

Eye Diseases in People 40-84. The Barbados Eye Studies: *A Summary Report*

THS/OS/06/8
Original in English

January 2006



**Pan American
Health
Organization**



Regional Office of the
World Health Organization

***Area of Technology and Health Services Delivery (THS)
Unit of Health Services Organization (THS/OS)***

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Eye Diseases in Latin America
Handbook for the Ophthalmologist
Spanish

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87	Authenticity
88	Non-repudiation
89	Accountability
90	Transparency
91	Openness
92	Participation
93	Empowerment
94	Ownership
95	Control
96	Choice
97	Freedom
98	Privacy
99	Security
100	Reliability

SUMMARY OVERVIEW

The Barbados Eye Studies (1987-2002) were developed to provide the first population-based data on major eye diseases affecting persons of African descent, including open-angle glaucoma, age-related cataract, diabetic retinopathy and age-related macular degeneration. Their objective was to document the prevalence, incidence, and risk factors for ocular conditions, thus providing essential information to develop strategies to prevent or control blindness.

The studies were based on a cohort of over 4,700 Barbadians, 40-84 years, or 84% of a randomly selected sample of the general population of the country. After baseline examinations ending in 1992, the cohort was re-examined to obtain 4-year and 9-year incidence data. An additional study included over 1,000 relatives of persons with glaucoma, with the intent of determining the mechanisms of disease transmission among black families.

Results have substantiated the unusually high frequency of open-angle glaucoma and its importance as a cause of visual loss in the black population. Considerable information was also obtained on its associated risk factors, such as intraocular pressure and family history, thus assisting in the better knowledge of the disease and in identifying high-risk groups. The studies also determined that cortical cataract was the major type of lens opacity in this population and identified various risk factors, some being potentially modifiable and amenable to possible interventions. These factors include diabetes, hypertension and obesity, which the studies also linked to other major eye diseases. Analyses of the long-term follow-up data are providing information on the risk and progression of all major blinding eye diseases; these data are essential to develop sound prevention and health delivery policies.

The objective of this report is to provide a comprehensive summary of the results of the Barbados Eye Studies (1987-2002), which are a series of investigations on the major eye diseases affecting a Caribbean population. The major goal of the studies was to obtain information that could be used to prevent or control the main causes of visual loss. Consistent with this aim, the current report emphasizes results most relevant for informing public health policy and formulating strategies to address visual impairment and blindness.

BACKGROUND

Epidemiologic studies to determine the distribution of eye diseases among European-derived populations began in the 1960s, but very limited information has been available on persons of African descent. While some reports indicated a high frequency of blindness and visual loss in black communities, the data were incomplete and often not population-based. The Barbados Eye Studies (BESs) were designed to fill this gap by conducting a series of epidemiologic investigations to determine the prevalence, incidence and risk factors for major eye diseases among persons of African origin. The studies were directed to obtain data on the main causes of visual loss, that is, primary open-angle glaucoma (OAG), age-related cataract, diabetic retinopathy and age-related macular degeneration. While OAG and age-related cataract were suspected to be important causes of blindness in black populations^{1, 2, 3} little was known about the occurrence of age-related macular degeneration⁴ and diabetic retinopathy in these groups.

The Barbados Eye Studies are the first epidemiologic investigation that collected data on all major eye diseases in a predominantly African-origin population⁵. Such data are essential to measure the magnitude of the problem in the population and to obtain information on risk factors, thus providing clues as to the possible causes of each eye condition. By so doing, the studies aimed to provide the necessary data to inform the development of public health policies and planning of health services. The ultimate goal of the studies was to assist in the prevention and control of visual impairment in black populations.

METHODS

ORGANIZATION

The studies represent a collaboration between the Department of Preventive Medicine, State University of New York at Stony Brook, NY, which was the Coordinating Center, and the Ministry of Health, Barbados, West Indies, which was the Data Collection Center, with The Johns Hopkins School of Medicine, Baltimore, MD being the Fundus Photography Reading Center for the studies. Support was provided by the National Eye Institute, National Institutes of Health, USA.

CHRONOLOGY

Pilot phase for the Barbados Eye Study; (1985-1986). A one-year pilot study was conducted to evaluate the feasibility of the intended major study and to test its protocols^{6,7}. This pilot phase included 213 persons and had a high participation rate of 95%.

Prevalence phase- Barbados Eye Study (BES); 1987-1992. After the successful completion of the pilot study, a prevalence phase began. A simple random sample of Barbadians 40-74 years of age was drawn by the Barbados Statistical Service. Through the use of computerized recruitment systems, persons in the sample were invited to participate and 4,709 persons or 84% of the sample had an eye examination as part of the study. The prevalence phase provided baseline data for the follow-up examinations of cohort participants.

Incidence phase- Barbados Incidence Study of Eye Diseases (BISED); 1992-2002. Participants in the initial prevalence phase were followed up with two cycles of repeat examinations during this interval. The first cycle took place 4 years after baseline and re-examined 3,427 persons or 85% of the eligible survivors from the prevalence phase. The second cycle was 9 years after baseline and re-examined 2,793 individuals or 81% of the eligible survivors.

Family-based phase- Barbados Family Study of Open-angle Glaucoma (BFSG); 1995-2000. A separate study focused on recruiting and examining first degree relatives of persons identified with open-angle glaucoma, since the initial results of BES highlighted the importance of family history as a risk factor for OAG. The study included 1,056 family members of persons affected with glaucoma, as well as 207 affected probands, with 78% participation.

STUDY PROTOCOL

All study phases were conducted at a Ministry of Health polyclinic and followed a standardized protocol, administered by nursing staff and an ophthalmologist. The comprehensive examination included refraction; visual acuity testing (Bailey-Lovie chart following a modified Early Treatment of Diabetic Retinopathy Study protocol; computerized perimetry (Humphrey Visual Field Analyzer; suprathreshold C-64; full threshold C24-2 and C30-2 tests); Goldmann applanation tonometry; slit-lamp grading of lens opacities (Lens Opacities Classification System II); color stereo fundus photographs (Zeiss fundus camera); pulse; blood pressure (random zero sphygmomanometer);

anthropometric measurements (height, weight, circumferences); total glycosylated hemoglobin; and a structured interview to obtain medical history and risk factor data.

RESULTS

Table 1 provides information on the baseline characteristics of the participants, as obtained in the BES prevalence phase. The demographic composition of the sample was similar to that found in the general population⁸. Their median age was 58 years and 57% were female. By self-report, over 93% of the participants were black, 3% were white and the rest were of mixed or other races. The median duration of education was 10 years and there was a wide range of occupations. The table also presents the frequency of various risk factors and self-reported medical history and shows the high prevalence of diabetes history, hypertension (average SBP $\geq$ 140 mmHg and/or DBP $\geq$ 90 mmHg and/or antihypertensive treatment) and obesity (body mass index >27 kg/m²).

Table 1. Baseline Characteristics of BES Participants

Variable	
Age, median (years)	58
Female, %	57
Self-reported race, %	
- Black	93
- Mix	4
- White/other	3
Education, median (years)	10
Occupation, %	
- Service	36
- Professional/clerical	20
- Technical/production	14
- Other	30
Diabetes history, %	17
Hypertension, %	55
Obesity (body mass index >27), %	44

The sections that follow summarize the prevalence, incidence and risk factor data on various ocular conditions. Except when noted, all results are based on the black population, given the small sample size for other groups.

