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Trends in Visual Health Inequalities in Childhood Through Associations of Visual Function With Sex and Social Position Across 3 UK Birth Cohorts

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Supplemental content

IMPORTANCE Despite the existing country-specific strategies tackling social inequalities in visual health in adults, little is known about trends in visual function in childhood and its association with social position.

OBJECTIVE To investigate the distribution of childhood visual function in the United Kingdom and associations with early-life social position between 1961 and 1986, a period of significant social change.

DESIGN, SETTING, AND PARTICIPANTS Longitudinal cohort study using harmonized data sets from the British 1946, 1958, and 1970 national birth cohorts. In total, 14 283 cohort members with complete data on visual acuity at age 15 or 16 years, measured in 1961, 1974, and 1986, respectively, for each cohort, and social position were assessed.

MAIN OUTCOMES AND MEASURES Using habitual distance visual acuity (with correction if prescribed), participants were assigned to a visual function category ranging from bilateral normal to visual impairment/severe visual impairment/blindness (*International Statistical Classification of Diseases, Tenth Revision, Clinical Modification*). Distribution of visual function over time and associations with social position (risk ratios [RRs] and 95% confidence intervals) were analyzed.

RESULTS Complete data were available for 3152 participants (aged 15 years; 53% boys [n = 1660]) in the 1946 Medical Research Council National Survey of Health and Development, 6683 participants (aged 16 years; 51% boys [n = 3420]) in the 1958 National Child Development Study, and 4448 participants (aged 16 years; 48% boys [n = 2156]) in the 1970 British Birth Cohort Study. The proportion of children with bilateral normal vision decreased by 1.3% (95% CI, −5.1% to 2.7%) in 1974 and 1.7% (95% CI, −5.9% to 2.7%) in 1986. The risk of overall impaired vision increased by 1.20 times (95% CI, 1.01-1.43) and the risk of visual impairment/severe visual impairment/blindness by 1.75 times (95% CI, 1.03-2.98) during this period. Girls were consistently at increased risk of all vision impairment categories. Higher social position at birth and in childhood was associated with reduced risk of visual impairment/severe visual impairment/blindness (RR, 0.58; 95% CI, 0.20-1.68) and unilateral impairment (RR, 0.89; 95% CI, 0.72-1.11), respectively.

CONCLUSIONS AND RELEVANCE Our study provides evidence of temporal decline in childhood visual function between 1961 and 1986. Despite the limited power of the analysis owing to the small sample size of those with impaired vision, we found an emergence of a contribution of sociodemographic status to the cohort effect that may be the antecedent of the current picture of childhood blindness. Equally, early-life social position may also have contributed to the current social patterning in visual function in older adults in the United Kingdom. These findings highlight the potential value of targeting children in national ophthalmic public policies tackling inequalities.

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Given the life-changing consequences of vision loss at all stages of life, clinical practice, public health policies, and research in ophthalmology have mainly been directed toward addressing visual impairment rather than promoting visual health. However, a growing evidence base demonstrates that (1) even mildly reduced visual function (including unilateral impairment) in adult life is associated with adverse health and social outcomes[1,2]; (2) a sizeable proportion of the population, approximately one-quarter in some countries,[2] falls into this part of the spectrum that ranges from mild to severe impairment; and (3) social inequalities exist in visual health in adult life[2-4] and increase with aging.[5,6] Thus, country-specific strategic plans are being implemented to tackle visual health inequalities in adults.[7,8] In stark contrast, little is known about the relationship between social position and visual function (across the spectrum of visual acuity) in childhood per se. It is also unknown whether extant inequalities in visual health in adult life may have childhood antecedents, as might be reasonably anticipated from the established public health evidence base outside ophthalmology.[9]

Investigation of these questions and elucidation of the emergence of an association between social position and visual function requires representative population-based studies of childhood in which both visual function and social determinants have been measured together and harmonized across studies carried out sequentially over time. In this study, we examine the distribution of visual function in children born in the United Kingdom between 1946 and 1970 and analyze associations between visual function and social position during these 25 years of significant social change. This work forms part of our broader program of eyes and vision research within the Cohort and Longitudinal Studies Enhancement Resources initiative, which brings together the United Kingdom's unique collection of birth cohort studies of health and disease.[10]

Key Points

Question Has the distribution of visual function in childhood changed over time, and are there associations with social position?

