVI, socially significant visual impairment; SVI, severe visual impairment; VI, visual impairment.

^a Multinomial regression with reference category (employed). Risk ratios were adjusted for sex, age, ethnicity, Townsend Index,¹⁸ and educational qualifications.

^b Ordinal logistic regression – 9 categories of job description (standard occupational classification top-level categories). Estimates were adjusted for sex, age, ethnicity, Townsend Index, and educational qualifications.

^c Logistic regression comparing individuals in the lowest income band (less than £18 000) with those in all other income bands combined (as reference).

Estimates were adjusted for sex, age, ethnicity, Townsend Index, and educational qualifications, with additional adjustment for number of household members. Mean total household income was not requested for those in sheltered accommodation or care home and was missing for 15 089 of 110 134 (13.7%) participants. A higher proportion of those with VI had missing income data. The proportion increased from 13.1% of individuals with bilateral normal vision to 20.5% of those with SSVI or VI.

^d Multinomial regression with reference category (≥2 people). Risk ratios were adjusted for sex, age, ethnicity, Townsend Index, and educational qualifications.

paternal grade, with the risk increasing steadily across the spectrum of impairment. Impaired visual function was independently inversely associated with mean total household income as well

as with an increased risk of living alone or living in sheltered accommodation or a residential care home, with a gradient across the acuity spectrum (Table 4).

Table 5. Associations Between Visual Function and General and Mental Health Outcomes and Disability/Attendance Allowance

| Visual Function Category | Adjusted OR (95% CI) ^a | | | |
|--------------------------|-----------------------------------|--|-------------------|---------------------------------|
| | Poorer Rating of General Health | Sought Care for Mental Health ^b | | Disability/Attendance Allowance |
| | | From General Practitioner | From Psychiatrist | |
| Bilateral normal | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Unilateral near normal | 1.08 (1.05-1.11) | 1.00 (0.97-1.04) | 1.05 (0.95-1.16) | 1.20 (1.01-1.31) |
| Unilateral VI | 1.10 (1.06-1.15) | 0.95 (0.93-0.97) | 0.99 (0.95-1.04) | 1.41 (1.29-1.54) |
| Bilateral near normal | 1.12 (0.94-1.35) | 0.99 (0.92-1.07) | 1.14 (0.95-1.38) | 1.64 (1.25-2.16) |
| SSVI | 1.09 (0.93-1.27) | 0.90 (0.83-0.98) | 1.12 (1.04-1.20) | 1.80 (1.45-2.23) |
| VI/SVI/blind | 1.44 (1.29-1.61) | 1.23 (1.02-1.48) | 1.39 (1.07-1.79) | 4.18 (3.53-4.94) |

Abbreviations: OR, odds ratio; SSVI, socially significant visual impairment; SVI, severe visual impairment; VI, visual impairment.

^a All estimates were adjusted for sex, age, ethnicity, Townsend Index,¹⁸ and educational qualifications. Ordinal regression was used for general health rating; logistic regression was used for mental health and disability/attendance allowance outcomes.

^b Included nerves, anxiety, tension, and depression.

Impaired Visual Function, Education, and Social Position

In the subgroup analysis restricted to individuals with higher educational qualifications, impaired visual function was associated independently with an increased risk of being unable to work, unemployed, and in a lower occupational category as well as having a lower household income (eTable 3 in the Supplement). Gradients in effect sizes across the acuity spectrum were observed but less consistently than in the full group analyses reported above.

Visual Function and Health Outcomes

In the adjusted model presented in Table 5, impaired visual function was associated with poorer self-reported general health. Those in the VI/SVI/blind category were 44% more likely than were those with normal vision to self-report poorer health and were also more likely to have ever visited a general practitioner or psychiatrist for common mental health conditions; individuals with socially significant VI were more likely to have visited a psychiatrist.

Of 109 172 participants with information on governmental financial assistance, 4537 persons (4.2%) were receiving assistance as a disability or attendance allowance. Those in the VI/SVI/blind category were more than 4 times more likely to be receiving this assistance than were those with normal vision, with a gradient of association with all levels of impaired function. These associations are likely to reflect impaired visual function in association with other disabling disorders since they remained statistically significant after adjusting for income.

