Refractive Errors in a Black Adult Population: The Barbados Eye Study

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Purpose. To describe the prevalence of refractive errors in a black adult population.

Methods. The Barbados Eye Study, a population-based study, included 4709 Barbados-born citizens, or 84% of a random sample, 40 to 84 years of age. Myopia and hyperopia were defined as a spherical equivalent <-0.5 diopters and $>+0.5$ diopters, respectively, based on automated refraction. Analyses included 4036 black participants without history of cataract surgery. Associations with myopia and hyperopia were evaluated in logistic regression analyses.

Results. The prevalence of myopia was 21.9% and was higher in men (25.0%) than in women (19.5%). The prevalence of hyperopia was 46.9% and was higher in women (51.8%) than in men (40.5%). The prevalence of myopia decreased from 17% in persons 40 to 49 years of age to 11% in those 50 to 59 years of age, but increased after 60 years of age. The prevalence of hyperopia increased from 29% at 40 to 49 years of age to 65% at 50 to 59 years of age, and tended to decline thereafter. A higher prevalence of myopia was positively associated ($P < 0.05$) with lifetime occupations requiring nearwork, nuclear opacities, posterior subcapsular opacities, glaucoma, and ocular hypertension. Factors associated with hyperopia were the same as for myopia, except for occupation, and in the opposite direction.

Conclusions. High prevalences of myopia and hyperopia were found in this large black adult population. The prevalence of myopia (hyperopia) increased (decreased) after 60 years of age, which is inconsistent with data from other studies. The high prevalence of age-related cataract, glaucoma, and other eye conditions in the Barbados Eye Study population may contribute to the findings. (*Invest Ophthalmol Vis Sci.* 1999;40:2179–2184)

Refractive errors are the most common eye conditions in the world. Although most errors can be corrected by optical or surgical methods, these treatments have some drawbacks and pose a large economic burden. In the US, an estimated 12.8 billion dollars were spent on the correction of refractive errors in 1990.[1] The etiologic mechanisms of refractive errors can be both genetic and environmental.[2–4] Genetics plays a role in the growth and structure of the eye, as demonstrated in twin and family studies.[5–7] Close-up work, particularly reading, is generally considered as an environmental factor that may lead to myopia.[2–4] Furthermore, other eye conditions such as cataract, glaucoma, or ocular hypertension often coexist with refractive errors.[8–13] The interaction of all these factors and the underlying mechanisms of refractive errors remain unclear.

Prevalence data on the magnitude and distribution of refractive errors are important for public health care planning. However, limited population-based data exist on the distribution of refractive errors in black adults. The National Health and Nutrition Examination Survey (NHANES; 1971–1972) showed a lower prevalence of myopia for African–Americans than for whites between the ages of 12 and 54 years of age.[14] More recently, the Baltimore Eye Survey reported that refractive errors are common among adult inner city residents ≥40 years, but African–Americans had less myopia and hyperopia than whites.[15] In addition to race, the distribution of refractive errors varies by age and gender.[14,15] This report describes the prevalence of refractive errors in a large predominantly black adult population from the Barbados Eye Study (BES). An additional aim is to evaluate associations with demographic factors, while accounting for concomitant ocular conditions.

Methods

The Barbados Eye Study (BES), a population-based study, included 4709 Barbados-born citizens, or 84% of the eligible members of a simple random sample, 40 to 84 years of age. The BES (1987–1992) aimed to determine prevalence and evaluate factors for ocular diseases, and its design and methods have been described elsewhere.[16] In brief, the BES protocol included various ophthalmic and other measurements, such as best-corrected visual acuity with a Ferris–Bailey chart, Humphrey perimetry, applanation tonometry, lens grading, and

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TABLE 1. Demographic Characteristics of Study Participants

Age, y	
Mean ± SD	58.2 ± 11.7
Median	57
Female, %	57
Race, %	
Black	93
Mixed	4
White/other	3
Education, y	
Mean ± SD	10.4 ± 3.2
Median	10
Occupation, %	
Nearwork related	
Professional, managerial	10
Clerical	10
Technical, electrical	12
Other	
Service	36
Agricultural, water-related activities	16
Production work	2
Homemaker/other	14

n = 4330.

color stereophotography. The study followed the tenets of the Declaration of Helsinki. Non-cycloplegic refractive errors were measured on all participants with the Humphrey Automated Refractor #530. When the refractor could not be used or refraction was unreliable, the participant's present correction, if any, was determined with a lensometer.