Findings In this longitudinal cohort study, harmonized data from 3 UK birth cohorts spanning 25 years suggest that social position at birth and during childhood were independently associated with visual function, across the full spectrum from normal acuity to blindness, in a complex pattern that changed over time.

Meaning Early-life social position contributed to a temporal decline in visual function in childhood, which supports the hypothesis that it contributes to the current known social patterning in visual function in older adults.

Methods

Study Sample

We drew on the 3 directly comparable birth cohort studies that sampled all births in a single week in England, Scotland, and Wales and also measured visual acuity during childhood. The studies comprise (1) the 1946 Medical Research Council National Survey of Health and Development, consisting of 5362 singleton babies born to married parents, (2) the 1958 National Child Development Study of 17 634 babies (singleton or multiple), and (3) the 1970 British Birth Cohort Study, with 17 287 babies. The 1946 Medical Research Council National Survey of Health and Development study was conducted with the approval of the Medical Research Council Ethics Committee. The 1958 National Child Development Study was approved by the National Health Service Research Ethics Committee. All data collection on 1970 British Birth Cohort Study received a full ethical approval from London Central Research Ethics Committee. All participants gave individual informed written consent to participation and had the option to withdraw from the study. Detailed cohort profiles have previously been published.[11-13] Our study thus examined the 25-year period between 1961 and 1986, as shown in **Figure 1**.

Visual Function

Best-achieved habitual distance visual acuity (ie, with correction if prescribed) was measured at age 15 or 16 years in each cohort using conventional Snellen charts at a distance of 6.1 m.[14-16] Using distance acuity in each eye, we assigned individuals to 1 of 6 mutually exclusive categories, ranging from normal vision to visual impairment, severe visual impairment, or blindness (VI/SVI/BL), extending the World Health Organization taxonomy of visual impairment to include vision loss at a level recognized to affect personal and social life[17,18]:

- Normal (6/4 to 6/9.5 in both eyes)
- Unilateral visual impairment (6/4 to 6/9.5 in one eye and 6/12 or worse in the other eye)
- Socially significant visual impairment (6/12 to 6/18 in the better-seeing eye)
- Visual impairment (6/19 to 6/60 in the better-seeing eye)
- Severe visual impairment (less than 6/60 to 3/60 in the better-seeing eye)
- Blindness (less than 3/60 in both eyes)

Social Position

We were interested a priori in early-life social position but distinguished between prenatal and childhood social position. We thus chose the 2 variables considered to most sensitively capture this at an individual level and that were thus also harmonized across the cohorts[19]: first, mother's educational level (trichotomized as statutory schooling based on the minimum school-leaving age applicable to the mother in that era, extended schooling, ie, to age 18 years, and all further/higher education beyond age 18 years, ie, university or professional training) and second, father's social class based on occupation when the cohort member was aged 10 or 11 years, using the Registrar-General's Social Classes classification (trichotomized as "unskilled/semiskilled," "skilled," or "professional").

Data Management and Statistical Analysis

Because of the small numbers, we combined the visual impairment, severe visual impairment, and blindness categories to facilitate meaningful analysis. The distribution of

Figure 1. Timeline of Visual Acuity Measurements Undertaken in 3 UK Birth Cohorts Since 1946