Discussion

We report a novel, large-scale investigation of the relationship between social position and visual health (ie, full continuum of visual function) as well as the association between visual function and key general health and socioeconomic outcomes in a contemporary adult population in the United Kingdom. Of the population analyzed, 23.0% had real-life impaired visual function. We demonstrate that visual health is associated with known key social determinants of health^{10,11} acting independently in the axes of social differentiation captured by age, sex, ethnicity, area or community-based deprivation, and educational experience and with a trend across the full spectrum of visual acuity. All-cause impaired visual function, a functional outcome of diverse

processes analogous to all-cause mortality, was independently associated with adverse outcomes relating to employment, occupation, economic status, and self-reported general and mental health, with a gradient of increasing severity from the mildest impairment affecting only 1 eye to bilateral blindness.

Although it is a unique bioresource,¹⁴ UK Biobank study has limitations. Because it is not a random subsample of the UK population, frequency and distribution cannot be interpreted as prevalence. The frequency of VI and blindness was lower than what might have been anticipated,^{9,17,21-24} reflecting nonrandom recruitment, exclusion by protocol of some participants, and exclusion of other individuals without visual acuity data for both eyes that are necessary for categorization of visual status. Thus, we report indicative minimum estimates of frequency. The limited number of participants in the worst categories of VI/SVI/blindness precluded conclusive analysis of differences between these groups. Nevertheless, the very large size as well as diversity and number of details of the study sample, combined with the low levels of missing data, allowed robust investigation. Although the cross-sectional design precludes elucidation of temporal relationships (eg, between visual function and education, employment, and occupational categories), which is necessary to confirm causality, the findings nevertheless serve to identify the existence of patterns of inequality and delineate new hypotheses for testing in longitudinal research to identify pathways of action.²⁵

The epidemiologic literature^{22,26-28} on visual function in adults has understandably principally addressed the worst end of the spectrum (ie, low vision and blindness), which is known to be associated with belonging to an ethnic minority and having lower socioeconomic status. Longitudinal research on the 1958 British birth cohort by our group^{17,24} provided the conceptual basis for the present study that has exploited the greater scale and diversity of UK Biobank, albeit using cross-sectional data, to identify and understand current patterns of social inequalities in visual health across the spectrum from normal vision to VI, SVI, and blindness.

Only 76.5% of the adults in the present study had normal habitual vision in both eyes. The rest of the population had impaired visual function, which even in its mildest form (eg, affecting only 1 eye or still exceeding the minimum threshold for driving) was associated with an increased risk of adverse social and health outcomes. This finding flags a significant burden of underrecognized and/or preclinical disability,²⁹ which may be masked by adaptive

strategies (eg, avoiding driving) that may themselves lead to inequalities of opportunity and go unrecognized without acuity testing during, for example, general health or well-being checks. In addition, we have demonstrated dose-response-type gradients starting with mildly reduced visual function, with any level of bilateral visual impairment being associated with greater disadvantage than any level of unilateral impairment. Although there appear to be no studies directly comparable to ours, the broader literature^{10,11,13} on social determinants and health inequalities supports our hypothesis that such associations are likely to exist worldwide, although the scale will vary.

From a health policy perspective, our findings highlight the value of shifting thinking to overall population visual health and away from exclusive consideration of visual impairment. Our findings point to the antecedents of inequalities in visual health and highlight the potential for widening of gaps over time, particularly with an aging population. We suggest that visual function needs to be embedded better in public health structures and processes as a key sensory health indicator that is routinely considered, both independently and as part of all-cause morbidity, as both a risk factor and health outcome measure. Inclusion of visual health indicators within measures routinely monitored in health services, such as in the United Kingdom within the National Health Service Outcomes Framework,³⁰ would facilitate alignment of strategies against avoidable VI,^{5,6} with the broader key initiatives tackling general health inequalities.^{11,13,31} Such inclusion would add mutual value and improve cost-effectiveness; for example, smoking cessation or uptake prevention strategies may prove valuable in preventing blindness³² as well as reducing mortality, and citing the risk to visual health could be a powerful addition to general public health and health promotion campaigns.³³ In tandem, eye- and vision-specific strategies addressing diseases with known sociodemographic correlates, such as glaucoma³⁴ and diabetic eye disease,³⁵ through targeted approaches to improving early detection, including formal screening programs, could routinely include metrics of social position to good effect within treatment and visual rehabilitation protocols.

There is increasing worldwide attention to refractive error as a readily remediable cause of impaired vision when undetected or uncorrected due to limited access to or use of services or affordability of eyeglasses.^{36,37} Because uncorrected refractive error was present in only 1.2% of the participants in our study, it is not a major contributor to the findings but illustrates the complexities and challenges of condition-specific approaches. There is limited and inconsistent literature³⁸ indicating that differential uptake of free sight tests or free eyeglasses can paradoxically widen rather than eliminate inequality gradients.³⁹ In developing new strategies, it will be important to remember that the determinants of visual health may differ from the determinants of inequalities in visual health and that these factors may work in opposing directions.