Evaluations in this report were based on automated refractor data, after excluding participants with a previous history of cataract surgery. Because of the high correlation between eyes (Pearson's $r = 0.78$) and because of the similarity of results based on left or right eyes, we report data from right eyes only. For the purpose of comparison across studies, myopia was defined as having a spherical equivalent <-0.5 diopter (D), and hyperopia was defined as having a spherical equivalent >0.5 D. Additional analyses based on a more stringent definition using cutoff values such as ± 1 D were also conducted. Distributions of refractive errors by self-reported race were compared and evaluated in regression analysis, controlling for

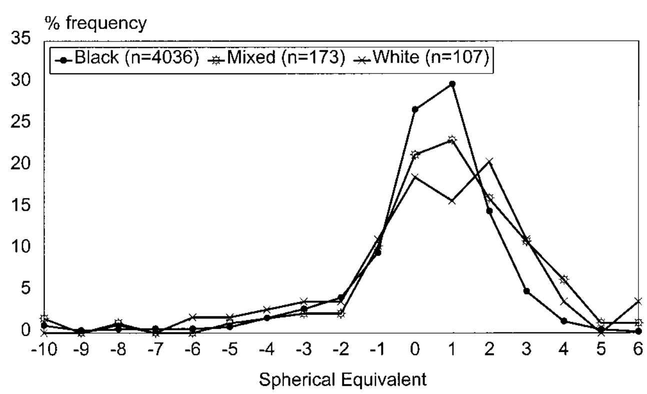

FIGURE 1. Refractive errors* (spherical equivalent) by self-reported race. *OD only; mean ± sd (median): 0.14 ± 2.24 (0.5) for black, 0.57 ± 2.74 (0.75) for mixed, 0.55 ± 2.52 (0.75) for white participants.

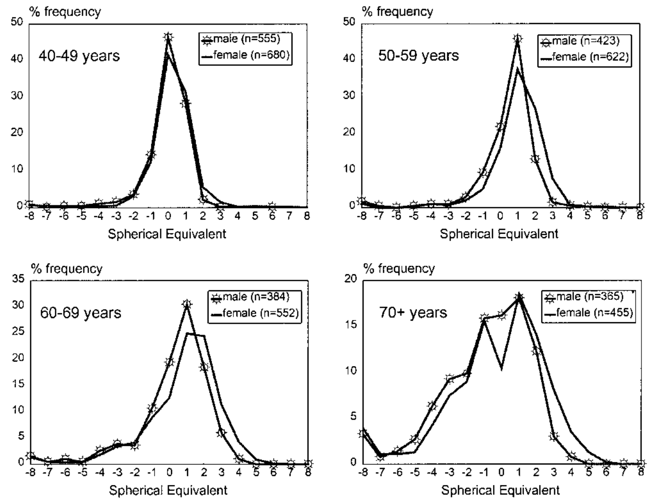

FIGURE 2. Refractive errors (spherical equivalent) by age and gender in BES black participants.

age and gender. Age-gender specific distributions of refractive errors and prevalence of myopia/hyperopia, as well as risk factor analyses, were limited to black participants. Associations with myopia/hyperopia were evaluated by logistic regression. Factors evaluated included age, gender, years of education, lifetime occupation, lens opacities (by type), and glaucoma status. The lifetime occupation (based on the question: "what kind of work have you done for MOST of your life") was categorized as mainly involving nearwork (including professional, managerial, clerical, and technical or electrical occupations) or not (including service, agricultural, forestry, fishing or water-related activities, production work, and homemaker). The classification of lens status was based on LOCS II[17] gradings at the slit lamp and a score ≥2 was used to define nuclear, posterior subcapsular (PSC), and cortical opacities.[18] For this report, individuals with any glaucoma included those with open-angle glaucoma, which required both visual field and optic disc criteria for glaucoma damage as described previously,[16] suspected glaucoma, and other types of glaucoma. Ocular hypertensives included persons with an intraocular pressure >21 mm Hg or with a history of intraocular pressure–lowering treatment, but without glaucoma visual field defects or disc damage.[19]