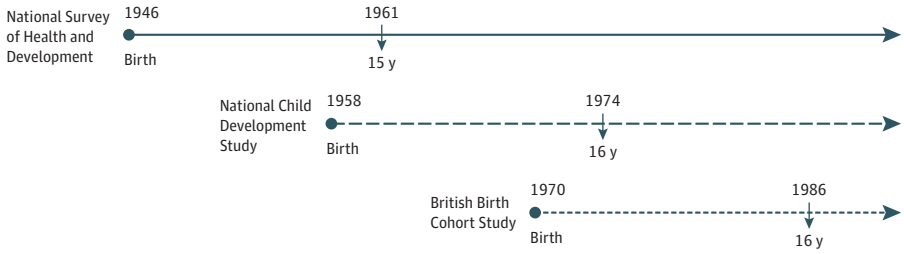
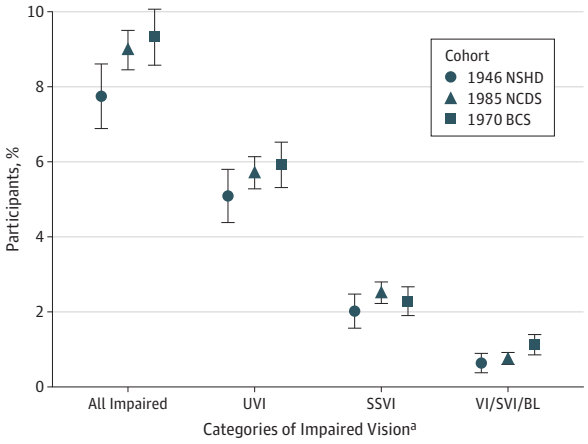


Figure 2. Distribution of Impaired Vision Categories Between Cohorts



Bars represent 95% CIs, symbols represent point estimates. BCS indicates British Birth Cohort Study; NCDS, National Child Development Study; NSHD, National Survey of Health and Development; SSVI, socially significant visual impairment; UVI, unilateral visual impairment; VI/SVI/BL, visual impairment/severe visual impairment/blindness.

[a] Because more than 90% of cohort members (n = 21 048) are within the normal category in each cohort, this plot shows only the impaired visual function categories.

visual function and social position were analyzed as frequencies with 95% confidence intervals. Nested logistic regression (all impaired vision categories combined) as well as multinomial regression models were used to investigate longitudinal trends in visual function, unadjusted (univariable, model 1), adjusted for sex (model 2), prenatal social position (mother's educational level; model 3), and then additionally for childhood social position (father's occupation; model 4). We estimated risk ratios (RRs) with 95% confidence intervals for being in any category of reduced visual function as well as for each category. To examine whether the effect of sex on visual impairment was modified by the varying levels of social class interaction, terms were also tested in the models but excluded from the final model because they were nonsignificant, indicating that there was no evidence that social class modified the association between sex and impaired vision. Analyses were performed using Stata, version 13 (StataCorp LP). All plots were produced using package "ggplot2" in R, version 3.2.0 (R Programming)[20,21] and were restricted to show the distribution of the impaired categories to facilitate their presentation. All tests were 2-sided, with $P < .05$ at 95% confidence interval significance level.

Results

Our analysis is based on participants for whom both social position data and valid visual acuity measurements on both eyes were available at age 15 or 16 years, comprising 3152 children in the 1946 Medical Research Council National Survey of Health and Development (53% boys; n = 1660), 6683 children in the 1958 National Child Development Study (51% boys; n = 3420), and 4448 children in the 1970 British Birth Cohort Study (48% boys; n = 2156). The participant flowchart is shown in the eFigure in the Supplement. Data collection on the 1970 birth cohort was carried out in 1986 during a period of industrial action resulting school closures that prevented medical examinations, including visual acuity measurements, resulting in a sample that was biased toward higher paternal social class and girls. Nevertheless, differences between participants and nonparticipants were negligible with respect to baseline characteristics (eTable 1 in the Supplement). In addition, no bias regarding members' baseline characteristics between those with and without acuity values was evident (eTable 2 in the Supplement). The upward shift in both maternal education level and paternal occupational social class during the study period is shown in eTable 3 in the Supplement.

Cohort Effect in Visual Function

The proportion of 15- or 16-year-old youths with normal vision in both eyes declined from 92.2% (95% CI, 91.4% to 93.1%) for children born in 1946 to 91.0% (95% CI, 90.5% to 91.6%) for those born in 1958 and to 90.7% (95% CI, 89.9% to 91.4%) for those born in 1970, accounted for by an increase in each category of vision impairment during this time. Specifically, over the 25-year period, there was an increase from the 1946 baseline of 16% (95% CI, −2.5% to 40%) for the unilateral visual impairment; 13% (95% CI, −15% to 52%) for the socially significant visual impairment; and 76% (95% CI, 14% to 205%) for the VI/SVI/BL was evident, as shown in **Figure 2**.

