Ethnic Differences in the Prevalence of Myopia and Ocular Biometry in 10- and 11-Year-Old Children: The Child Heart and Health Study in England (CHASE)

Alicja R. Rudnicka, Christopher G. Owen, Claire M. Nightingale, Derek G. Cook, and Peter H. Whincup

PURPOSE. Ethnic differences in childhood prevalence of myopia have not been well characterized in the United Kingdom. In this study, ethnic differences in refractive status and ocular biometry were examined in a multiethnic sample of British children.

METHODS. This was a cross-sectional study of 10- and 11-year-old school children of South Asian, black African Caribbean, and white European ethnic origin. Vision, open-field autorefraction (without cycloplegia), and ocular biometry were measured in each eye. Myopia was defined as spherical equivalent refraction of −0.50 D with unaided vision of 20/30 or worse (in one or both eyes). Ethnic differences in the prevalence of myopia were examined by using logistic regression, and multiple linear regression was used for ethnic differences in ocular biometry. All models were adjusted for age, sex, and clustering within school.

RESULTS. Data were available for 1179 children. The prevalence of myopia was 25.2%, 10.0%, and 3.4%, respectively, in the South Asian, black African Caribbean, and white European children. Adjusted odds ratios (ORs) of myopia compared with the white European children were 8.9 (95% confidence interval [CI] 4.0 to 19.4) in the South Asian and 3.2 (95% CI, 1.4 to 7.2) in black African Caribbean children. Ethnic differences in the prevalence of myopia were largely accounted for by ethnic differences in axial length. The South Asian and black African Caribbean children had longer axial lengths (0.44 mm; 95% CI, 0.30 to 0.57 mm and 0.30 mm; 95% CI, 0.16 to 0.44 mm, respectively).

CONCLUSIONS. Among British children exposed to the same schooling environment, the South Asians had the highest prevalence of myopia, followed by the black African Caribbeans compared with the white Europeans. A quarter of British South Asian children were myopic, which is strongly related to increased axial length. (*Invest Ophthalmol Vis Sci.* 2010;51:6270–6276) DOI:10.1167/iovs.10-5528

From the Division of Community Health Sciences, St. George's, University of London, London, United Kingdom.

This study was performed during a cardiovascular survey funded by the British Heart Foundation project grant (PG/07/033/22770), and the study of myopia and ocular biometry was supported by the Bupa Foundation. The Child Heart and Health Study in England (CHASE) was supported by a grant from the Wellcome Trust (068362/Z/02/Z).

Submitted for publication March 15, 2010; revised July 2, 2010; accepted July 7, 2010.

Disclosure: **A.R. Rudnicka**, None; **C.G. Owen**, None; **C.M. Nightingale**, None; **D.G. Cook**, None; **P.H. Whincup**, None

Corresponding author: Alicja R. Rudnicka, Division of Community Health Sciences, St George's, University of London, Cranmer Terrace, London, SW17 ORE UK; arudnick@sgul.ac.uk.

Myopia is the most common cause of correctable visual impairment in the developed world and a leading cause of preventable blindness in developing countries.[1] Reduced vision in childhood is predominantly due to myopia,[2–5] with a shift toward higher levels of myopia with increasing age.[6] Poor vision as a consequence of uncorrected refractive error has been identified as a priority area by the World Health Organization's global initiative to eliminate avoidable blindness by the year 2020.[7] Geographic variations in myopia prevalence are marked in both child and adult populations with the highest levels of myopia in East Asia, where approximately 80% of young adults are myopic.[8,9] Compared to East Asian children the prevalence of myopia is lower in children from South Asia.[10,11] The lowest prevalence appears to be in white children,[12–14] with similarly low levels of myopia in children of African Caribbean origin.[3,15,16] These variations together with the recent rapid increases in the prevalence of myopia (especially among children in Asia[17] and in higher income countries,[18]) suggest that environmental factors are important determinants of myopia[17] and hence of reduced unaided distance vision.[14] Axial length is a key determinant of the degree of myopia.[19,20] Thus, it is likely that ethnic differences in myopia prevalence would reflect ethnic differences in ocular biometry. However, few studies have examined these differences in children.[3,21,22]

The population prevalence of childhood myopia is not well characterized in the United Kingdom, and little is known about levels of myopia in ethnic minority groups. We therefore examined ethnic differences in the prevalence of myopia and ocular biometry among children of white European, South Asian, and African Caribbean origin, who shared similar geography (resident in London or the Midlands) and schooling. Ocular and potential sociodemographic determinants of myopia in these children were explored.

METHODS

The Child Heart and Health Study in England (CHASE study) is a school-based, cross-sectional survey designed to investigate ethnic differences in the cardiovascular health of children of white European, South Asian, and African Caribbean origin. Multiple Research Ethics Committee approval was obtained for the study. Details of the main study have been reported elsewhere.[23] In brief, 200 state primary schools from three cities (London, Birmingham, and Leicester) with a predefined ethnic mix (based on ethnic composition data provided by the Government Department for Education and Skills) of white European, South Asian (with balanced representation of Indian, Pakistani, and Bangladeshi), and African Caribbean (both African and Caribbean) children were invited to participate. Nonparticipating schools were replaced by neighboring schools from the sampling frame with similar ethnic compositions. Schools that took part in the main study between September 2006 and March 2007 were targeted a year later for the eye

Investigative Ophthalmology & Visual Science, December 2010, Vol. 51, No. 12

study from June 2007 to March 2008. This investigation is based on children from one school year (aged 10 and 11 years) in 46 state primary schools. Informed written consent was obtained from the pupils' parents or guardians, and the research complied with the tenets of the Declaration of Helsinki. Measurements were made by a single trained field team that visited schools in different parts of London, Leicester, and Birmingham, in rotation.