RESULTS

Of the 4631 participants who completed the BES visit at the study site, 137 had a previous history of cataract surgery, and another 164 had no data on the Humphrey refractor because of poor visual acuity, media opacities, or other reasons. After excluding these participants, the distribution of refractive errors by self-reported race was based on 4330 right eyes. Table 1 presents demographic information on this study population. Median age was 57 years; and 57% of the participants were female. Over 90% of the population self-reported their race as black and most participants (36%) had a lifetime occupation in the service industry. Although persons excluded from the analysis were older (median age, 73 years), the age and gender distributions of the 4330 participants in this report were sim-

TABLE 2. Age-Gender Specific Prevalence of Myopia in BES Black Participants

Age, y	n	Male, % (95% CI)	n	Female, % (95% CI)	n	Total, % (95% CI)
40–49	555	18.6 (15.4, 22.1)	680	15.7 (13.1, 18.7)	1235	17.0 (15.0, 19.2)
50–59	423	14.7 (11.4, 18.4)	622	8.7 (6.6, 11.2)	1045	11.1 (9.3, 13.2)
60–69	384	23.7 (19.5, 28.3)	552	18.7 (15.5, 22.2)	936	20.7 (18.2, 23.5)
70–79	298	46.3 (40.5, 52.2)	375	38.1 (33.2, 43.3)	673	41.8 (38.0, 45.6)
80+	67	56.7 (44.0, 68.8)	80	53.8 (42.2, 65.0)	147	55.1 (46.7, 63.3)
Overall	1727	25.0 (23.0, 27.1)	2309	19.5 (17.9, 21.2)	4036	21.9 (20.6, 23.2)

ilar to the total BES study population (median age, 58 years; 57% female).

Figure 1 presents the distribution of refractive errors by self-reported race. Based on the ±0.5 D cutoff points, the prevalence of myopia for black, mixed (black and white), and white participants was 21.9% (95% confidence interval, 20.6–23.2), 19.7% (14.0–26.4), and 26.2% (18.2–35.6), respectively. The prevalence of hyperopia was 46.9% (45.4–48.5), 57.2% (49.5–64.7), and 54.2% (44.3–63.9) for the respective self-reported racial groups. After controlling for age and gender, the overall distribution of refractive errors differed ($P < 0.05$) between black and white groups. Further analyses are limited to the 4036 black participants, due to the small numbers in other racial groups.

Figure 2 presents the age-gender–specific distributions of refractive errors. Women tended to have a higher frequency of positive and less negative spherical equivalents than men in every age group. Specifically, the prevalence of myopia (i.e., spherical equivalent <-0.5 D) was higher in men (25.0%) than in women (19.5%), and the same pattern was seen in each age group. The overall prevalence of myopia decreased from 17.0% in persons 40 to 49 years of age to 11.1% in those 50 to 59 years and increased thereafter (i.e., from 20.7% for age 60–69 years to 41.8% for age 70–79 years, reaching 55.1% for those 80 years of age or older; Table 2). Table 3 shows that the prevalence of hyperopia (>0.5 D) was higher in women (51.8%) than in men (40.5%), and this pattern was also observed in each age group. The prevalence of hyperopia increased from 28.8% at 40 to 49 years of age to 64.9% at 50 to 59 years of age, and tended to decline thereafter.

Using a more stringent definition, the proportion of participants with spherical equivalent <-1 D was 9.7%, 6.9%, 16.0%, 33.8%, and 44.9%, respectively, in each age group. The corresponding proportion with spherical equivalent >1 D was 10.0%, 40.9%, 44.6%, 29.1%, and 21.8%, respectively.

Table 4 presents results from logistic regression analyses, which show differences in prevalence by age, after controlling for gender, indicators of socioeconomic status (such as lifetime occupation and education), and various ocular conditions. Age had a complex relationship with refractive errors. Persons 50 to 59 years of age had a significantly decreased prevalence of myopia compared with persons 40 to 49 years of age (OR = 0.58). This relationship was not seen in the age group 60 to 69 years (OR = 1). Furthermore, there was a nearly twofold increased likelihood of being myopic for persons 70 years of age or older, compared with those 40 to 49 years of age (OR = 1.77).

Men (OR = 1.41) and persons with nearwork-related lifetime occupations (OR = 1.28) were more likely to have myopia. When all different types of lens opacities were considered simultaneously, eyes with nuclear opacities (OR = 4.45) and PSC opacities (OR = 1.81) were more likely to be myopic, whereas eyes with cortical opacities (OR = 0.79) were less likely to be myopic. Persons with any type of glaucoma (OR = 1.48) and persons with ocular hypertension (OR = 1.43) had a higher prevalence of myopia.