The crude and adjusted relative risks for the different categories of impaired vision are shown in the **Table**. Sixteen-year-old children born in 1970 had a 1.20-fold (95% CI, 1.01-1.43) greater risk of any level of impaired vision and a 1.75-fold (95% CI, 1.03-2.98) greater risk of VI/SVI/BL compared with those born in 1946, after adjustment for sex and social position.

Table. Cohort Effect and Associations Between Early Social Position and Risk of Impaired Visual Function in Childhood[a]

Models	RR (95% CI)			
	All Impaired Vision[b] (n = 1219)	UVI[c] (n = 797)	SSVI[c] (n = 313)	VI/SVI/BL[c] (n = 109)
Model 1				
Year of birth				
1958 vs 1946	1.11 (0.95-1.30)	1.11 (0.92-1.34)	1.22 (0.91-1.65)	0.80 (0.47-1.36)
1970 vs 1946	1.23 (1.04-1.45)	1.21 (0.99-1.48)	1.12 (0.81-1.55)	1.64 (0.99-2.71)
Model 2				
Year of birth				
1958 vs 1946	1.11 (0.95-1.30)	1.11 (0.92-1.34)	1.22 (0.91-1.65)	0.80 (0.47-1.35)
1970 vs 1946	1.22 (1.03-1.44)	1.21 (0.99-1.48)	1.11 (0.80-1.54)	1.60 (0.97-2.65)
Sex				
Female vs male	1.16 (1.03-1.30)	1.06 (0.92-1.23)	1.22 (0.97-1.52)	1.84 (1.24-2.72)
Model 3				
Year of birth				
1958 vs 1946	1.10 (0.94-1.29)	1.09 (0.90-1.32)	1.21 (0.89-1.64)	0.84 (0.49-1.43)
1970 vs 1946	1.20 (1.01-1.43)	1.17 (0.95-1.45)	1.10 (0.78-1.54)	1.76 (1.03-3.00)
Sex				
Female vs male	1.16 (1.03-1.30)	1.06 (0.92-1.23)	1.22 (0.97-1.53)	1.84 (1.24-2.73)
Maternal educational level				
Extended vs statutory schooling	1.02 (0.90-1.16)	1.07 (0.91-1.24)	1.00 (0.78-1.27)	0.82 (0.55-1.23)
Higher education vs statutory schooling	1.09 (0.81-1.47)	1.09 (0.76-1.57)	1.26 (0.74-2.15)	0.68 (0.24-1.93)
Model 4				
Year of birth				
1958 vs 1946	1.09 (0.93-1.28)	1.08 (0.89-1.32)	1.20 (0.89-1.64)	0.84 (0.49-1.44)
1970 vs 1946	1.20 (1.01-1.43)	1.17 (0.94-1.45)	1.10 (0.78-1.55)	1.75 (1.03-2.98)
Sex				
Female vs male	1.15 (1.03-1.30)	1.06 (0.92-1.23)	1.21 (0.97-1.52)	1.85 (1.25-2.74)
Maternal educational level				
Extended vs statutory schooling	1.04 (0.91-1.18)	1.09 (0.93-1.27)	1.03 (0.81-1.32)	0.77 (0.51-1.17)
Higher education vs statutory schooling	1.14 (0.84-1.55)	1.16 (0.79-1.69)	1.39 (0.79-2.42)	0.58 (0.20-1.68)
Paternal social class				
Skilled vs unskilled	0.97 (0.83-1.12)	0.98 (0.82-1.18)	0.84 (0.64-1.11)	1.40 (0.81-2.41)
Professional vs unskilled	0.90 (0.76-1.08)	0.89 (0.72-1.11)	0.76 (0.55-1.07)	1.67 (0.92-3.05)

Abbreviations: RR, risk ratio; SSVI, socially significant visual impairment; UVI, unilateral visual impairment; VI/SVI/BL, visual impairment/severe visual impairment/blindness.