Vision Assessment

Unaided distance vision was measured in each eye at 3 m (at 1 m if line 1 could not be seen; LogMAR Acuity Charts; Keeler, Ltd., Windsor, UK). In children who reported wearing spectacles, visual acuity was measured with current spectacle correction when present. If the best measure of vision was line 6 or worse (logMAR ≥0.3, equivalent to Snellen ≥20/40), the vision tests were repeated using a pin hole.

Assessment of Ocular Refraction

Five measures of ocular refraction in each eye without cycloplegia, using an open-field autorefractor (SRW-5000; Shin-Nippon Commerce Inc., Tokyo, Japan). Each subject was seated with the head positioned using chin and forehead rests and eyes aligned with the eye mark, while observing a red Maltese cross at 5 m through the viewing window. The accuracy and vertex distance of the instrument were set to the default settings of 0.12 D and 12 mm, respectively.

Ocular Biometry

Axial length (AL), anterior chamber depth (ACD), and front surface keratometry (FSK) were measured with noncontact optical coherence biometry (IOL Master; Carl Zeiss Meditec, Ltd. Welwyn Garden City, UK). Calibration was performed with the manufacturer's test eye before each session. A minimum of five measures of AL (differing by <0.2 mm, with a signal-to-noise ratio >2), three measures of keratometry (differing by <0.1 mm), and one measure of ACD (with depths less than <3 mm being repeated) were obtained per eye.

Definition of Refractive Error and Myopia

Definitions of refractive error were similar to those in the Refractive Error Study in Children.[24] Myopia was defined as a spherical equivalent refraction (SER, using autorefractor measurements in negative cylinder form) of −0.50 D or worse in one or both eyes. The maximum positive (least negative) of five readings in each eye was used, as cycloplegia was not used in this study. In addition, a visual cutoff was imposed therefore, those with vision better than logMAR 0.17 (equivalent to 20/30) could not be classified as myopic. Children were classified as myopic if one or both eyes fulfilled these criteria.

Questionnaire Data

The ethnic origin of each child was based on self-defined parental ethnicity (coded with a classification similar to the 2001 U.K. Census) or (if not available) parental report of the ethnic origin of the child. In a small number of subjects without parental data (n = 8, 0.7%) ethnicity was based on the child's report of parental and grandparental place of birth. In the present analyses, *white European* included children whose ethnic origin was defined as white British, white Irish, and white European (or a combination of these) and excludes white Other. *South Asian* included Indian, Pakistani, Bangladeshi, and Sri Lankan (or a combination of these). The remaining Asian children were classified as Asian Other and included Asian-mixed ethnicity, Chinese, and Middle-Eastern ethnic groups. *Black African Caribbean* included black African, black Caribbean, black British, and black Other (or combination of these). Children of other ethnic groups and mixed ethnic origin (except Asian) were allocated to a separate Other group. The ethnic subcategories Indian, Pakistani, Bangladeshi were restricted to children whose parents both originated in the same country and the black African and black Caribbean groups to those who originated in the same region. Socioeconomic status was based on self-reported parental occupation (coded using the SOC2000 occupational classification).[25]

Statistical Analysis

The prevalence of myopia and mean values for ocular biometric measures (SER, AL, ACD, FSK) are presented by sex and ethnicity, with 95% confidence intervals (CIs) adjusted for clustered sampling (Stata/SE software; Stata/SE 10.1 for Windows; StataCorp LP, College Station, TX). Odds ratios (ORs) of myopia (using logistic regression models) comparing the white Europeans with other ethnic groups and girls with boys were adjusted for age, sex (for ethnic comparisons), and ethnicity (for comparisons between the sexes), with random effect for school. For biometric comparisons, linear regression used data from both right and left eyes with additional adjustment for ocular asymmetry as a fixed effect and child and school as random effects; adjustment for height was explored. Residuals from regression models with ocular biometric measures as outcome variables appeared normally distributed; hence, ocular biometric measures were not transformed before the analyses were performed. To examine the contribution of ocular biometric measures explaining ethnic differences in the prevalence of myopia, we also adjusted the ORs for myopia for AL, FSK, and ACD.

Results

Of the 1654 invited, 1179 children (71%) took part. Participation rates were similar among the white Europeans (76%), South Asians (77%), and other ethnic groups (73%), with slightly lower response rates in the black African Caribbeans (61%). The average age was 10.9 years; 561 boys and 618 girls completed vision and ocular biometry assessments. The sampling strategy resulted in a homogeneous group of schools from less-privileged urban settings. Sociodemographic characteristics by ethnic group are shown in Table 1. Age and sex were equivalent in the different ethnic groups. Autorefraction data were measured in 1029 of these children, as the open-field autorefractor was not available for the initial phase of the study. The white European children were mainly white British (with a small number Irish and Eastern European). The black African Caribbean children were 55% black African, 37% black Caribbean, and 8% black Other. The South Asian children were 41% Pakistani, 27% Indian, and 23% Bangladeshi; the remaining 9% were mostly Sri Lankan. Seven percent of the children were assigned to Asian Other, and 18% were included in the Other group.