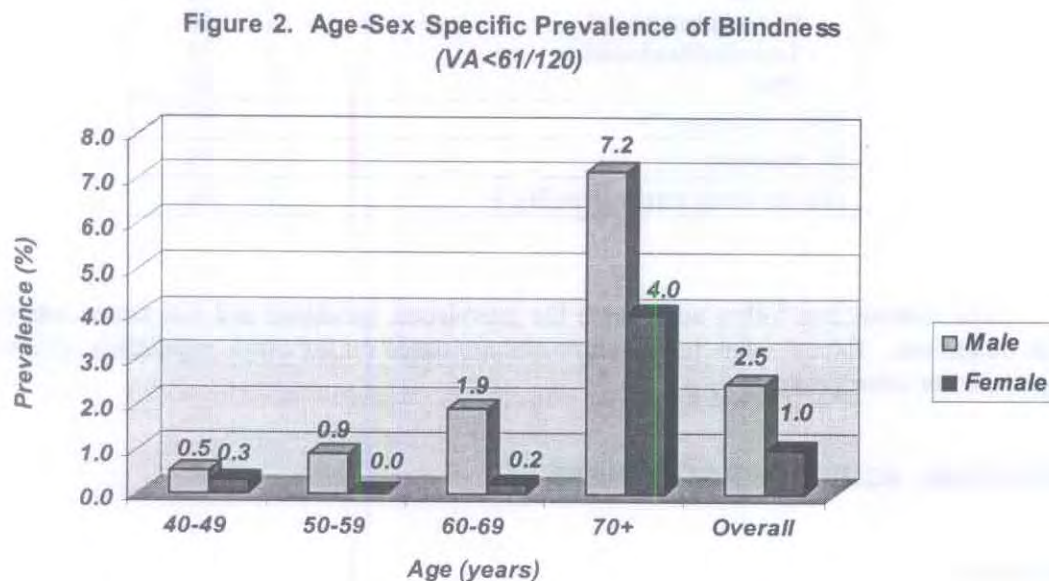
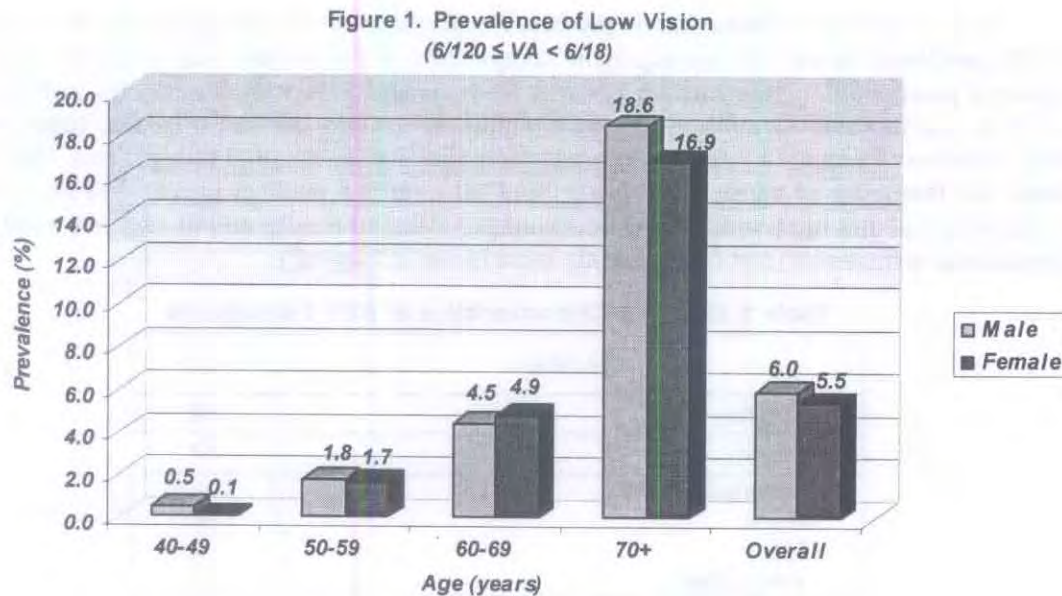
LOW VISUAL ACUITY AND BLINDNESS

DEFINITION

The BES findings documented the high prevalence and incidence of low vision and blindness in the population, as defined by the visual acuity-based criteria of the World Health Organization (WHO). Low vision included visual acuity worse than 6/18 (20/60) to 6/120 (20/400) or better; blindness was defined as visual acuity worse than 6/120 (20/400). All results are based on the visual acuity in the better eye.

PREVALENCE

Figures 1-2 show the age and sex-specific prevalence of low vision and blindness. As seen in these figures, visual impairment increased steeply with age and was higher in men than in women.



In the BES population, the overall prevalence of low vision was 5.9% and the prevalence of blindness was 1.7%, with higher rates seen in men. In contrast, comparable rates in white populations over 40 years are generally 0.5-1.6%, and $\leq 0.5\%$, respectively. When comparing blindness in BES to findings from other black populations, the BES black participants had twice as much blindness as

African-Americans from the Baltimore Eye Survey⁹ and the Salisbury Eye Evaluation¹⁰. They also had higher rates than the BES white and mixed race participants, although these comparisons are based on small numbers. Table 2 presents a comparison of prevalence among various population studies.

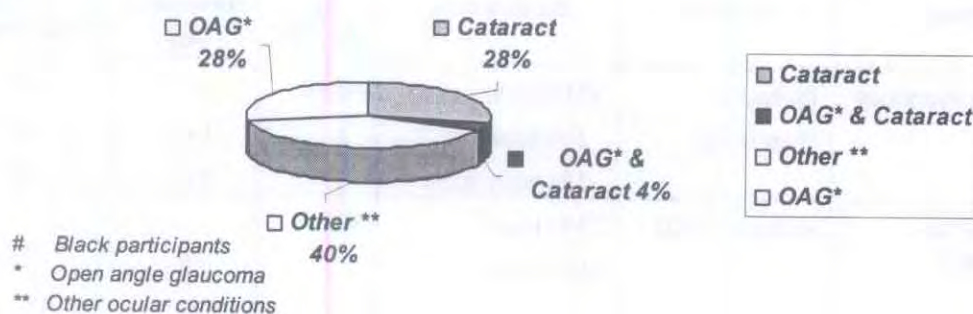
Table 2. Comparison of Blindness and Visual Impairment Prevalence Rates (%) in Population-based Studies According to WHO criteria

Study	Location	Sample Size	Age (years)	Blindness (%)	Visual Impairment (%)
Barbados Eye Study	Barbados, West Indies	4314 black	40-84	1.7	5.9
		184 mixed		1.6	2.7
		133 white/other		0.0	3.0
Baltimore Eye Study, 1992	Baltimore, MD	2395 black	40+	0.9	N/A
		2913 white		0.5	N/A
Rotterdam Study, 1998	Rotterdam, The Netherlands	6775 white	55+	0.5	1.4
Salisbury Eye Evaluation Project, 1997	Salisbury, MD	~ 665 black	65-84	0.8	3.3
		~1855 white		0.2	1.6
Melbourne Visual Impairment Project, 1997	Melbourne, Australia	3,268 white	40-98	0.1	0.5

Figure 3 shows the distribution of primary causes of prevalent blindness, which was based on all eyes from the participants who were bilaterally blind. Among the 148 eyes of 74 bilaterally blind persons in BES, glaucoma and cataract accounted for over 60% of blindness according to WHO criteria (VA <6/120)¹¹. Glaucoma and cataract were the primary causes of blindness, each accounting for 28% of the blindness cases; an additional 4% of cases were due to combined OAG and cataract. The importance and frequency of glaucoma as a cause of blindness in this black population is an important new finding, as glaucoma blindness accounts for a smaller percent (13.5%) of blindness, world-wide¹². A similar pattern emerges when using the US definition of blindness (20/200 or worse), with these results being confirmed from data on African-Americans in the Baltimore Eye Survey and the Salisbury Eye Evaluation.¹¹

**Figure 3. Primary Causes of Prevalent Blindness
(VA < 61/120)**

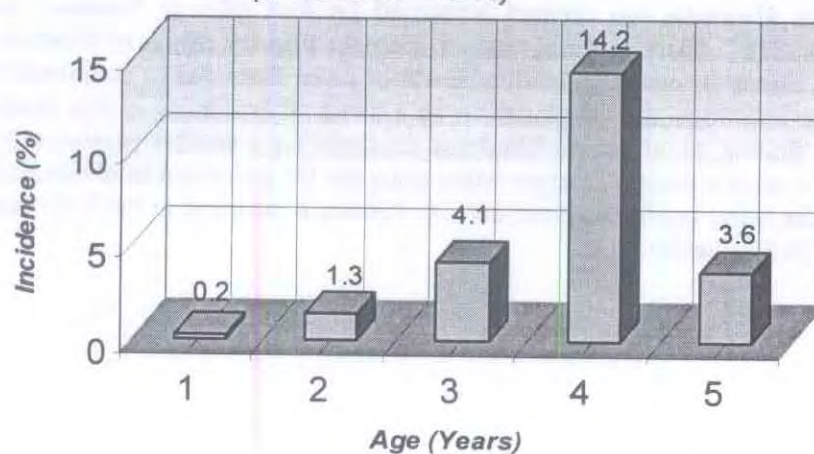
148 Eyes from 74 Bilaterally Blind Persons[#]