[a] Modeling was based on 14 283 cases for which complete data were available. The normal category (n = 13 064) was used as the baseline for the risk ratio against which the other categories were compared.

[b] Binary logistic regression model.

[c] Multinomial regression model.

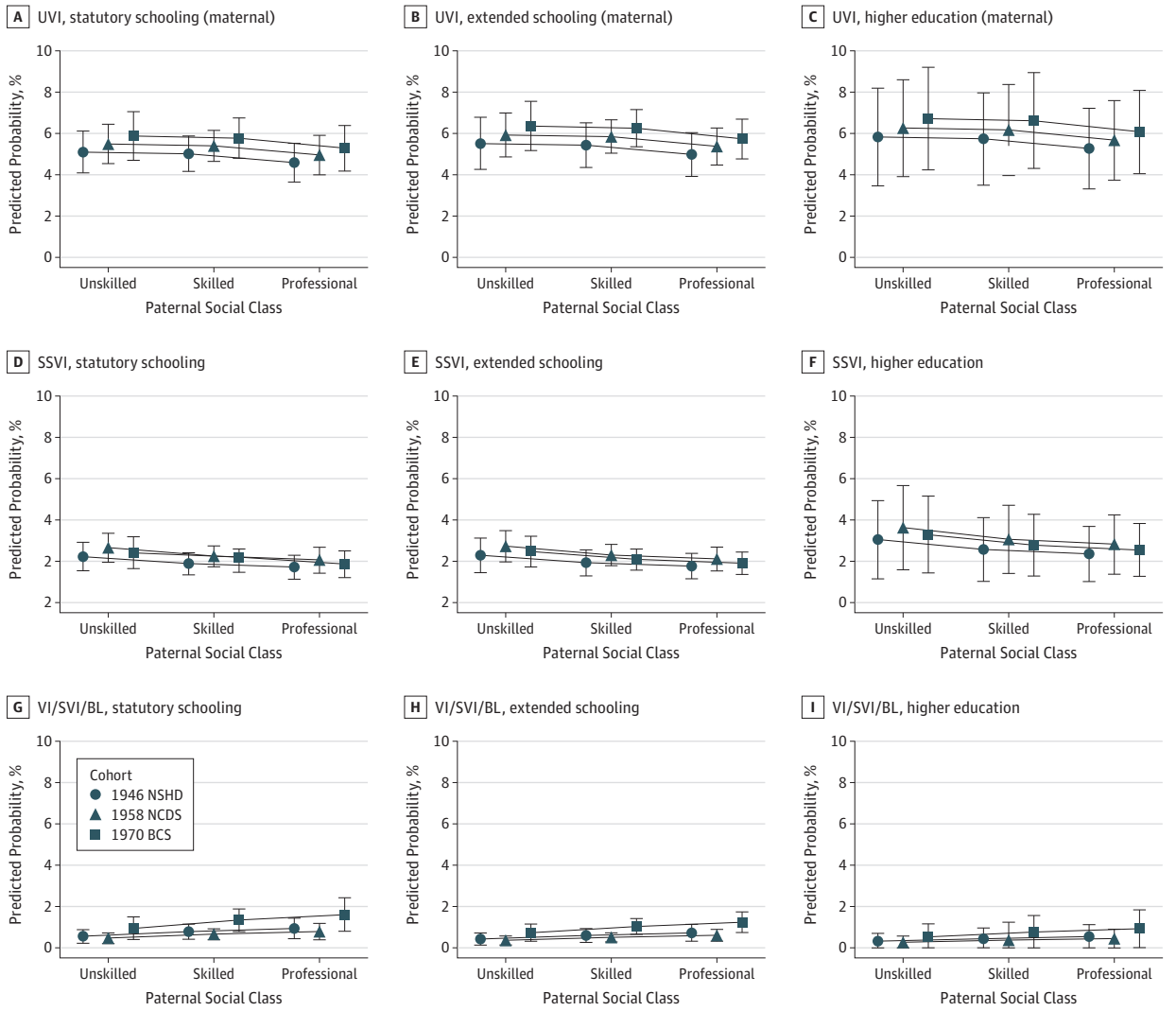
Social Position, Sex, and Visual Function