Prevalence of Myopia

Overall, the prevalence of myopia was 11.9%. It was similar in the boys and the girls and showed no evidence of change over the narrow age range of the children measured (range, 9.8–11.9 years; Table 2). The ethnicity patterns of myopia showed a low prevalence in the white Europeans (3%), moderate in the black African Caribbeans (10%) (as well as Asian Other and Other ethnic groups), and high in the South Asians (25%). Taking the most myopic SER from either eye in those classified as myopic, the median (range) SER was −1.0 D (−0.7 to −1.5 D) in the white Europeans, −1.4 D (−0.8 to −5.4 D) in the black African Caribbeans, −1.5 D (−0.6 to −9.9) in the South Asians, and −2.2 D (−1.1 to −8.9 D) in the South Asian Others. Among the South Asian myopes, 80% myopes wore spectacles, compared with 73% of the black African Caribbean and 63% of the white European myopes. This apparent difference in frequency of spectacle use was not statistically significant (P = 0.80).With adjustment for age and sex, compared with the white European children, those of black African Caribbean origin were 3.2 times more likely to be myopic,

TABLE 1. Demographic Characteristics of 1179 Children Who Underwent Ocular Assessment

	WE (*n* = 268)		BAC (*n* = 280)		SA (*n* = 338)		AO (*n* = 81)		Other (*n* = 212)	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Age, y										
9.8 to <11	168	63	196	70	183	54	60	74	146	69
11 to 11.9	100	37	84	30	155	46	21	26	66	31
Sex										
Male	137	51	119	43	161	48	40	49	104	49
Female	131	49	161	58	177	52	41	51	108	51
Parental occupation										
Managers and senior officials	31	11.6	33	11.8	43	13	10	12	22	10
Professional occupations	40	14.9	27	9.6	30	9	2	2	25	12
Associate professional and technical	27	10.1	47	16.8	22	7	6	7	23	11
Admin and secretarial occupations	28	10.4	27	9.6	28	8	5	6	21	10
Skilled trades occupations	52	19.4	29	10.4	42	12	11	14	37	17
Personal service occupations	21	7.8	39	13.9	20	6	5	6	19	9
Sales and customer service	15	5.6	16	5.7	30	9	6	7	10	5
Process and machine operatives	17	6.3	12	4.3	41	12	11	14	11	5
Elementary occupation	23	8.6	26	9.3	51	15	12	15	26	12
Unclassified	14	5.2	24	8.6	31	9	13	16	18	8

Data are expressed as the number of participants, with the percentage of the corresponding ethnic group. WE, white European; BAC, black African Caribbean; SA, South Asian; AO, Asian other.

whereas the South Asian children were almost 9 times more likely to be myopic (Table 1). These ethnic comparisons were similar in the boys and the girls (*P* for interaction ≥ 0.16).

Although within the black African Caribbean children the black African subgroup showed the strongest OR for myopia, the *P* for heterogeneity was not statistically significant (*P* = 0.28). ORs for myopia were heterogeneous within South Asians (*P* for heterogeneity = 0.05). South Asian Other children (predominantly of Sri Lankan origin) were 26 times more likely to have myopia than were white European children, although this was a small subgroup. ORs for myopia for the remaining South Asian subgroups were 10.4 for the Indian, 7.8 for the Pakistani, and 4.3 for the Bangladeshi children compared with the white European children.

Other Measures of Ocular Biometry

Measures of ocular biometry, including AL, ACD, FSK, SER, and level of astigmatism (in negative form), by sex and ethnic group are summarized (means and 95% CI) in Table 3. Data by age are not presented, because there was no evidence of any changes with age. Corresponding mean differences comparing boys with girls and white Europeans with other ethnic groups are also shown in Table 3. Although there was no evidence of differences between the sexes in SER and level of astigmatism (in agreement with the observations of no difference in the prevalence of myopia), the girls had shorter ALs (by nearly 0.5 mm), shallower ACD (by 0.1 mm), and steeper FSK (by 0.1 mm).

TABLE 2. Prevalence of Myopia by Age, Sex, and Ethnic Group with Mutually Adjusted Odds Ratios

	n	% Myopia Prevalence (95% CI)*	Adjusted OR† (95% CI)
All	1029	11.9 (10.0–14.0)	
Sex			
Male	496	11.7 (8.1–16.7)	1.00
Female	533	12.0 (8.4–16.8)	1.07 (0.72–1.60)
Age, y			
9.8 to <11	727	11.3 (8.4–14.9)	1.00
11 to 11.9	302	13.3 (8.1–21.0)	1.03 (0.66–1.60)
Ethnic group			
White European	233	3.4 (1.7–6.6)	1.00
Black African Caribbean (all)	260	10.0 (7.3–13.5)	3.15 (1.38–7.16)
Caribbean	96	7.3 (3.8–13.5)	2.21 (0.78–6.31)
African	142	12.7 (8.4–18.7)	4.05 (1.70–9.62)
Other	22	4.5 (0.6–25.8)	1.32 (0.16–11.11)
South Asian (all)	262	25.2 (17.7–34.5)	8.85 (4.04–19.41)
Indian	78	26.9 (19.8–35.4)	10.36 (4.30–24.93)
Pakistani	108	22.2 (13.9–33.6)	7.75 (3.26–18.42)
Bangladeshi	45	13.3 (6.2–26.5)	4.31 (1.40–13.23)
South Asian Other	31	48.4 (39.8–57.0)	25.73 (8.92–74.20)
Asian Other	80	12.5 (6.6–22.5)	4.25 (1.58–11.41)
Other	194	6.2 (3.5–10.7)	1.90 (0.76–4.79)

* 95% CI accounts for the clustering of children within school.