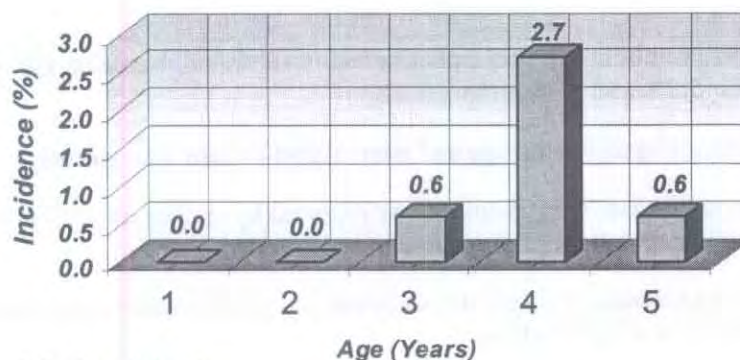
4-YEAR INCIDENCE

Figures 4 and 5 present the 4-year incidence of low vision and bilateral blindness, which were 3.6% and 0.6%, respectively. In addition, for every case of bilateral blindness, there were approximately 3 cases with unilateral blindness. As expected, both incidence of blindness and low vision increased with age. Among persons 70 years of age or older at baseline, approximately one in 14 persons developed blindness and one in 5 persons developed low vision in 4 years¹³.

**Figure 4. Four-Year Incidence* of Low Vision
(6/120 ≤ VA < 6/18)**



**Figure 5. Four-Year Incidence* of Blindness
(VA <6/120)**

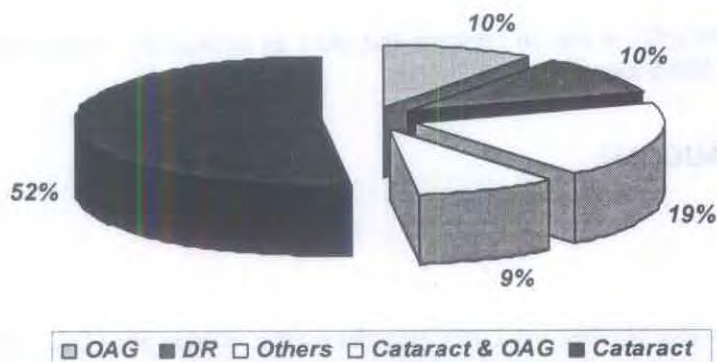


* Black participants

Figure 6 shows the reasons for development of new bilateral blindness among 92 eyes of 46 persons. Because of the small numbers, results are based on the US definition (20/200 or worse), rather than the WHO definition. Approximately one-half of incident or new blindness was due to age-related cataract, which was by far the most frequent cause. Nearly one-fifth of new blindness was caused by OAG alone or combined with cataract and approximately one-tenth was caused by diabetic retinopathy (DR)¹³. The importance of DR as a cause of new blindness differs from the results of the prevalence study, where cataract and glaucoma blindness predominated and DR blindness was not as frequent.

**Figure 6. Causes of Four-Year Incident Blindness
(VA ≤ 6/60)**

92 Eyes from 46 Bilaterally Blind Persons #



■ OAG ■ DR □ Others □ Cataract & OAG ■ Cataract

Black participants

SUMMARY AND CONCLUSIONS

Prevalence

- High prevalence of low vision and blindness were found, based on the WHO criteria for visual acuity loss (5.9% and 1.7%, respectively)
- Rates increased greatly with age and were higher in men than women
- Blindness rates were about double those reported by studies of African-Americans and 3 times higher than those found in European-derived populations
- Open-angle glaucoma and cataract were the major causes of visual acuity loss, accounting for about 60% of existing blindness

Incidence

- After 4 years, the incidence rates of low vision and blindness were 3.6% and 0.6% respectively and were also higher in older persons and in men
- Cataract was the main cause of new blindness, being responsible for about half of the cases
- Glaucoma was the cause of about ¼ and DR of about one-tenth of new blindness

Conclusions

- The considerable high occurrences of blindness and low vision in the study cohort confirm the public health impact of eye diseases in persons of African descent
- The high rates also substantiate the need for closer monitoring and effective treatment of ocular disorders, such as OAG and cataract, which are the main causes of existing and new blindness in African-origin populations
- Diabetic retinopathy is also of concern and must be addressed as a preventable and important cause of new blindness

OPEN-ANGLE GLAUCOMA

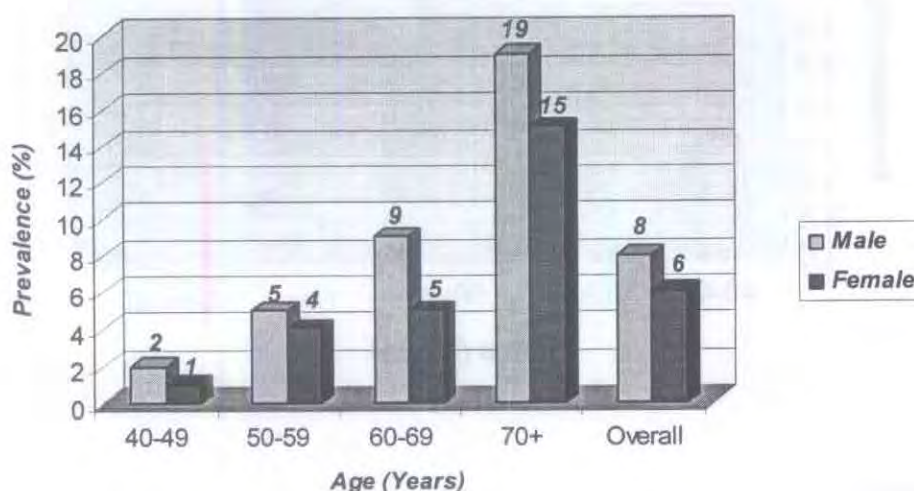
DEFINITION

The Barbados Eye Studies used stringent diagnostic criteria for OAG, which were based on the presence of the two major signs of the condition, that is, both visual field defects and optic disc damage in at least one eye, after the exclusion of other possible causes⁸. Intraocular pressure (IOP) was not part of this definition.

PREVALENCE

Figure 7 presents the age-specific distribution among black and mixed race BES participants. Overall, the prevalence of OAG was 6.8%, with a consistently higher prevalence in men than women (8.3% and 5.7% respectively). Prevalence rates increased markedly in each age group, so that 1 in 9 individuals over the age of 60 years were affected and 1 in 6 over the age of 70 years. There was considerable under detection of the disease, since only half of those affected knew their diagnosis; the rest were newly detected by the study examination.

Figure 7. Prevalence of Open-Angle Glaucoma (n=309)



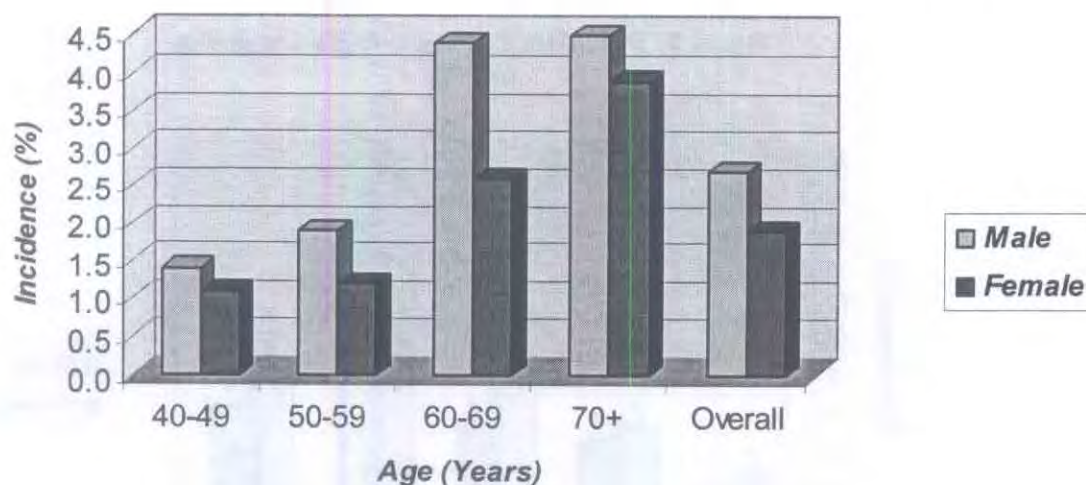
The prevalence of OAG in the BES is higher than the 4% prevalence in Afro-Americans in the Baltimore Eye Survey and a study in Tanzania, but somewhat lower than the 8.8% (at ages 30 years and older) prevalence found in St. Lucia, although comparisons are difficult because of varying definitions of OAG among studies¹⁴. In populations of European origin, the prevalence of OAG is considerably lower and varies around 1% to 2%¹⁴.