Conclusions

We propose that the conceptual framework for thinking about vision that focuses on impairment rather than health, together with extant gaps in knowledge, are hindering the development and application of proportionate universalism¹¹ (ie, evidence-based policies and interventions) to achieve higher levels of visual health and improve life chances of the whole population while simultaneously reducing the magnitude and gradient of inequalities. Evidence from other clinical disciplines supports the potential gain, with relatively little additional effort, that may be achieved with routine inclusion of visual function in individual health assessments of patients at risk for visual impairment and from routine inclusion of vision and eye health in its broadest sense in existing national and international initiatives addressing social determinants of disease and tackling health inequalities.^{11,13} Longitudinal research delineating mechanisms and pathways, including consideration of both specific eye diseases and visual neurodevelopment and cognition, is needed to develop new targeted strategies.

ARTICLE INFORMATION

Submitted for Publication: January 31, 2016; final revision received April 14, 2016; accepted April 22, 2016.

Published Online: July 28, 2016.

doi:10.1001/jamaophthalmol.2016.1778.

Author Affiliations: Life Course Epidemiology and Biostatistics Section, University College London Institute of Child Health, London, England (Cumberland, Rahi); Ulverschroft Vision Research Group, London, England (Cumberland, Rahi); Great Ormond Street Hospital, University College London Institute of Child Health Biomedical Research Centre, London, England (Rahi); Moorfields Eye Hospital National Health Service Foundation Trust, National Institute for Health Research, Moorfields Biomedical Research Centre, London, England (Rahi); University College London Institute of Ophthalmology, London, England (Rahi).

Author Contributions: Ms Cumberland had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Rahi.

Acquisition, analysis, or interpretation of data: Cumberland.

Drafting of the manuscript: Both authors.

Critical revision of the manuscript for important intellectual content: Rahi.

Statistical analysis: Cumberland.

Obtained funding: Both authors.

Study supervision: Rahi.

Conflict of Interest Disclosures: Both authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Ms Cumberland and Dr Rahi are members of the Ulverschroft Vision Research Group. No other disclosures were reported.

Funding/Support: This work was supported by National Eye Research Centre grant SCiAD 066. Ms Cumberland is supported by the Ulverschroft Foundation. The work was undertaken at University College London (UCL) Institute of Child Health/ Great Ormond Street Hospital for children, London, England, which received a proportion of funding from the Department of Health's National Institute for Health Research (NIHR) Biomedical Research

Centres' funding scheme. Dr Rahi is supported in part by the NIHR Biomedical Research Centre based at Moorfields Eye Hospital National Health Service (NHS) Foundation Trust and UCL Institute of Ophthalmology. Collection of eye and vision data in the UK Biobank was supported in part by grant BRC2_009 from the NIHR Biomedical Research Centre at Moorfields Eye Hospital and UCL Institute of Ophthalmology. The UK Biobank Eye and Vision Consortium is supported by grant ST 12 09 from the Special Trustees of Moorfields Eye Hospital.

Role of the Funder/Sponsor: The funding organizations had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Group Information: The UK Biobank Eye and Vision Consortium includes the following investigators: *Cardiff University:* John Gallacher, Jeremy Guggenheim, and James Morgan (steering committee member); *City University (London):* David Crabb and Haogang Zhu; *Edinburgh University:* Bal Dhillon (steering committee

member); *Gloucestershire Hospitals NHS Foundation Trust*: Irene Stratton; *King's College London*: Chris Hammond, Eoin O'Sullivan, and Katie Williams; *Kingston University*: Sarah Barman; *Leeds Teaching Hospitals NHS Trust*: Martin McKibbin; *Manchester University*: Tariq Aslam and Paul Bishop (steering committee member); *Moorfields Eye Hospital (London)*: Peter Blows, Catey Bunce, Michelle Chan, Alexander Day, Parul Desai, Anthony Khawaja, Gerassimos Lascaratos, Praveen Patel, Tunde Peto, Nicholas Strouthidis, Dhane Thomas, Adnan Tufail, and Ananth Viswanathan; *Newcastle University*: David Steel; *Queen's University Belfast*: Michelle McGaughey, Bernadette McGuinness, Gareth McKay, Usha Chakravarthy, Ruth Hogg, and Anne Hughes; *St George's University of London*: Chris Owen and Alicja Rudnicka; *St James's University Hospital (Leeds)*: Sarah Mackie; *UCL Institute of Child Health*: Philippa Cumberland, Antonietta Chianca, and Jugnoo Rahi; *UCL Institute of Ophthalmology*: Valentina Cipriani, Paul Foster, David (Ted) Garway-Heath, Priyal Gupta, Pearse Keane, Peng Tee Khaw (steering committee member), Phil Luthert, Tony Moore, Zaynah Muthy, and Caroline Thuang; *University Hospital, Nottingham*: Stephen Vernon; *University of Bristol*: Andrew Dick (steering committee cochair) and Cathy Williams; *University of Cambridge*: John Yates, Jennifer Yip, and Keith Martin; *University of Dundee*: Emanuele Trucco; *University of East Anglia*: Carlota Grossi Sampedro and Max Yates; *University of Edinburgh*: Tom MacGillivray, Danny Mitry, and Cathie Sudlow; *University of Liverpool*: Simon Harding (steering committee member); and *University of Southampton*: Srinii Goverdhan and Andrew Lotery (steering committee chair).