Except for occupation, which was not statistically significant, the associations with hyperopia were the same as those found for myopia and as expected, in the opposite direction (Table 4). In the multivariate analysis, increasing age was associated with a higher prevalence of hyperopia, as shown by the odds ratios over unity. However, in every decade of life after the age of 60 years, the magnitude of the odds ratios decreased as the age advanced. Therefore, although there were positive associations between the prevalence of hyperopia and advancing age, the odds of becoming hyperopic decreased after the age of 60 years. Very similar results were found when the associations were evaluated using cutoff values of ±1D (data not shown).

DISCUSSION

The BES is a large epidemiologic study that investigated major eye diseases in a predominantly black population with a high

TABLE 3. Age-Gender Specific Prevalence of Hyperopia in BES Black Participants

Age, y	n	Male, % (95% CI)	n	Female, % (95% CI)	n	Total, % (95% CI)
40–49	555	25.4 (21.8, 29.2)	680	31.6 (28.1, 35.3)	1235	28.8 (26.3, 31.4)
50–59	423	56.7 (51.9, 61.5)	622	70.4 (66.7, 74.0)	1045	64.9 (61.9, 67.8)
60–69	384	52.6 (47.5, 57.7)	552	63.2 (59.1, 67.3)	936	58.9 (55.6, 62.0)
70–79	298	33.2 (27.9, 38.9)	375	44.3 (39.2, 49.5)	673	39.4 (35.7, 43.2)
80+	67	25.4 (15.5, 37.5)	80	33.8 (23.6, 45.2)	147	29.9 (22.7, 38.0)
Overall	1727	40.5 (38.2, 42.8)	2309	51.8 (49.7, 53.8)	4036	46.9 (45.4, 48.5)

TABLE 4. Results of Logistic Regression for Associations of Myopia/Hyperopia in the BES Black Participants

Factors	Myopia, OR (95% CI)	Hyperopia, OR (95% CI)
Age, y		
50–59†	0.58 (0.45, 0.75)*	4.69 (3.89, 5.66)*
60–69†	1.00 (0.77, 1.30)	4.15 (3.36, 5.12)*
70+†	1.77 (1.30, 2.41)*	2.61 (2.00, 3.41)*
Male gender	1.41 (1.18, 1.69)*	0.64 (0.55, 0.74)*
Nearwork-related occupation‡	1.28 (1.04, 1.57)*	0.97 (0.82, 1.15)
Education, y	1.02 (0.99, 1.05)	0.99 (0.96, 1.01)
Nuclear opacities (N ≥ 2§)	4.45 (3.49, 5.69)*	0.36 (0.28, 0.45)*
PSC opacities (P ≥ 2§)	1.81 (1.02, 3.23)*	0.38 (0.20, 0.70)*
Cortical opacities (C ≥ 2§)	0.79 (0.63, 0.98)*	1.39 (1.16, 1.67)*
Any glaucoma‖	1.48 (1.12, 1.95)*	0.52 (0.41, 0.67)*
Ocular hypertension¶	1.43 (1.11, 1.84)*	0.69 (0.56, 0.86)*

* $P < 0.05$.

† Reference group: 40–49 years of age.

‡ Including professional, managerial, clerical, electrical, and technical.

§ LOCS II score.

‖ Including definite open-angle glaucoma (OAG), suspect OAG, and other types of glaucoma.

¶ Intraocular pressure > 21 mm Hg without glaucoma visual field defects or disc damage.

participation rate. The study had a demographic composition similar to the census population,[16] thus supporting the generalizability of the findings. Refractive errors were very common in the BES adult population, 40 years of age and older, in which approximately 1 in 4 persons was estimated to be myopic and 1 in 2 persons was hyperopic. Based on self-reported race, a definition supported by results of blood group distribution and pigmentation gradings,[20] differences were observed in the distributions of refractive errors between black and white groups (Fig. 1). Black participants had less deviations from emmetropia than white participants, after adjusting for age and gender. Although such comparisons were based on small numbers of participants in the white and mixed racial groups (and should be interpreted cautiously), the result was consistent with data reported in the Baltimore Eye Survey.[15] Despite the lower prevalence of myopia found in the black than in the white participants of the NHANES[12] and the Baltimore Eye Survey,[15] myopia was nonetheless fairly common in the black participants of these two studies, 13% and over 25%, respectively. In contrast, one survey of the prevalence of refractive errors conducted in Malawi reported that only 2.5% of participants had an error of ≤−0.5 D.[21]