4-YEAR INCIDENCE

The follow-up phase of the BES cohort has led to the first published rates of the incidence of OAG¹⁵ that are based on the largest number of new cases to date (n=67). Figure 8 shows the age-sex specific 4-year incidence rates, which increased with age and were higher in men. The overall incidence was 2.2% over a 4-year period, or 0.6% per year, reaching 1% per year at older ages. While there are no sufficiently precise estimates for comparison, these rates are higher than those derived from studies of white populations, which have been based on a very small number of definite new cases.

Of the incident OAG developing during the 4-years after the BESs baseline, only half had been diagnosed in the interval. Most of the undetected cases had IOP <21 mmHg at baseline.

Figure 8. Four-Year Incidence of Open-Angle Glaucoma
(*n*=67)



RISK FACTORS

As seen in Figures 7 and 8, prevalent and incident OAG were more frequent in older persons and in men. Table 3 summarizes risk factors for OAG, as compared to other conditions. Having a high intraocular pressure (IOP) at baseline was a major risk factor for developing OAG after 4 years¹⁵. However, since most persons in the population do not have high IOP levels, about half of the new OAG developing after 4 years had IOP under 21mmHg at baseline. These results highlight the role of other factors, besides IOP, in the development of glaucoma.

Multivariate analyses identified additional characteristics associated with the presence of OAG at baseline, such as a low differential between the blood pressure and the intraocular pressure (suggesting low perfusion pressure of the optic nerve); family history of glaucoma (with a 7-fold excess in men and a 3-fold excess in women); lean body mass; cataract history; myopia; and Duffy Fya+ blood group^{16, 17, 18}. These risk factors suggest that familial/genetic causes play a role in OAG etiology, possibly interacting with potential environmental factors^{19, 20}. Although hypertension and diabetes are highly prevalent in black populations and were very common in the cohort (Table 1), they were not positively related to OAG (Table 3).

Table 3. Summary of Risk Factors for Prevalent/Incident Open-angle glaucoma (OAG), Ocular hypertension (OHT), and Cataract

Factors	OAG	OHT	Cataract*
Age	↑	↑	↑ (C,N,P)
Gender	Male↑	Female↑	Female↑ (C, N)
Low education/non-professional			↑ (C)
High body mass index	↓	↑	↓ (N)
High waist-hip ratio			↑ (C)
High blood pressure/hypertension	↓	↑	↑ (C)
High IOP/IOP-lowering treatment	↑		↑ (N)
Low perfusion pressure (BP-IOP)	↑		
Diabetes history		↑	↑ (C,N,P)
High glycosylated hemoglobin			↑ (C,P)
Family history of glaucoma	↑	↑	
Regular use of nutritional supplements			↓ (C)
Regular use of aspirin			↓ (C)
Darker complexion		↑	
Darker iris color			↑ (N)
Cataract history	↑		
Myopia	↑	↑	↑ (N,P) ↓ (C)
Smoking		↑	
Alcohol use		↑	
Duffy Fya+ blood group	↑		

OAG=open-angle glaucoma; OHT=ocular hypertension, IOP= intraocular pressure

* C=cortical opacities; N= nuclear opacities; P= posterior subcapsular opacities

↑: increased risk; ↓: decreased risk

Intraocular pressure

Given the importance of IOP as a risk factor, analyses also focused on the distribution of this variable in the population at baseline. IOP was significantly higher in BES black than white participants, with mean (+ standard deviation) values being 18.7 (+5.2) mmHg and 16.5 (+3.0) mmHg, respectively. Using the traditional cut-off of 21 mmHg, the odds of elevated IOP were 5 times higher in the black than white participants (18.4% vs. 4.6%). The BES black population had a 12.7% prevalence of ocular hypertension (defined as IOP >21 mmHg or IOP-lowering treatment, without glaucoma disc or field damage)²¹. As seen in Table 3, persons having ocular hypertension were more likely to have systemic hypertension, diabetes, obesity, to smoke and use alcohol, but these factors were not related to OAG^{22, 23}.

Similar results were obtained at the 4-year follow-up. Of those persons without high IOP or OAG at baseline, 12.9% were found to develop IOP > 21 mmHg after 4 years²⁴. Factors associated with the development of high IOP in a multivariate analysis included age, baseline IOP, systolic and diastolic blood pressure, and hypertension. The vascular factors related to developing high IOP, such as hypertension and blood pressure, were not positively associated with developing OAG. Similarly, although OAG was more common in men, gender was not a significant factor for incident elevated IOP²⁵. It appears that hypertension and diabetes, which are very prevalent in black populations, are likely to contribute to high IOP levels, but do not appear to explain the high prevalence or incidence of OAG in black Barbadians. Aside from age, factors related to OAG were different to those related to high IOP (Table 3).

When reporting on IOP results, the potential effect of corneal thickness needs to be considered. Several studies, mainly in white populations, have reported a positive correlation between central corneal thickness (CCT) and IOP^{26, 27, 28} suggesting that CCT may affect IOP measurements. These findings have clinical implications in that tonometry may not provide a valid measurement of IOP. As such, thick corneas may lead to artifactually high IOP measurements; conversely, persons with thin corneas may have higher IOPs than their measured values. Although black BES participants have higher IOP measurements than white populations,²¹ they were found to have thinner corneas than their Caucasian counterparts²⁹. Those with younger age, a history of diabetes and more positive refractive errors had significantly thicker corneas, whereas a marginally significant result was noted among those with thinner corneas and a clinical diagnosis of OAG. Based on the finding that IOP was not associated with CCT among black BES participants, CCT seems an unlikely explanation for the higher IOP in this population. Since CCT has been found to increase the risk of developing glaucoma³⁰, the thinner corneas of black populations may be a partial explanation for their higher OAG risk.

Family history

A positive familial history of OAG was another major risk factor. For this reason, BFSG was developed to learn more about the potential genetic transmission of OAG within families. BFSG is the first large-scale genetic study of OAG in a predominantly black population and its results indicate a high proportion of affected relatives within families with a history of glaucoma²⁰. The study included over 200 families and found that approximately one-quarter of the family members examined had OAG or suspected OAG. Additionally, one out of every 5 siblings was found to have glaucoma. Comparison of risk factors between affected probands and their siblings found no major differences²⁰. Since OAG is a disease with a late age-of-onset, generally striking during the 6th decade of life or later, the BFSG findings are likely to be conservative, as the median age of family members in the study was 47 years.

A segregation analysis was conducted to determine the mode of inheritance for OAG in the BFSG families. The results indicated that OAG is likely due to a major gene with codominant effect (a Mendelian codominant mode of inheritance)³¹. It should be noted that this finding does not preclude the existence of an environmental or minor gene effect for OAG. A subsequent linkage analysis was then carried out using the parameter estimates obtained from the segregation analysis³². The linkage analyses indicated that OAG may be linked to chromosome 2q between D2S2188 and D2S2178, and chromosome 10p between D10S1477 and D10S601, with multipoint LOD scores > 3.0 in both regions. Heterogeneity testing strongly supports linkage for OAG to at least one of those regions and possibly both. TIGR/myocilin and OPTN mutations have been reportedly linked to OAG in other populations, however, neither of these were found to be causally linked to glaucoma in the BFSG population. These findings require further replication and identification of causative genes for

OAG in this black population. Further BFGS analyses are ongoing to learn more about genetic issues in OAG.