† Multilevel logistic regression adjusted for age, sex, and ethnic group with random effect for school.

Table 3. Ocular Biometric Measures by Sex and Ethnic Group, Together with Adjusted Differences by Sex and Ethnic Groups Compared with White Europeans

	n	Axial Length (mm)	Front Surface Keratometry (mm)	Anterior Chamber Depth (mm)	Spherical Equivalent Refraction (D)	Astigmatism (D)
Mean (95% CI)*						
Sex						
Males	561	23.47 (23.40 to 23.55)	7.87 (7.85 to 7.90)	3.47 (3.44 to 3.49)	0.31 (0.16 to 0.47)	−0.58 (−0.63 to −0.53)
Females	618	23.01 (22.93 to 23.08)	7.77 (7.74 to 7.79)	3.36 (3.34 to 3.38)	0.33 (0.18 to 0.48)	−0.61 (−0.66 to −0.56)
Ethnic group						
White Europeans	268	23.01 (22.90 to 23.11)	7.80 (7.77 to 7.84)	3.42 (3.38 to 3.45)	0.75 (0.56 to 0.93)	−0.52 (−0.59 to −0.46)
Black African Caribbean (All)	280	23.25 (23.15 to 23.35)	7.85 (7.82 to 7.88)	3.39 (3.36 to 3.42)	0.31 (0.13 to 0.48)	−0.68 (−0.74 to −0.62)
Black Caribbean	103	23.27 (23.10 to 23.43)	7.82 (7.77 to 7.88)	3.49 (3.44 to 3.53)	0.38 (0.11 to 0.64)	−0.62 (−0.71 to −0.53)
Black African	154	23.26 (23.13 to 23.40)	7.84 (7.79 to 7.88)	3.43 (3.39 to 3.47)	0.25 (0.04 to 0.47)	−0.59 (−0.66 to −0.51)
Black other	23	23.11 (22.76 to 23.46)	7.91 (7.79 to 8.02)	3.42 (3.32 to 3.52)	0.86 (0.32 to 1.40)	−0.73 (−0.91 to −0.54)
South Asian (All)	368	23.43 (23.34 to 23.53)	7.81 (7.78 to 7.84)	3.42 (3.38 to 3.45)	−0.26 (−0.45 to −0.07)	−0.61 (−0.67 to −0.54)
Indian	90	23.47 (23.29 to 23.65)	7.77 (7.72 to 7.83)	3.48 (3.43 to 3.54)	−0.35 (−0.65 to −0.05)	−0.65 (−0.75 to −0.55)
Pakistani	137	23.43 (23.29 to 23.58)	7.82 (7.77 to 7.86)	3.49 (3.44 to 3.53)	−0.06 (−0.32 to 0.20)	−0.59 (−0.67 to −0.50)
Bangladeshi	78	23.26 (23.07 to 23.45)	7.80 (7.74 to 7.86)	3.45 (3.39 to 3.50)	0.22 (−0.16 to 0.61)	−0.43 (−0.56 to −0.30)
South Asian other	33	23.77 (23.48 to 24.06)	7.77 (7.68 to 7.87)	3.47 (3.38 to 3.56)	−0.93 (−1.43 to −0.44)	−0.59 (−0.74 to −0.43)
Asian other	81	23.29 (23.10 to 23.48)	7.78 (7.72 to 7.84)	3.44 (3.38 to 3.50)	0.14 (−0.15 to 0.44)	−0.56 (−0.66 to −0.46)
Other	212	23.16 (23.05 to 23.28)	7.82 (7.79 to 7.86)	3.42 (3.38 to 3.45)	0.48 (0.29 to 0.68)	−0.58 (−0.65 to −0.51)
Adjusted differences (95% CI)†						
Sex						
Females vs males		−0.48 (−0.58 to −0.39)	−0.11 (−0.14 to −0.08)	−0.11 (−0.13 to −0.08)	0.02 (−0.14 to 0.17)	−0.02 (−0.07 to 0.03)
Ethnic group						
Black African Caribbean (all)		0.30 (0.16 to 0.44)	0.05 (0.01 to 0.10)	−0.01 (−0.05 to 0.03)	−0.45 (−0.68 to −0.22)	−0.15 (−0.22 to −0.08)
Black Caribbean		0.29 (0.10 to 0.48)	0.03 (−0.03 to 0.10)	0.02 (−0.03 to 0.08)	−0.47 (−0.77 to −0.17)	−0.16 (−0.25 to −0.06)
Black African		0.32 (0.15 to 0.48)	0.06 (0.00 to 0.11)	−0.03 (−0.08 to 0.01)	−0.50 (−0.77 to −0.23)	−0.13 (−0.22 to −0.05)
Black other		0.17 (−0.18 to 0.53)	0.12 (0.01 to 0.24)	−0.03 (−0.13 to 0.07)	−0.04 (−0.59 to 0.52)	−0.25 (−0.43 to −0.07)
South Asian (all)		0.44 (0.30 to 0.57)	0.01 (−0.04 to 0.05)	0.00 (−0.04 to 0.04)	−1.00 (−1.23 to −0.76)	−0.08 (−0.15 to 0.00)
Indian		0.45 (0.25 to 0.64)	−0.03 (−0.09 to 0.03)	0.01 (−0.05 to 0.06)	−1.15 (−1.49 to −0.82)	−0.11 (−0.22 to 0.00)
Pakistani		0.43 (0.26 to 0.60)	0.03 (−0.03 to 0.08)	0.02 (−0.04 to 0.07)	−0.85 (−1.15 to −0.55)	−0.11 (−0.21 to −0.02)
Bangladeshi		0.31 (0.10 to 0.52)	0.02 (−0.04 to 0.09)	−0.03 (−0.09 to 0.03)	−0.63 (−1.03 to −0.22)	0.05 (−0.08 to 0.19)
South Asian other		0.76 (0.46 to 1.06)	−0.01 (−0.11 to 0.09)	−0.01 (−0.10 to 0.08)	−1.78 (−2.28 to −1.28)	−0.09 (−0.25 to 0.07)
Asian other		0.30 (0.10 to 0.51)	−0.02 (−0.09 to 0.05)	0.03 (−0.03 to 0.09)	−0.60 (−0.93 to −0.27)	−0.03 (−0.14 to 0.07)
Other		0.17 (0.02 to 0.32)	0.02 (−0.03 to 0.07)	0.00 (−0.04 to 0.05)	−0.26 (−0.51 to −0.02)	−0.06 (−0.13 to 0.02)