Girls were at increased risk of being in any and all visual impairment categories, and this gap widened over time, as shown in the Table. This effect was largely driven by the strong association of sex with VI/SVI/BL (model 2; Table) and remained unaffected by adjustment for social position (models 3 and 4; Table). Associations with social position were most clearly discerned when examining specific categories of impaired vision because the pattern was complex. Consistent gradients in the associations of impaired vision categories with social position were found; however, the patterns for social position at birth and in childhood were in the opposing directions, as shown in the Table and **Figure 3**. Higher prenatal social position was associated with a small increased risk of being in any visual impairment category; this was largely driven by the association with unilateral visual impairment, which can be seen by the point estimates of model 4 (Table). The risk of VI/SVI/BL decreased with higher social position (Table). By contrast, higher social position in childhood reduced the risk of being in all categories of impaired vision except for VI/SVI/BL, where the risk was significantly increased. Adjustment for childhood social position altered the size of associations of impaired vision categories with prenatal social position by approximately 10% without changing the direction of the association.

Discussion

Our study demonstrates a decline in visual function during childhood between 1961 and 1986, in which considerable social change occurred in the United Kingdom. This is attributable to increases in all categories of sight impairment, ranging from unilateral impairment to SVI/BL. This cohort effect is associated with sex and with social position in a complex

Figure 3. Predicted Probabilities for Being in 1 of the Categories of Reduced Visual Function Between Cohorts, According to Paternal Social Class and Maternal Educational Level

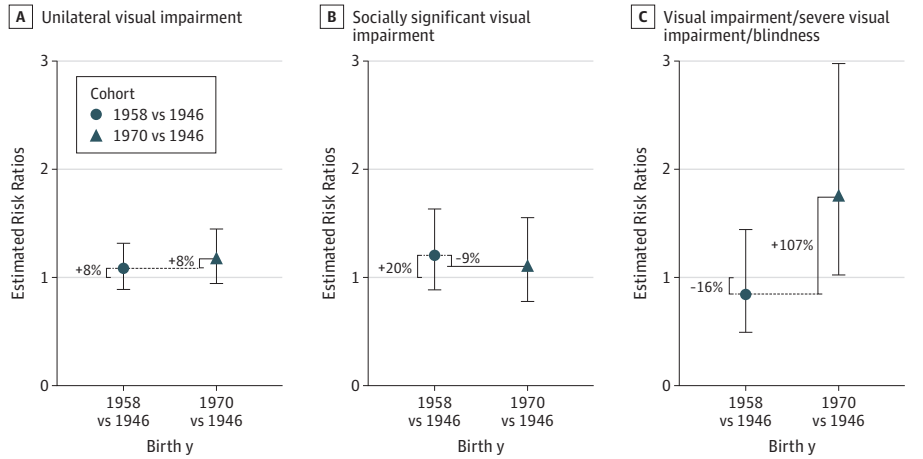


A-C, Plots derived from model 4 presented in the unilateral visual impairment (UVI) column of the Table. D-F, Plots derived from model 4 presented in the socially significant visual impairment (SSVI) column of the Table. G-I, Plots derived from model 4 presented in the visual impairment/severe visual impairment/blindness (VI/SVI/BL) column of the Table. All plots were derived while keeping constant sex. Bars represent 95% CI, symbols represent point estimates, and the y-axis was adjusted to the range of the predicted probability for each visual function category to optimize the visualization of the graph. There is a mean gradual increase over time in the predicted probability for being in the impaired visual function categories. However, the probability for being in the UVI and SSVI categories was decreased as father's social class improved but increased as maternal educational level improved. The opposite trend was noticed for those in the visually impaired category (ie, the probability for being in the visually impaired category increased as father's social class improved but decreased as maternal educational level improved).

pattern that changed over time. These associations evident in childhood per se also mirror known associations between visual function, sex, and social position in adult life.