Hypertension and diabetes

As mentioned previously, neither diabetes or hypertension were related to OAG at baseline. However, persons with systemic hypertension at baseline had half the relative risk of developing OAG during 4 years of follow-up³³. The relative risk also tended to decrease as the systolic blood pressure increased. Consistent with these findings, a lower perfusion pressure also increased the relative risk approximately three-fold. These findings suggest that hypertension does not increase the risk of OAG, but may instead have a protective effect on early OAG development, a result supportive of the vascular hypothesis of glaucoma pathogenesis.

SUMMARY

Prevalence

- Black participants had a high prevalence of OAG, with 7% of persons 40 years and older being affected; prevalence was lower in white and mixed (black and white) participants
- Men were more frequently affected than women (8% vs. 6%)
- Prevalence increased with age: 1 in 9 persons over 60 years were affected and 1 in 6 persons over 70 years
- Only half of prevalent cases were aware of their OAG diagnosis
- The 7% prevalence was higher than the 4% reported for an African-American and an East African population of similar ages

Incidence

- After 4-years, 2.2% developed new OAG or 0.6%/year
- These rates are based on the largest number of new cases in any population study (n=67), thus yielding reasonably precise estimates; rates appear to be higher than in white populations, although the latter are based on small numbers
- Incidence rates increased greatly with age and were higher in men than women
- Only half of incident cases had been diagnosed during the 4-year interval

Risk factors

- At baseline, the presence of OAG was related to elevated intraocular pressure, low differential between the IOP and the blood pressure (suggesting low perfusion pressure), family history, lean body mass, cataract history, myopia and the Duffy Fya+ blood group

- IOP:
 - IOP levels were significantly higher in the black population.....
 - Persons having elevated IOP at baseline were older and more likely to have hypertension, diabetes and obesity, as well as to use tobacco and alcohol; aside from age, those factors were unrelated to OAG
 - After 4-years, elevated IOP was confirmed as a strong risk factor for developing OAG; the higher the IOP, the higher the risk
 - However, since the majority of the population does not have elevated IOP, about half of the new OAG cases developed in persons with IOP under 21mmHg at baseline
 - Vascular factors, such as hypertension, were more frequent in persons developing elevated IOP at follow-up, but not in persons developing OAG
 - Although central corneal thickness (CCT) in the black population was thinner than in whites, the CCT was not related to the IOP
- Family history:
 - In a separate study of black families with OAG, ¼ of relatives had OAG or suspect OAG and 1 in 5 siblings of affected probands had OAG
 - Risk factors for siblings and probands were similar to those found in the black population
 - A segregation analysis suggested that OAG is likely to have a Mendelian codominant mode of inheritance
 - Linkage analyses revealed linkages to regions in chromosomes 2q and 10p, but no associations to TIGR/myocillin or OPTN mutations
- Hypertension and diabetes:
 - While both conditions were positively related to elevated IOP, no such association was found with prevalent or incident OAG
 - In fact, hypertension was associated with a halving of the risk of incident OAG after 4 years, a result consistent with an etiologic role for perfusion pressure

Conclusions

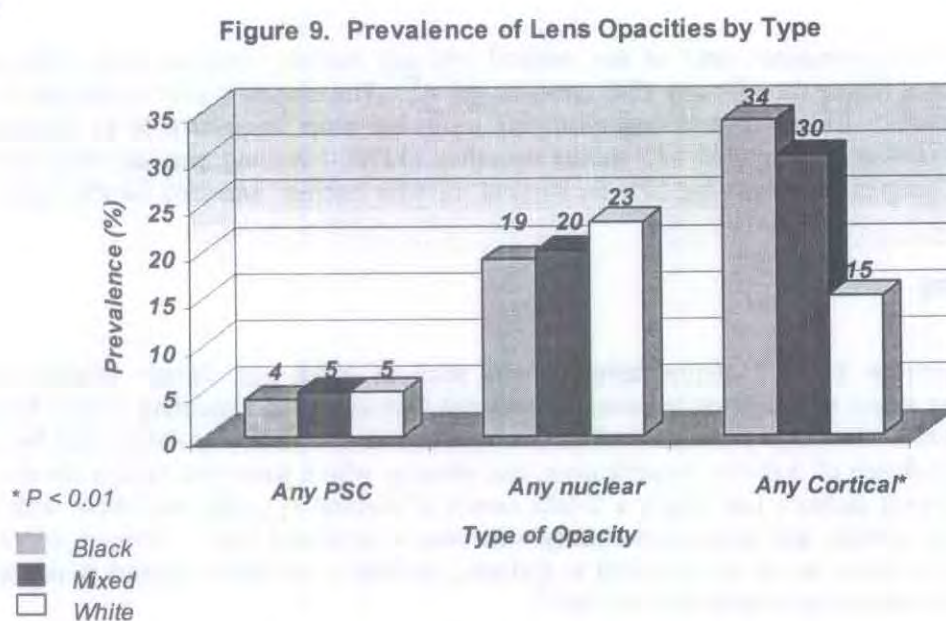
- OAG is more prevalent in black than white populations and seems especially frequent in Afro-Caribbeans
- There is considerable underdetection of the disease, as only half of those affected are being diagnosed
- Groups at higher risk are the elderly, men, those with elevated IOP and with positive family history; efforts at detection should target those high-risk groups, particularly family members of OAG patients
- While high IOP is confirmed as a strong risk factor, tonometry alone is a poor detection tool, due to its low sensitivity; it is also a poor predictor of future OAG development
- Risk factors for developing OAG and high IOP are not the same, suggesting different etiologic mechanisms; in this regard, of interest are the discrepant associations with hypertension (negatively related to OAG and positively related to high IOP) and with diabetes (not related to OAG and positively related to high IOP)

AGE-RELATED CATARACT

To study cataract in a standardized manner, lenses were graded using the Lens Opacities Classification System II (LOCS II) at the slit lamp, under maximum dilatation with tropicamide³⁴. LOCS II, which was developed for use in the BES, employs photographic standards to grade opacities into 5 nuclear (N0-N4), 7 cortical (C0, trace, C1-C5), and 5 posterior subcapsular (P0-P4) ordinal grades of increasing severity. Nuclear, cortical and PSC lens opacities were defined by a LOCS II score >2 of the respective type.

PREVALENCE

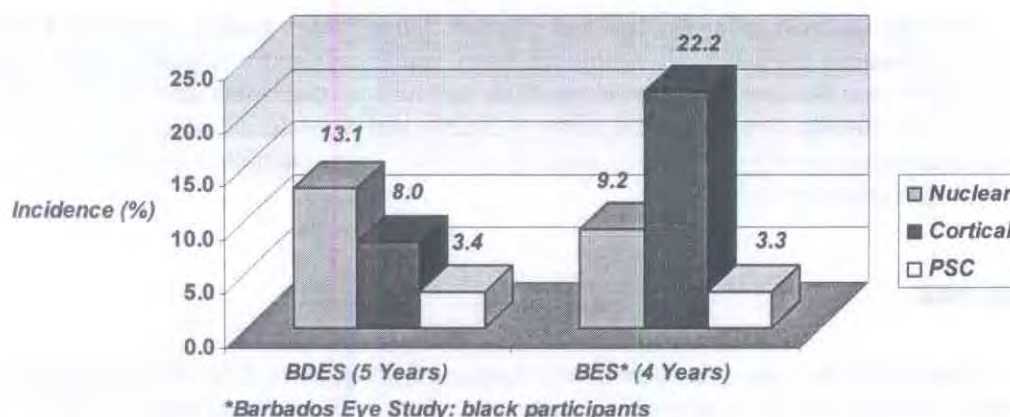
At baseline, lens opacities were a very frequent finding, since 41% of the population had some form of lens opacity or history of previous cataract surgery³⁵. The type of opacity varied according to self-reported race, as shown in Figure 9. The black population had a predominance of cortical opacities (4 times more frequent than in whites), while white participants tended to have more nuclear cataract. Prevalence was higher in women and at older ages.