Refractive outcome measures are limited to 1029 children who had autorefraction in both eyes (496 boys and 533 girls). Three children did not have anterior chamber depth measurements.

* The 95% CIs account for the clustering of children within school.

† Multilevel linear regression adjusted for age, sex, and ethnic group with random effects for school and child.

The black African Caribbean children were the tallest (mean height, 148.3 cm) followed by the white European (144.5 cm) and South Asian (144.2 cm) children. Adjustment for height made little difference in the results in Table 2 (data not presented). Compared with the white European children, the South Asian children had 0.4 mm longer ALs, 1 D more myopia, and slightly higher levels of negative astigmatism; FSK and ACDs were similar. Differences between the white European, Asian Other, and black African Caribbean children followed a pattern similar to that in the South Asian children, but the differences were less marked (except for FSK, where the black African Caribbeans had flatter corneas). The Other ethnic group showed ocular biometry similar to that of white Europeans, except for marginally longer ALs and slightly more myopia. Patterns were very similar in the black African and black Caribbean ethnic subgroups. The South Asian Others had the longest AL and most myopic average SER (the same patterns as observed in the prevalence of myopia). The Indian and Pakistani subgroups had similar biometric characteristics, except the Indian children, who had a more myopic SER than did the Pakistani children; less extreme differences were observed in the Bangladeshis and Asian Others.

There was a suggestion ($P = 0.02$) that the ethnic differences in AL and SER were marginally larger in the South Asian girls than in the South Asian boys. Ethnic differences in AL (95% CI) and SER were 0.28 mm (0.09 to 0.47 mm) and −0.72 D (−1.02 to −0.40 D) in the South Asian boys and 0.59 mm (0.40 to 0.78 mm) and −1.27 D (−1.60 to −0.94 D) in the South Asian girls, compared with the measurements in the white European children. For the other main ethnic groups, there was no evidence of an interaction between ethnicity and sex.

There was some evidence that the South Asian children came from a lower socioeconomic level than did the white European children. However, additional adjustment for parental socioeconomic position had marginal impact on sex and ethnic differences, and hence these results are not presented.

Effect of Adjusting Ethnic Differences in Prevalence of Myopia for Ocular Biometry

Ethnic differences in myopia prevalence (adjusted for age and sex) were weakened after further adjustment for AL. The OR (95% CI) comparing the white European with the black African Caribbean children was reduced from 3.2 (1.4–7.2) to 1.7 (0.7–4.0) after adjustment for AL. Further adjustment for keratometry and ACD weakened the OR further to 1.4 (0.4–4.1). In the comparison of the white Europeans with the South Asians, the OR was reduced by a smaller amount, from 8.8 (4.0–19.4) to 5.4 (2.4–12.1) after adjustment for AL and to 2.1 (0.7–6.2) after additional adjustment for keratometry and ACD. Ethnic differences in mean SER were also weakened after adjustment for AL, FSK, and ACD but remained statistically significant. Compared with the white Europeans, the black African Caribbeans, and South Asians had a more myopic SER of −0.11 D (−0.23 to +0.02) and −0.20 D (−0.33 to −0.07 D), respectively, after full adjustment, with the largest contribution being ethnic differences in AL. Adjustment for AL reduced the total residual variance in SER by 35%. There was insufficient power to provide clear evidence of ethnic subgroup differences in myopia prevalence and SER with the additional adjustment for biometric measures; hence, data are not presented.

Discussion

In this study, provides strong evidence that British South Asian children have a higher prevalence of myopia than do white European children. The black African Caribbean children also showed a higher prevalence of myopia compared with the white children, but not to the same degree as the South Asian children. Differences in myopia prevalence and SER corresponded with ethnic differences in ocular biometry, with black African Caribbean children and especially South Asians having longer ALs.