All 3 cohorts, reflecting the ethnic makeup of the UK population at that time, had so few participants from ethnic minorities that this marker of social position, highly relevant today,[9,22-24] could not be considered. Because impaired vision in childhood is uncommon, despite drawing on 3 national birth cohorts, the sample size without normal vision in both eyes was small, which limited the power of multivariable analysis, as evidenced by the finding of consistent trends in associations that did not always reach conventional statistical significance. Despite these limitations, our observation of declining visual function in childhood occurring during a period that experienced and perhaps more importantly heralded subsequent major changes in social position as well as medical care has potential implications for policy and research now. Our study quantifies a substantial increase in risk of VI/SVI/BL during a relatively short time. While this may not be unexpected, given other prior research on childhood blindness,[15,25] it is nevertheless a striking metric of the balance between changing frequency of underlying conditions (in

Figure 4. Estimated Risk Ratios (95% CI) for the Association Between Birth Year and the Categories of Visual Acuity



The plot was derived from the coefficients of birth year in model 4 presented in the unilateral visual impairment column of the Table. Bars represent 95% CIs, symbols represent point estimates. Dashed lines represent the percentage change between those born in 1958 vs 1946, while solid lines indicate the percentage change between those born in 1970 vs 1958. The horizontal line at y = 1 indicates the reference value for 1946 against which all the comparisons were made.

turn reflecting changing incidence of disease, risk factors, and survival of affected children) and the availability and effectiveness of prevention or treatment for specific disorders during this period. Perhaps most importantly, this finding points to the likely ongoing impact of broader trends in child health such as increasing survival of preterm infants and those with complex systemic conditions, including neurological/neurodevelopment disorders, who are at increased risk of visually impairing eye disease.[26-28]

The 20% overall increased risk of being in any category of impaired vision is unexpected and of interest in the context of the widespread implementation of childhood (mainly preschool) vision screening in the United Kingdom during the 1970s,[29] expected to have a differential effect on prevalence of amblyopia persisting after treatment as the main cause of unilateral vision impairment at age 15 or 16 years. This would be consistent with our finding of a 1.08-fold (95% CI, 0.89-1.32) increased risk of being in this category in 1961, with an additional 1.08-fold (95% CI, 0.91-1.27) increased risk in 1986, as shown in **Figure 4**.

There are no directly equivalent contemporary national birth cohort studies in the United Kingdom with acuity measurements in childhood that would allow us to interrogate further the emerging relationship between childhood visual function and the sociodemographic factors to which our study points. However, from other research from the past decade, we know that both socioeconomic disadvantage and ethnic minority status are risk factors for all-cause SVI/BL in childhood as well as for various ophthalmic conditions,[22,23,30-33] and that social position is associated with visual function in adult life today.[2,6,34] Thus, we suggest that the association between social position and visual function in childhood evidenced by our study is likely to be substantially stronger today, given the well-established literature on widening of social inequalities in child health more broadly.[3,24,35]

Our striking finding that girls were consistently at increased risk of impaired vision, in particular of being VI/SVI/BL, contrasts with the contemporary picture of childhood blindness in the United Kingdom, although it is in line with findings elsewhere[36] and does tally with current[2,37,38] and projected sex inequalities in visual health in adults.[4] Thus, this may provide a clue to the potential role of early life in extant social patterning in visual function in adult life.

Limitations

This is, to our knowledge, the first cross-cohort investigation of the distribution of visual function (across the full spectrum of acuity) and sociodemographic factors in childhood. It draws on a unique, large harmonized nationally representative data set that we assembled as part of the Cohort and Longitudinal Studies Enhancement Resources initiative. Nevertheless, there are limitations. Neither clinical examinations nor information from medical records were available to allow analysis of specific conditions, eg, amblyopia, which is likely to account for most children in the unilateral impairment category and thus postulation of biological mechanisms. Thus, in keeping with the broader literature on social position and health,[9,39,40] our findings relate to all-cause impaired vision as a sensory health outcome rather than addressing questions about etiologic pathways for specific conditions.