4-YEAR INCIDENCE

Figure 10 presents the 4-year incidence of lens opacities, which increased greatly with age and was more common in women. The incidence of cortical cataract was five times greater among black than white participants³⁶. In the black population, 1 in 4 to 5 persons developed cortical opacities after 4 years, while 1 in 11 developed nuclear opacities and 1 in 30 developed posterior subcapsular opacities. Single cortical opacities were the type of cataract most likely to develop among persons free of lens opacity at baseline.

Figure 10. Incidence of Lens Opacities by type in the Beaver Dam Eye Study (BDES) vs BES*



9-YEAR INCIDENCE

The 9-year incidence rates of any cortical and any nuclear opacities were 34% and 42%, respectively, and higher than for any PSC opacities (6%)³⁷. The overall 9-year incidence of any lens changes was 46%. Single cortical opacities were again the most frequent type to develop (23%), followed by nuclear only (17%) and mixed opacities (15%). Among persons with pre-existing opacities, the progression rates were 22% for cortical, 18% for nuclear, and 26% for PSC opacities³⁷.

RISK FACTORS

As seen in Table 3, demographic factors such as older age, female gender and lower socioeconomic status were related to cataract³⁸, but risk factors varied according across the different lens opacity types. The high prevalence of cortical opacities in the black population may be related to their high prevalence of diabetes, hypertension, and obesity, which were risk factors for this opacity type. Persons with diabetes had nearly a 2-fold excess of cortical opacities and those with elevated diastolic blood pressure and abdominal obesity were also at increased risk³⁹. Overall, about 14% of the cataract prevalence could be attributed to diabetes, and this association appears to partly explain the increased mortality associated with cataract⁴⁰.

Regular use of nutritional supplements, mainly cod liver oil and multivitamins, was associated with a lower prevalence of cortical opacities in people aged less than 70 years³⁸. High intraocular pressure and a history of cardiac disease were related to prevalent nuclear opacities.

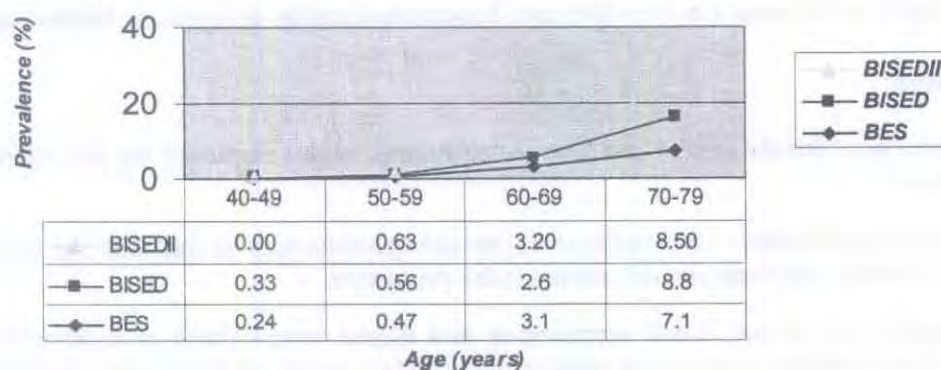
Analyses evaluated risk factors for the development of nuclear opacities after 4-years of follow-up⁴¹. These results confirmed previous findings from other populations, such as the increased risk of women and of persons with darker iris color, myopia, diabetes and leaner body mass. A relevant new finding is that treatment to lower the IOP, mainly topical beta-blockers, may increase the risk of nuclear opacities (Relative Risk=2.7).

As in the prevalence study, diabetes and older age at baseline were associated with the development of cortical and PSC opacities, while female gender was also predictive of incident cortical but not PSC opacities⁴². Other factors associated with increased risk of incident nuclear cataract, however, were not associated with the development of cortical or PSC opacities in 4 years. Low socioeconomic status at baseline increased the likelihood of incident cortical cataract but not other types of opacities, while aspirin decreased risk, an apparently protective effect that merits further investigation⁴².

CATARACT SURGERY

Overall, the prevalence of cataract surgery at baseline was low (3%). New cases of cataract surgery increased over the study period, with cumulative incidence being 1.6% at 4-years and 4.2% at 9-years. As seen in Figure 11, the age-specific frequencies of cataract surgery at each of the three study examinations indicated only a slight increase by time, but was more evident among the oldest age group of 80 years or older, where prevalence increased from 13% at baseline to 15% at 4-year and 22% at 9-year follow-up³⁷. The 9-year incidence was highest among eyes with PSC only and with mixed types of opacities at baseline. There seems to be a need to increase cataract surgery in the population.

Figure 11. Cataract Surgery and Age in the 3 Phases of the Barbados Eye Studies



CATARACT AND MORTALITY

Of the individuals who participated in the baseline examination, 7% were deceased by the 4-year follow-up. Cardiovascular disease was the main cause of death in black participants (3.6%), followed by malignant neoplasms (1.4%). The cumulative 4-year mortality varied according to lens type, increasing from a low of 3.2% for those without cataract to 6% for those with cortical-only, 8.8% for nuclear-only and 20.9% for mixed opacities. Participants with mixed opacities or with any nuclear opacities had increased 4-year mortality rates. Co-existing diabetes further increased mortality risk, as people with mixed opacities and diabetes had a 2.7 fold increased risk of death. Results also suggested

that persons with mixed or any nuclear opacities may be at an increased risk of death from malignant neoplasms, an association that needs further confirmation⁴⁰.

SUMMARY

Prevalence:

- Lens opacities were a very frequent finding in the black population, with 41% of persons 40 years and older having positive lens findings
- Prevalence of lens opacities was higher in women and at older ages
- Cortical cataract predominated, being 4 times more frequent in the black than the white population

Incidence:

- After 4-years, 1 in 5 persons developed cortical opacities; 1 in 11 developed nuclear opacities and 1 in 30 developed posterior subcapsular opacities
- Incidence was higher in women and at older ages
- The incidence of cortical opacities was 5 times higher in black than white participants
- After 9-years, the incidence of any lens changes was 46%
- Single cortical opacities were the most frequent to develop, followed by nuclear opacities

Risk factors:

- Older age, female gender and low socioeconomic status increased the risk of most cataract types
- The high prevalence and incidence of cortical opacities may be linked to the high prevalence of diabetes, hypertension and obesity in the population
- Regular use of nutritional supplements and aspirin were related to a lower frequency of cortical opacities, a result that requires confirmation, given the potential for prevention
- IOP-lowering treatment at baseline increased the risk of nuclear opacities

Conclusions:

- Results substantiate the very large problem that cataract represents in the population, a finding related to diabetes and perhaps to hypertension
- These results suggest that control of diabetes and hypertension may also have an effect on eye diseases, a possibility that merits further evaluation
- Additional efforts to increase cataract surgery are needed

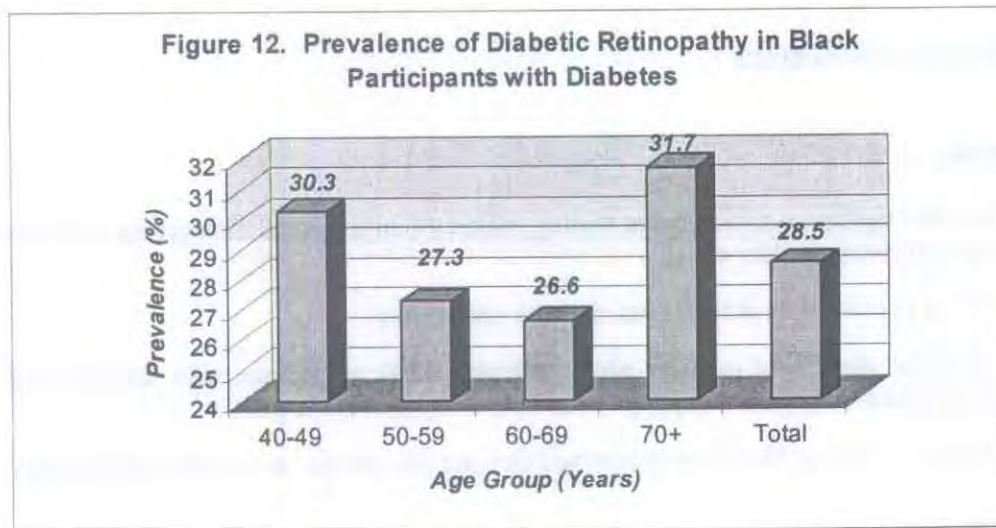
DIABETIC RETINOPATHY

DEFINITION

Standard fundus photographs were used to define the presence of diabetic changes. These included the following: at least three microaneurysms, retinal hemorrhages, hard and soft exudates, intraretinal microvascular abnormalities, new vessels within one disc diameter of the disc, and new vessels originating elsewhere, as well as other abnormalities such as clinically significant macular edema, venous beading, focal narrowing, and venous loops.