The prevalence of myopia observed in white Europeans (OR, 3.4%; 95% CI, 1.7%–6.6%) is similar to that reported in studies in which different methods were used to define myopia in white British children of a similar age, including definitions based on vision cutoffs in three large birth cohorts[14] and lower than in a recent U.K. study of older children,[26] in which Refractive Error Study in Children definitions were used.[24] The mean SER (+0.75 D) in the present study lay between levels reported in younger and older white U.K. children (Logan N, et al. *IOVS* 2008;49:ARVO E-Abstract 2602). Collectively, these studies provide little evidence that there has been a sizeable change in the recent prevalence of myopia or degree of myopia among British white children. Similar estimates have been reported in white children in the United States[3] and Australia,[13] with the prevalence of myopia among white populations in Australia remaining stable over time.[27]

Studies in nonwhite populations have suggested rapid increases in the prevalence of myopia, especially among children from Asia (particularly in children living in East Asia).[9,28–30] Moreover, a high prevalence of myopia in childhood has also been observed among Asians resident outside their country of origin, both in the United States[3] and Australia.[13] Preliminary findings in other U.K.-based studies have suggested a higher prevalence of myopia among Asians compared with non-Asians at 10 years of age,[31] and the emergence of higher levels of myopia among South Asians in adolescence (Logan N, et al. *IOVS* 2008;49:ARVO E-Abstract 2602). However, in most studies to date, the sampling frames used were not specifically designed to examine ethnic differences (mostly white populations studied).[3,13,31] The present study provides strong evidence that the burden of myopia is higher among British South Asians than among white Europeans (especially among Pakistani and Indian children). Our estimate of myopia's prevalence in British Indian children (27%) agrees with a study of migrant[13] and indigenous[32] Indian children. Others have reported much lower estimates of between 4% and 10% in similar aged children living in India.[10,33–35] The prevalence of myopia was similar between children of black African and Carib bean origin, and our estimates agree with studies in black Americans,[3] but lower estimates have been reported in black Africans living in Africa.[15,16,36] Most of the black African Caribbean children in the present study were born in the United Kingdom. The frequency of spectacle use was similar across the ethnic groups and suggests that cultural/ethnic differences in health-seeking behavior are unlikely to explain these findings.

Differences between the sexes in the prevalence of myopia and SER were absent in the present study (except perhaps for South Asians), in agreement with findings in studies in similar aged children.[13,14,37] Sex-related differences have been reported later in childhood and adolescence, with higher levels of myopia in girls.[13,14,37,38] The reason for sex-related differences remains unclear but it may reflect differences between the sexes in response to environmentally determined factors, such as educational demand. The observation that girls have shorter ALs, steeper corneas, and shallower anterior chambers than boys at this age is supported by others[13,22,38,39] and was unaffected by adjustment for height.

An important feature of the present study design was to ensure similar numbers of children of white European, South Asian, and black African Caribbean origin. The cluster sampling design limits the influence of confounding factors, such as area of residence, degree of urbanization, educational status, and other sociodemographic factors. The high response rate (71%) and the similar response rates of the ethnic groups, limits the role of selection bias, wherein those with different visual characteristics do not participate.

One potential weakness of the present study is the use of habitual levels of ametropia as opposed to using levels ascertained after cycloplegia. There has been considerable debate about using cycloplegia in child surveys.[28,40] The current consensus recommends the use of cycloplegia to allow latent hyperopia and pseudoaccommodative myopia to be identified.[24] It was not feasible to include cycloplegia in the present study because of the possibility that it would influence the systemic vascular measures (carotid–femoral pulse wave velocity) that were performed at the same time. There were also concerns about short-term effects on the child's schooling and mobility, which could have led to lower participation rates. Hence, noncycloplegic levels of refraction were used to define myopia, which may overestimate the burden of myopia.[27] However, a recent study showed the open-field autorefraction without cycloplegia in 7- to 12-year-old children agreed well with cycloplegic refraction for the diagnosis of myopia of ≥0.5 D,[41] and this approach was validated in a similar age group showing a 90% detection rate for myopia (Logan N, personal communication, 2010; Aston Eye Study, Aston University, Birmingham, UK; information available at http://www1.aston.ac.uk/lhs/research/health/org/eye-study/). The use of an open- rather than closed-field autorefractor with a nonaccommodative distant target (along with using the most positive of five consecutive readings with an appropriate visual cutoff) limits the extent of myopia misclassification. This approach is likely to limit difficulties encountered in earlier studies in which closed-field autorefraction without cycloplegia has been used to define myopia[40,42–44] and is unlikely to invalidate the ethnic differences in myopia observed, as any potential measurement error would exert a similar effect across ethnic groups.

High levels of educational demand and urbanization, rather than genetic predisposition, have been proposed as factors that contribute to the increased prevalence of myopia in childhood and adolescence,[18] especially among children resident in East Asia.[45–48] Our method of sampling resulted in such factors being balanced across the ethnic groups as the children in this study were of similar background with shared schooling; additional adjustment for parental socioeconomic status had little impact on the findings. Hence, the results of this study suggest that, as well as environmental factors and cultural patterning of visual activities,[13] certain ethnic groups may be more susceptible to myopia in response to their visual environment. This conclusion is contrary to the perceived view that populations are equally susceptible to environmental risk factors for myopia.[18] Variations in susceptibility, either as a result of genetic factors or early life exposure, such as birthweight,[14,49,50] may be responsible for the myopic shift in East Asians and potentially emerging myopic shift in South Asian and black African children, although further studies quantifying the global variation in prevalence of myopia are needed. Heterogeneity between South Asian boys and girls in comparison to white children for AL and SER may be indicative of the difference between the sexes in refractive error and myopia prevalence, emerging earlier within South Asians. Differences between the sexes have been observed in other studies.[13,14,37,38] It remains to be established whether these myopigenic environmental influences extenuate ethnic differences in later childhood; longitudinal studies will help in investigating this question.