It was interesting to note that the prevalence of myopia in the black BES participants ≥60 years increased with advancing age (Table 2). In addition, the prevalence of hyperopia peaked in the age group of 50 to 59 years but started to decline thereafter (Table 2). These results are inconsistent with data from other studies. The NHANES (1971–1972),[14] although based on a younger population (12–54 years of age) than the BES, showed little variation in the overall prevalence of myopia with age. However, prevalence increased with age in persons with less than 2 D of myopia, whereas prevalence decreased with age in persons with 2 D or more of myopia. In the Melbourne Visual Impairment Project, the proportion of participants (≥40 years of age) with myopia decreased significantly with age when gender was controlled for.[22] Figure 3 depicts the prevalence of myopia by age in the BES and in two other population-based studies. The Beaver Dam Eye Study,[23] a population-based study in predominantly white participants 43 to 84 years of age, reported that the prevalence of myopia decreased from 43% at 43 to 54 years of age to 14.4% at 75 years of age or older. In that study, the prevalence of hyperopia increased from 22% in those 43 to 54 years of age to 68.5% in those 75 years of age or older. The Baltimore Eye Survey[15] also found that myopia prevalence declined with age and that hyperopia prevalence increased with age in black and white persons. Different definitions were used in these studies. In the NHANES,[14] myopia was defined as any negative spherical equivalent, which was calculated from the current correction for eyes with visual acuity 20/40 or better, and from retinoscopy or spherical equivalent refraction for eyes with visual acuity worse than 20/40. The Beaver Dam Eye Study,[23] also using the Humphrey 530 refractor as in our study, defined myopia and hyperopia as refractive errors <−0.5 D and >0.5 D, respectively. The study included subjects without cataract surgery and those who had a best-corrected visual acuity better than 20/40 in at least one eye. The same cutoff points for myopia and hyperopia were used in the Baltimore Eye Survey,[15] in which a subjective automated refraction was performed, although this survey did not include a visual acuity criterion. However, these differences in methods and definitions do not seem to account for the discrepant findings with our study. For example, the age patterns observed in the BES persisted even after excluding participants with visual acuity 20/40 or worse, with myopia prevalence descending from 16% at 40 to 49 years of age, to 9% at 50 to 59 years of age, and then increasing to 12%, 23%, and 35%, respectively, for each age group after 60 years of age. Furthermore, the age patterns of myopia and hyperopia found in BES remained similar when –2 D and 2 D were used as cutoff points (data not shown). The same age patterns were also found after changing the definition of myopia (hyperopia) from <−0.5 D (>0.5 D) to a spherical equivalent <−1.0 D (>1.0 D), with overall prevalences of 15.8% and 29.6% for myopia and hyperopia, respectively. Multivariate

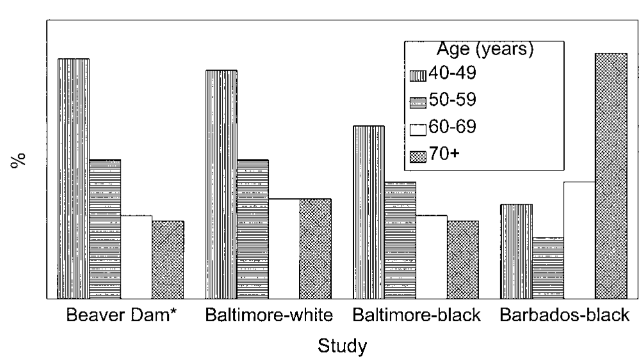

FIGURE 3. Prevalence of myopia by age among different studies. *Excluding participants with visual acuity 20/40 or worse; age groups are 43–54, 55–64, 65–74, and 75+ years respectively.

analyses based on the study definition yielded the same age patterns, after controlling for possible confounding factors such as education, occupation, and various ocular conditions (Table 4).