PREVALENCE

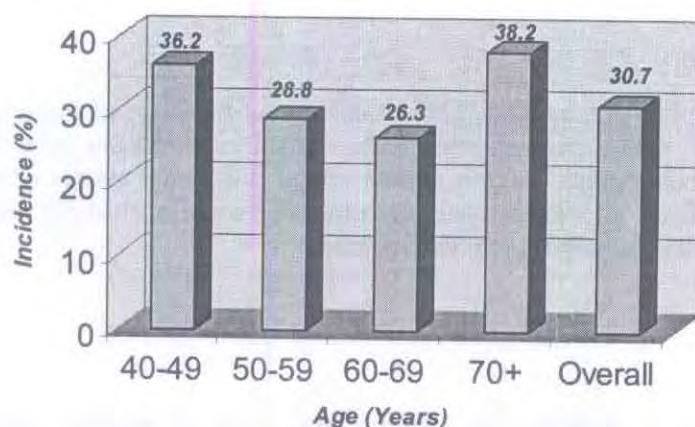
As seen in Table 1, diabetes was reported frequently at baseline, with 18% of black participants giving a history of physician-diagnosed diabetes mellitus⁴³. Since this self-reported frequency does not include undetected cases, the true prevalence of diabetes should be considerably higher. The predominant type reported was older-onset diabetes (after the age of 30 years), with very few persons classified as having an earlier diabetes onset. Over 5% of the total black population had diabetic changes in their fundus photographs. Among the subgroup of participants with diabetes, the prevalence of DR was about 30%, as shown in Figure 12⁴⁴. Clinically significant macular edema (CSME) was seen in 8.6% of persons with diabetes and about 1% of this group had proliferative diabetic retinopathy. Persons with DR had a longer duration of diabetes, as well as high blood pressure⁴⁴. These findings highlight the public health importance of diabetes and its ocular complications in this population.



4-YEAR INCIDENCE

Among persons with diabetes who were unaffected by DR at baseline, 31% had developed DR after 4 years, as shown in Figure 13. The 4-year incidence of DR was 32% in those with known DM at baseline and 21% in newly diagnosed DM. The incidence of CSME was 4.5%. Nearly 7% of persons with minimum or moderate DR at baseline progressed to proliferative DR⁴⁵.

Figure 13. Diabetic Retinopathy Incidence by Age



RISK FACTORS

Risk factors for DR included younger age of diabetes onset, as well as using oral hypoglycemics and insulin. The association between duration and DR was not linear, which may be confounded by the strong link to the severity of diabetes, as implied by the associations with treatment status. Additional risk factors included having a higher systolic blood pressure and having an elevated glycosylated hemoglobin.

SUMMARY AND CONCLUSIONS

Prevalence:

- Diabetes mellitus was a frequent finding, with 18% of the population giving a diabetes history, predominantly of older-onset
- 30% of persons with diabetes had diabetic retinopathy
- Clinically significant macular edema affected 8.6% of persons with diabetes and 1% had proliferative diabetic retinopathy
- Overall, 5% of the black population had diabetic changes in their fundus photographs

Incidence:

- After 4 years, 31% of persons with diabetes developed new diabetic retinopathy
- The incidence of clinically significant macular edema was 4.5%
- About 7% of persons with existing diabetic retinopathy progressed to proliferative DR

Risk factors:

- Higher systolic blood pressure, higher glycosylated hemoglobin and previous use of oral hypoglycemics and insulin as well as younger age of diabetes onset increased the risk of diabetic retinopathy development in persons with diabetes

Conclusions:

- High rates of prevalence and incidence of DR were evident in the study cohort, also known to have high rates of diabetes mellitus
- Prevention of visual loss due to DR in this population has high priority, including optimal glycemic and blood pressure control

AGE-RELATED MACULAR DEGENERATION**DEFINITION**

AMD-related macular changes were based on gradings from 30o stereoscopic color fundus photographs. Macular changes were classified into “early” and “late” changes. Early changes were defined as: (a) any medium or large drusen ($>63\ \mu\text{m}$) or, (b) >20 small drusen ($\leq 63\ \mu\text{m}$) with RPE atrophy and/or pigment in at least one eye. Late AMD was defined as the presence of one or more of the following features in at least one eye: fluid, lipid, or hemorrhage (excluding non-AMD causes), geographic atrophy, or disciform scar.

PREVALENCE

The severe form of AMD was very infrequent in the black population, being only 0.57%⁴⁶. However, early signs of macular degeneration, such as drusen, were as frequent as that reported among whites.

4-YEAR INCIDENCE

The 4-year incidence of early macular changes in this African- descent population was lower than in white populations, with approximately one in 20 persons developing new lesions⁴⁷. The development of new severe macular disease with late AMD features was also very infrequently observed during the 4-year follow up. The findings are consistent with the low risk of macular degeneration in persons of African descent.

RISK FACTORS

Based on a very small number of cases identified in the study, our results suggested a possible link between incident RPE atrophy and lighter iris color, and possibly lighter skin pigmentation.

Summary and conclusions

Prevalence:

- Age-related macular degeneration is an infrequent finding in the black population, especially the severe form of the disease
- Early macular lesions, however, were as frequent as in white populations

Incidence:

- After 4 years, 1 in 20 persons developed macular findings
- Late macular disease was extremely infrequent

Risk factors:

- Inferences are limited because of the small number of cases

Conclusions:

- Age-related macular degeneration is less frequent in the black population and does not appear to be a public health priority, in contrast to white populations

REFRACTIVE ERROR

DEFINITIONS

Myopia was defined as having a spherical equivalent <-0.5 diopter (D) and hyperopia was defined as having a spherical equivalent >0.5 D, based on non-cycloplegic automated refraction.

PREVALENCE

High prevalences of myopia and hyperopia were found in this large black adult population. The prevalence of myopia was 21.9%; it decreased from 17% in persons 40-49 years of age to 11% in those 50-59 years, but increased after the age of 60 years. The prevalence of hyperopia was 46.9%; it increased from 29% at ages 40-49 years to 65% at ages 50-59 years, and tended to decline thereafter¹⁷.

RISK FACTORS

The prevalence of myopia was higher in men (25.0%) than in women, whereas the prevalence of hyperopia was higher in women than in men. A higher prevalence of myopia was positively associated with lifetime occupations requiring nearwork, nuclear opacities, PSC opacities, glaucoma, and ocular hypertension. Factors associated with hyperopia were the same as for myopia, except for occupation, and in the opposite direction. The high prevalence of age-related cataract, glaucoma and other eye conditions in the BES population may contribute to our findings¹⁷.

SUMMARY AND CONCLUSIONS

Prevalence:

- Myopia and hyperopia were frequent findings, affecting 22% and 47% of the population 40 years and older

Risk factors:

- Myopia was more frequent in men and was positively related to occupations requiring nearwork, nuclear and posterior subcapsular opacities, glaucoma and ocular hypertension
- Similar factors were related to presbyopia, except for occupation, and were in the opposite direction

Conclusions:

- The high frequency of refractive errors implies the need for adequate provision of corrective lenses

PTERYGIUM

DEFINITIONS

Pterygium was defined as the presence of a raised fleshy growth that crosses the limbus and encroaches onto the clear cornea, or having a history of pterygium surgery.

PREVALENCE

Pterygium is a common eye condition in Barbados, affecting approximately one-quarter of black BES participants and one in ten white participants⁴⁸.