Conclusion

Prevalence of myopia among British South Asian children is higher than among white European and black African Caribbean children attending the same schools. Understanding the reasons for these ethnic differences (the degree to which these are environmental and/or genetic) may help in formulating strategies to reduce the burden of myopia in later life, especially as myopia is a major cause of visual impairment in lower income countries with less scope for visual correction.

Acknowledgments

The authors thank the members of the CHASE study team (in particular, Alicja Kiedzik, Devina Jo-Anne Joysurry, and Melanie Prescott, who made the ocular measures); the participating schools, pupils, and parents; the Birmingham Optical Group (Birmingham, UK) who provided a handheld fundus camera (NM-200D; Nidek, Gamagori, Japan); and Nicola Logan (Aston University, Birmingham, UK) who provided an autorefractor (Shin-Nippon Commerce Inc., Tokyo, Japan) for the duration of the study.

References

1. Congdon NG, Friedman DS, Lietman T. Important causes of visual impairment in the world today. *JAMA.* 2003;290(15):2057–2060.
2. Junghans B, Kiely PM, Crewther DP, Crewther SG. Referral rates for a functional vision screening among a large cosmopolitan sample of Australian children. *Ophthalmic Physiol Opt.* 2002; 22(1):10–25.
3. Kleinstein RN, Jones LA, Hullett S, Kwon S, Lee RJ, Friedman NE et al. Refractive error and ethnicity in children. *Arch Ophthalmol.* 2003;121(8):1141–1147.
4. Lam CS, Goldschmidt E, Edwards MH. Prevalence of myopia in local and international schools in Hong Kong. *Optom Vis Sci.* 2004;81(5):317–322.
5. Cumberland PM, Peckham CS, Rahi JS. Inferring myopia over the lifecourse from uncorrected distance visual acuity in childhood. *Br J Ophthalmol.* 2007;91(2):151–153.
6. Weale RA. Epidemiology of refractive errors and presbyopia. *Surv Ophthalmol.* 2003;48(5):515–543.
7. Pizzarello L, Abiose A, Ffytche T, et al. VISION 2020: The Right to Sight: a global initiative to eliminate avoidable blindness. *Arch Ophthalmol.* 2004;122(4):615–620.
8. Chow YC, Dhillon B, Chew PT, Chew SJ. Refractive errors in Singapore medical students. *Singapore Med J.* 1990;31(5):472–473.
9. Saw SM. A synopsis of the prevalence rates and environmental risk factors for myopia. *Clin Exp Optom.* 2003;86(5):289–294.
10. Dandona R, Dandona L, Srinivas M, et al. Refractive error in children in a rural population in India. *Invest Ophthalmol Vis Sci.* 2002;43(3):615–622.
11. Goh PP, Abqariyah Y, Pokharel GP, Ellwein LB. Refractive error and visual impairment in school-age children in Gombak District, Malaysia. *Ophthalmology.* 2005;112(4):678–685.
12. Drover JR, Kean PG, Courage ML, Adams RJ. Prevalence of amblyopia and other vision disorders in young Newfoundland and Labrador children. *Can J Ophthalmol.* 2008;43(1):89–94.
13. Ip JM, Huynh SC, Robaei D, et al. Ethnic differences in refraction and ocular biometry in a population-based sample of 11–15-year-old Australian children. *Eye.* 2008;22(5):649–656.
14. Rudnicka AR, Owen CG, Richards M, Wadsworth ME, Strachan DP. Effect of breastfeeding and sociodemographic factors on visual outcome in childhood and adolescence. *Am J Clin Nutr.* 2008; 87(5):1392–1399.
15. Naidoo KS, Raghunandan A, Mashige KP, et al. Refractive error and visual impairment in African children in South Africa. *Invest Ophthalmol Vis Sci.* 2003;44(9):3764–3770.
16. Anera RG, Jimenez JR, Soler M, Perez MA, Jimenez R, Cardona JC. Prevalence of refractive errors in school-age children in Burkina Faso. *Jpn J Ophthalmol.* 2006;50(5):483–484.