Disclaimer: The views expressed in this publication are those of the authors and not necessarily those of the Department of Health, NHS, or NIHR.

REFERENCES

1. Knudtson MD, Klein BE, Klein R. Age-related eye disease, visual impairment, and survival: the Beaver Dam Eye Study. *Arch Ophthalmol*. 2006;124(2):243-249.
2. Dargent-Molina P, Favier F, Grandjean H, et al. Fall-related factors and risk of hip fracture: the EPIDOS prospective study. *Lancet*. 1996;348(9021):145-149.
3. Garin N, Olaya B, Lara E, et al. Visual impairment and multimorbidity in a representative sample of the Spanish population. *BMC Public Health*. 2014;14:815.
4. van der Aa HP, Comijs HC, Penninx BW, van Res GH, van Nispen RM. Major depressive and anxiety disorders in visually impaired older adults. *Invest Ophthalmol Vis Sci*. 2015;56(2):849-854.
5. Chapter 28: vision and hearing. National Institutes of Health. *Healthy People 2010 Final Review*. http://www.cdc.gov/nchs/data/hpdata2010/hp2010_final_review_focus_area_28.pdf. Accessed January 29, 2016.
6. International Agency for the Prevention of Blindness. Vision 2020: the Right to Sight. <http://www.iapb.org/vision-2020>. Accessed January 29, 2016.
7. Bourne RR, Jonas JB, Flaxman SR, et al; Vision Loss Expert Group of the Global Burden of Disease Study. Prevalence and causes of vision loss in high-income countries and in Eastern and Central Europe: 1990-2010. *Br J Ophthalmol*. 2014;98(5):629-638.
8. Stevens GA, White RA, Flaxman SR, et al; Vision Loss Expert Group. Global prevalence of vision impairment and blindness: magnitude and temporal trends, 1990-2010. *Ophthalmology*. 2013;120(12):2377-2384.
9. Taylor HR, Keeffe JE, Vu HT, et al. Vision loss in Australia. *Med J Aust*. 2005;182(11):565-568.
10. Graham H, Kelly M. *Health Inequalities: Concepts, Frameworks and Policy*. London, England: NHS Health Development Agency; 2004.
11. Marmot M, Atkinson T, Bell J, et al. *Fair Society, Healthy Lives*. London, England: Marmot Review; 2010.
12. The King's Fund. Time to think differently. <http://www.kingsfund.org.uk/time-to-think-differently>. Updated 2016. Accessed January 29, 2016.
13. CSDH. Closing the gap in a generation: health equity through action on the social determinants of health. Final report of the Commission on Social Determinants of Health. Geneva: World Health Organization. http://www.who.int/social_determinants/thecommission/finalreport/en/. Published 2008. Accessed January 29, 2016.
14. UK Biobank. <http://www.ukbiobank.ac.uk/>. Accessed January 29, 2016.
15. World Health Organization. *International Classification of Diseases*. Ratified by WHO-FIC network at the annual meeting in Tunis, October 2006. <http://www.who.int/classifications/icd/2006Updates.pdf?ua=1>. Published October 2006. Accessed May 19, 2016.
16. World Health Organization. Chapter VII: diseases of the eye and adnexa. *International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10)-2015-WHO version*. <http://apps.who.int/classifications/icd10/browse/2015/en#/H55-H59>. Accessed January 29, 2016.
17. Rahi JS, Cumberland PM, Peckham CS. Visual function in working-age adults: early life influences and associations with health and social outcomes. *Ophthalmology*. 2009;116(10):1866-1871.
18. Townsend P, Phillimore P, Beattie A. *Health and Deprivation: Inequality and the North*. London, England: Croom Helm Ltd; 1988.
19. Gov.UK. Disability living and attendance allowance for adults. <https://www.gov.uk/dla-disability-living-allowance-benefit>. Updated May 12, 2016. Accessed October 1, 2015.