Myopia is generally perceived as a condition that develops between 6 and 14 years of age; population prevalence remains relatively constant thereafter and tends to decline after middle age.[3] This decline can be attributed to a cohort effect, where younger generations have a higher myopia prevalence than in the past. Our finding that the prevalence of myopia in BES increased after 60 years of age is inconsistent with such effect. Systematic measurement errors affecting older individuals are unlikely, thus our results are not easily explained as an artifact. Both genetic and environmental factors may contribute to our unexpected findings of age patterns and refractive errors in the BES population. As discussed later, the high prevalence of concomitant eye pathology in the BES may be a related explanation.

Reports on the relationship between gender and refractive errors have not been uniform. In the BES, male gender was associated with a higher prevalence of myopia. Similarly, in a prevalence study of refractive errors of an adult rural population in Israel,[24] mild myopia was more common in males than in females. On the contrary, both NHANES[14] and the Beaver Dam Eye Study[23] reported that myopia is more prevalent in women than in men. Gender was not associated with myopia in the Baltimore Eye Survey.[15] The increased hyperopia prevalence in women, as seen in BES, is consistent with data from the Baltimore Eye Survey[15] and a prevalence study carried out in Israel.[24] No gender differences in hyperopia were seen in the Beaver Dam Eye Study.

Several studies have found a positive link between refractive errors and higher education,[14,15,23] supporting the possible role of nearwork factors on the pathogenesis of myopia. Although length of education was not associated with refractive errors in BES, a borderline association was found between education >9 years and myopia (OR = 1.21, P = 0.053). Lifetime occupations that usually require close-up tasks were associated with a higher prevalence of myopia (Table 4). Overall, 33% of the myopes and 31% of the nonmyopes had nearwork-related occupations. Most of the difference occurred in service-related occupations, which were reported by 33% of the myopes and 39% of the nonmyopes. Although the categorization of occupation in our analyses does not lead to a clear separation of nearwork versus nonnearwork, persons with nearwork-related occupations, as defined, were more likely to be myopic than those who performed less close-up work. These results are consistent with the use-abuse theory[2,3] that postulates that myopia is triggered by close-up work, as usually performed by those with higher education and those in white collar occupations. One explanation is the elongation of axial length during accommodation in nearwork.[3,4] Alternatively, visual demands from close-up work may cause dysfunction of the accommodation mechanism, which may result in retinal image defocus and lead to myopia.[3,25] The magnitude of the odds ratio found in BES, however, was very modest (close to 1), and our results do not necessarily indicate a cause and effect relationship.

Cataract often associates with myopia,[12,13] especially nuclear cataract. Lens changes were highly prevalent (42%) in the black participants of BES, with cortical opacities (34%) being most common, followed by nuclear (19%) and PSC (4%) opacities.[18] After controlling for other types of opacities, nuclear opacities were highly associated with a higher prevalence of myopia, as expected, and a lower prevalence of hyperopia (Table 4). To a lesser degree, PSC opacities were also related to a higher (lower) prevalence of myopia (hyperopia). Modest associations of refractive errors and cortical opacities were seen, which were opposite to those of nuclear and PSC opacities (Table 4). These association patterns can possibly be explained by the different anatomic location and rigidity of the various opacity types.

A high prevalence of open-angle glaucoma (7%) was found in the BES black population.[16] The prevalence rose to 11.4%[16] after including any type of glaucoma or suspected glaucoma. An additional 13% of the black participants had ocular hypertension.[19] Our results confirm the associations between refractive errors and glaucoma or ocular hypertension, as reported by various studies. Perkins and Phelps[9] found that myopia occurred more frequently in patients with primary open glaucoma, ocular hypertension, and low-tension glaucoma than in a normal population of similar age and also that myopes with ocular hypertension had a higher risk of developing visual field defects than emmetopes or hypermetropes.[9] Seddon et al.[10] found a higher prevalence of glaucoma among eyes with myopia than those with hyperopia and emmetropia. Chisholm et al.[11] found that the absence of hyperopia was a strong prognostic indicator for the development of visual field defects in patients with suspected glaucoma. Although some studies[10,26] found an association between intraocular pressure and refractive status, others did not.[27–29]

Conclusions

Myopia and hyperopia were common in the black population of BES, although black participants had less negative and positive deviations from emmetropia than white participants. The prevalence of myopia was higher in men and increased after 60 years of age. The prevalence of hyperopia was higher in women and decreased after 60 years of age. This age pattern is a new finding, which had not been reported in other population studies, and may be related to the high prevalence of age-related cataract, glaucoma, and other eye conditions in this population. Future studies in similar populations are needed to confirm these findings.

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Appendix

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