17. Saw SM, Tong L, Chua WH, et al. Incidence and progression of myopia in Singaporean school children. *Invest Ophthalmol Vis Sci.* 2005;46(1):51–57.
18. Morgan I, Rose K. How genetic is school myopia? *Prog Retin Eye Res.* 2005;24(1):1–38.
19. Saw SM, Chua WH, Hong CY, et al. Nearwork in early-onset myopia. *Invest Ophthalmol Vis Sci.* 2002;43(2):332–339.
20. Goss DA, Cox VD, Herrin-Lawson GA, Nielsen ED, Dolton WA. Refractive error, axial length, and height as a function of age in young myopes. *Optom Vis Sci.* 1990;67(5):332–338.
21. Garner LF, Meng CK, Grosvenor TP, Mohidin N. Ocular dimensions and refractive power in Malay and Melanesian children. *Ophthalmic Physiol Opt.* 1990;10(3):234–238.
22. Gwiazda J, Marsh-Tootle WL, Hyman L, Hussein M, Norton TT. Baseline refractive and ocular component measures of children enrolled in the correction of myopia evaluation trial (COMET). *Invest Ophthalmol Vis Sci.* 2002;43(2):314–321.
23. Whincup PH, Nightingale CM, Owen CG, et al. Early emergence of ethnic differences in type 2 diabetes precursors in the United Kingdom: the Child Heart And health Study in England (CHASE Study). *PloS Med.* 2010;7(4):e1000263.
24. Negrel AD, Maul E, Pokharel GP, Zhao J, Ellwein LB. Refractive Error Study in Children: sampling and measurement methods for a multi-country survey. *Am J Ophthalmol.* 2000;129(4):421–426.
25. Office for National Statistics. *Standard Occupational Classification 2000* vols 1 and 2. London: The Stationary Office; 2000.
26. O'Donoghue L, McClelland JF, Logan NS, Rudnicka AR, Owen CG, Saunders KJ. Refractive error and visual impairment in school children in Northern Ireland. *Br J Ophthalmol.* 2010;94(9);1155–1159.
27. Junghans BM, Crewther SG. Little evidence for an epidemic of myopia in Australian primary school children over the last 30 years. *BMC Ophthalmol.* 2005;5:1.
28. Saw SM, Goh PP, Cheng A, Shankar A, Tan DT, Ellwein LB. Ethnicity-specific prevalences of refractive errors vary in Asian children in neighbouring Malaysia and Singapore. *Br J Ophthalmol.* 2006;90(10):1230–1235.
29. Fan DS, Lam DS, Lam RF, et al. Prevalence, incidence, and progression of myopia of school children in Hong Kong. *Invest Ophthalmol Vis Sci.* 2004;45(4):1071–1075.
30. Quek TP, Chua CG, Chong CS, et al. Prevalence of refractive errors in teenage high school students in Singapore. *Ophthalmic Physiol Opt.* 2004;24(1):47–55.
31. Williams C, Miller LL, Gazzard G, Saw SM. A comparison of measures of reading and intelligence as risk factors for the development of myopia in a UK cohort of children. *Br J Ophthalmol.* 2008;92(8):1117–1121.
32. Khan AA, Nasti AR, Ayoub DM, Lone SA. Prevalence of refractive errors in school children. *JK Practitioner.* 2005;12(3):156–159.
33. Dandona R, Dandona L, Naduvilath TJ, Srinivas M, McCarty CA, Rao GN. Refractive errors in an urban population in Southern India: the Andhra Pradesh Eye Disease Study. *Invest Ophthalmol Vis Sci.* 1999;40(12):2810–2818.
34. Kalikivayi V, Naduvilath TJ, Bansal AK, Dandona L. Visual impairment in school children in southern India. *Indian J Ophthalmol.* 1997;45(2):129–134.
35. Murthy GV, Gupta SK, Ellwein LB, et al. Refractive error in children in an urban population in New Delhi. *Invest Ophthalmol Vis Sci.* 2002;43(3):623–631.
36. Johnstone WW, McLaren DS. Refraction anomalies in Tanganyikan children. *Br J Ophthalmol.* 1963;47:95–108.
37. Lin LL, Shih YF, Hsiao CK, Chen CJ. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. *Ann Acad Med Singapore.* 2004;33(1):27–33.
38. Zadnik K, Manny RE, Yu JA, et al. Ocular component data in schoolchildren as a function of age and gender. *Optom Vis Sci.* 2003;80(3):226–236.
39. Lin LL, Shih YF, Tsai CB, et al. Epidemiologic study of ocular refraction among schoolchildren in Taiwan in 1995. *Optom Vis Sci.* 1999;76(5):275–281.
40. Williams C, Miller L, Northstone K, Sparrow JM. The use of non-cycloplegic autorefraction data in general studies of children's development. *Br J Ophthalmol.* 2008;92(5):723–724.
41. Choong YF, Chen AH, Goh PP. A comparison of autorefraction and subjective refraction with and without cycloplegia in primary school children. *Am J Ophthalmol.* 2006;142(1):68–74.
42. Zhao J, Mao J, Luo R, Li F, Pokharel GP, Ellwein LB. Accuracy of noncycloplegic autorefraction in school-age children in China. *Optom Vis Sci.* 2004;81(1):49–55.
43. Fotedar R, Rochtchina E, Morgan I, Wang JJ, Mitchell P, Rose KA. Necessity of cycloplegia for assessing refractive error in 12-year-old children: a population-based study. *Am J Ophthalmol.* 2007; 144(2):307–309.
44. Williams C, Northstone K, Howard M, Harvey I, Harrad RA, Sparrow JM. Prevalence and risk factors for common vision problems in children: data from the ALSPAC study. *Br J Ophthalmol.* 2008; 92(7):959–964.
45. He M, Huang W, Zheng Y, Huang L, Ellwein LB. Refractive error and visual impairment in school children in rural southern China. *Ophthalmology.* 2007;114(2):374–382.
46. Wu HM, Seet B, Yap EP, Saw SM, Lim TH, Chia KS. Does education explain ethnic differences in myopia prevalence?—a population-based study of young adult males in Singapore. *Optom Vis Sci.* 2001;78(4):234–239.
47. Lam C, Goh W. The incidence of refractive errors among school children in Hong Kong and its relationship with the optical components. *Clin Exp Optom.* 1991;74(3):97–103.
48. Goldschmidt E, Lam CS, Opper S. The development of myopia in Hong Kong children. *Acta Ophthalmol Scand.* 2001;79(3):228–232.
49. Saw SM, Tong L, Chia KS, et al. The relation between birth size and the results of refractive error and biometry measurements in children. *Br J Ophthalmol.* 2004;88(4):538–542.
50. Ojaimi E, Robaei D, Rochtchina E, Rose KA, Morgan IG, Mitchell P. Impact of birth parameters on eye size in a population-based study of 6-year-old Australian children. *Am J Ophthalmol.* 2005;140(3): 535–537.