Conclusions

Increasing general child health inequalities over the past few decades are well documented.[24] Thus, the value of our study lies in identifying a historical springboard from which subsequent visual health inequalities in childhood are likely to have developed within the broader landscape. As such, it identifies the value of measuring visual function in childhood as a readily accessible marker of neurodevelopment and/or as a metric of sensory health in research investigating or addressing child health inequalities. Equally, although impaired vision in childhood is less common than in adult life, when impact is considered, eg, in terms of restricted educational, occupational, and

social opportunities or costs of medical and social care, the significance of impaired vision originating in childhood becomes apparent.[41] We urge that the importance of early years should not be overlooked in emerging national ophthalmic public health policies and services tackling inequalities.

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Invited Commentary

The Promise and Potential of Pediatric Vision Data

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Bountziouka et al[1] present a novel analysis of national UK data to explore a vitally important but often understudied topic, the visual health of children. Their findings show an overall temporal decline in childhood visual function and identify the potential contribution of sociodemographic status to the development of disparities. The article also demonstrates the potential utility of national vision surveillance in identifying disparities in childhood vision outcomes and understanding what causes them. However, while the large national birth cohort data sets used in this analysis allowed the authors to tease out patterns in visual health on a national scale, the study is unfortunately limited by the age of the data and is likely not representative of conditions in 2017. In fact, the data are so old that children measured in the 3 waves of data collection are now aged 47 years, 59 years, and 71 years, respectively. Therefore, while the Bountziouka et al analysis[1] does provide evidence of childhood visual trends and determinants in the past, more contemporary data would be needed to demonstrate that these have persisted until today.

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When undetected and untreated, childhood vision loss may have permanent effects on a child's life, affecting a child's ability to learn, participation in athletic activities, social interaction, and self-esteem. Good vision contributes to a strong foundation for school readiness and success in life. Early detection and care coordination are critical because some eye diseases, such as amblyopia, are more responsive to treatment before children reach the age of 7 years and, if left untreated, may cause permanent vision loss.[2] In addition, optical correction of significant refractive error may be related to improvements in child development and school readiness.[3-5]

Despite wide recognition and acceptance of the importance of good vision in children, our understanding of the epidemiology and trends of childhood vision problems remains limited. Evidence suggests that children with special health care needs, children from low-income families and who are ethnic and/or racial minorities, and children with reduced access to eye care services experience disproportionately high prevalence of vision problems.[6] These children are also generally underrepresented in data, further hampering efforts to extend care to these vulnerable populations. Nearly all existing estimates of childhood vision are hampered by severe limitations in data scope, limiting our understanding of which populations are at most risk and hindering the appropriate allocation and deployment of public health education and medical initiatives to support early identification of vision problems and care coordination to ensure receipt of eye examinations and treatment in vulnerable populations.

In an admirable attempt to explore temporal trends and disparities in childhood visual health, Bountziouka et al[1] analyzed UK national birth cohort samples (based on all singleton children born nationwide during a selected week) of 15- to 16-year-old children collected in 1961, 1974, and 1986, respectively. From these data, the authors investigate the association of visual function with birth cohort (model 1), birth cohort, sex, and maternal education level (model 2), and additionally by fathers' occupation (unskilled/semiskilled, skilled, and professional) class (model 3). The authors find that overall visual function declined over time; that girls were at higher risk for low visual function, a disparity that increased over time; and that there were mixed effects of prenatal social class (mother's education) and childhood social class (father's occupation), but with a general association of lower social class with higher risk of low vision.

These results both demonstrate a concerning longitudinal epidemiologic pattern and provide evidence to support the existence of disparities associated with sex and economic class. Unfortunately, these findings are not necessarily applicable to children living in 2017 because of the now advanced age of the cohort members. Thus, while Bountziouka et al[1] provide a novel analysis on an important topic, the data that were analyzed are too old to be generalized to children living today because of changes that have occurred since the 1970s, when the