20. Office for National Statistics. Standard occupational classification 2010 (SOC2010). <http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guide-method/classifications/current-standard-classifications/soc2010/index.html>. Accessed May 19, 2016.
21. Vitale S, Cotch MF, Sperduto RD. Prevalence of visual impairment in the United States. *JAMA*. 2006;295(18):2158-2163.
22. Chou CF, Cotch MF, Vitale S, et al. Age-related eye diseases and visual impairment among US adults. *Am J Prev Med*. 2013;45(1):29-35.
23. Sherrard CE, Vitale S, Frick KD, Ramulu PY. Association of vision loss and work status in the United States. *JAMA Ophthalmol*. 2014;132(10):1239-1242.
24. Rahi JS, Cumberland PM, Peckham CS. Visual impairment and vision-related quality of life in working-age adults: findings in the 1958 British birth cohort. *Ophthalmology*. 2009;116(2):270-274.
25. De Stavola BL, Nitsch D, dos Santos Silva I, et al. Statistical issues in life course epidemiology. *Am J Epidemiol*. 2006;163(1):84-96.
26. Congdon N, O'Colmain B, Klaver CC, et al; Eye Diseases Prevalence Research Group. Causes and prevalence of visual impairment among adults in the United States. *Arch Ophthalmol*. 2004;122(4):477-485.
27. Klein R, Lee KE, Gangnon RE, Klein BE. Incidence of visual impairment over a 20-year period: the Beaver Dam Eye Study. *Ophthalmology*. 2013;120(6):1210-1219.
28. Hong T, Mitchell P, Burlutsky G, Gopinath B, Liew G, Wang JJ. Visual impairment and depressive symptoms in an older Australian cohort: longitudinal findings from the Blue Mountains Eye Study. *Br J Ophthalmol*. 2015;99(8):1017-1021.
29. West SK, Munoz B, Rubin GS, Bandeen-Roche K, Broman AT, Turano KA. Compensatory strategy use identifies risk of incident disability for the visually impaired. *Arch Ophthalmol*. 2005;123(9):1242-1247.
30. Gov.UK. Policy paper: NHS Outcomes Framework 2014 to 2015. <https://www.gov.uk/government/publications/nhs-outcomes-framework-2014-to-2015>. Published November 12, 2013. Accessed October 1, 2015.
31. Koh HK, Piotrowski JJ, Kumanyika S, Fielding JE. Healthy people: a 2020 vision for the social determinants approach. *Health Educ Behav*. 2011;38(6):551-557.
32. Khan JC, Thurlby DA, Shahid H, et al; Genetic Factors in AMD Study. Smoking and age related macular degeneration: the number of pack years of cigarette smoking is a major determinant of risk for both geographic atrophy and choroidal neovascularisation. *Br J Ophthalmol*. 2006;90(1):75-80.
33. Ng DH, Roxburgh ST, Sanjay S, Au Eong KG. Awareness of smoking risks and attitudes towards graphic health warning labels on cigarette packs: a cross-cultural study of two populations in Singapore and Scotland. *Eye (Lond)*. 2010;24(5):864-868.
34. Fraser S, Bunce C, Wormald R. Risk factors for late presentation in chronic glaucoma. *Invest Ophthalmol Vis Sci*. 1999;40(10):2251-2257.
35. Sivaprasad S, Gupta B, Gulliford MC, et al. Ethnic variation in the prevalence of visual impairment in people attending diabetic retinopathy screening in the United Kingdom (DRIVE UK). *PLoS One*. 2012;7(6):e39608.
36. Pascolini D, Mariotti SP. Global estimates of visual impairment: 2010. *Br J Ophthalmol*. 2012;96(5):614-618.
37. Resnikoff S, Pascolini D, Mariotti SP, Pokharel GP. Global magnitude of visual impairment caused by uncorrected refractive errors in 2004. *Bull World Health Organ*. 2008;86(1):63-70.
38. Knight A, Lindfield R. The relationship between socio-economic status and access to eye health services in the UK: a systematic review. *Public Health*. 2015;129(2):94-102.
39. Dickey H, Ikenwilo D, Norwood P, Watson V, Zangelidis A. Utilisation of eye-care services: the effect of Scotland's free eye examination policy. *Health Policy*. 2012;108(2-3):286-293.