Risk factors

In addition to African ancestry, factors positively associated with pterygium were older age, fewer years of education, and an outdoor job location. In particular, pterygium was twice as frequent among persons who worked outdoors. Protective factors included darker skin complexion, use of sunglasses outdoors and use of prescription glasses. In fact, pterygium was only one-fifth as likely among persons who always used sunglasses outdoors⁴⁸.

SUMMARY AND CONCLUSIONS

Prevalence:

- Pterygium has a very high frequency in the population, affecting about 25% of black and 10% of white participants

Risk factors:

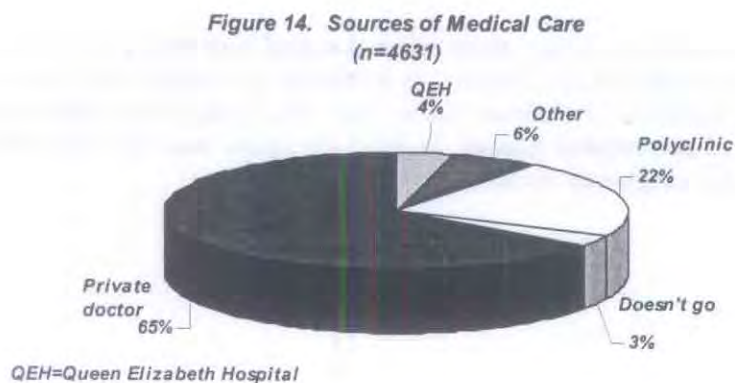
- Persons most frequently affected are those of older age, with lower education, and working outdoors
- Those less affected had darker skin and used sunglasses or prescription glasses
- Of importance, persons who always used sunglasses outdoors were one -fifth as likely to have pterygium as non-users

Conclusions:

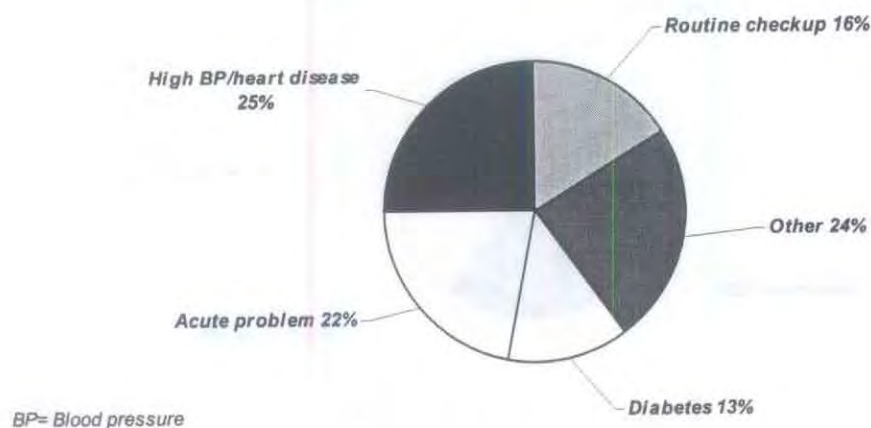
- The BESs findings substantiate highlight the importance of sunlight exposure in the development of pterygia
- Results also highlight the relevance of educational interventions to change modifiable risk factors, such as increasing the use of sunglasses, especially among those with outdoor occupations

MEDICAL AND EYE CARE

To provide a framework to better implement the BESs finding, this section briefly summarizes some information regarding medical and eye care in the population. Figures 14 and 15 show the sources and reasons for medical care visits at baseline. Private medical doctors provided the bulk of medical care, followed by Ministry of Health polyclinics, the Queen Elizabeth Hospital and other sources; 3% of the participants did not report any source. Acute problems and cardiovascular problems were the predominant reasons for medical visits; 16% reported routine visits.

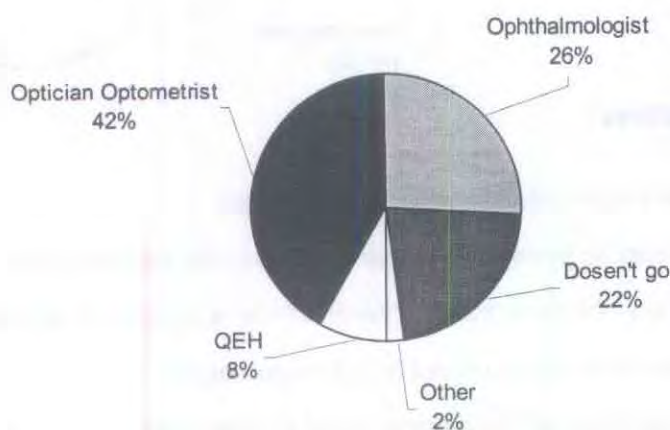


**Figure 15. Main reason for Medical Care Visits
(n=3733)**

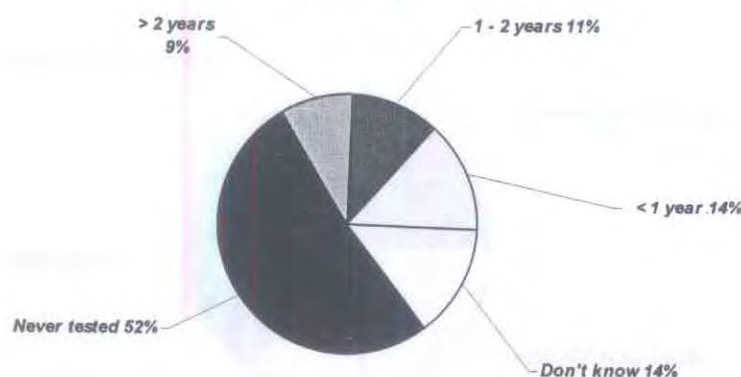


Figures 16-18 provide information on eye care. As seen in Figure 16, opticians and optometrists provided most of the eye care visits, with about one-fourth being provided by ophthalmologists; over one-fifth of the population did not seek eye care. Figures 17 and 18 contrast the glaucoma testing history of persons without and with glaucoma. Over half of the persons without glaucoma, had never been tested prior to participating in the BES and 14% could not recall; another 14% had been tested in the previous year. Similar results were found among persons with OAG who were newly diagnosed in BES, as 59% had never been tested and 17% did not remember. Surprisingly, 8% (12 of the 155 newly diagnosed) reported being tested for glaucoma in the previous year. In contrast, 86% of those with known glaucoma had been tested within the year.

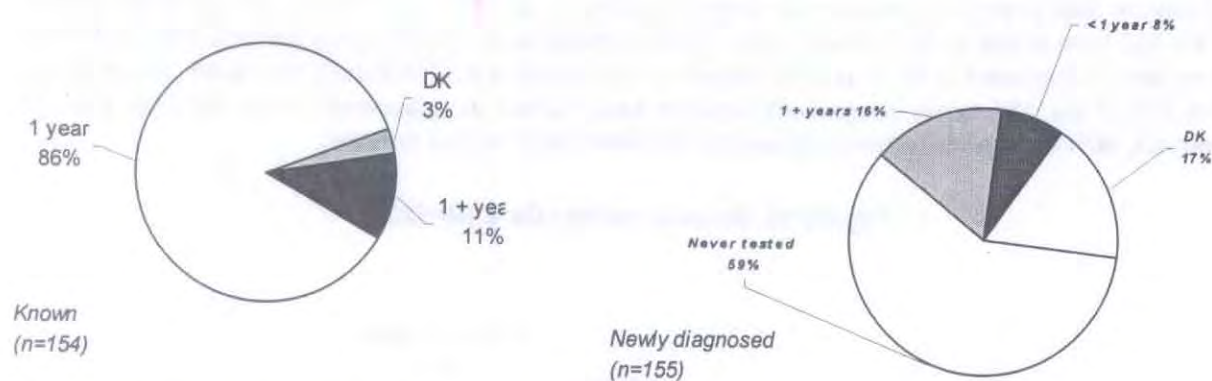
Figure 16. Sources of Eye Care (N=4631)



**Figure 17. Last Glaucoma Test
BES Participants without Glaucoma
(N=4119)**



**Figure 18. Last Glaucoma Test
BES Participants with Glaucoma (N=309)**



SUMMARY AND CONCLUSIONS

- Most medical care was provided by private practitioners
- Acute and cardiovascular problems were the main cause for medical visits
- Opticians and optometrists were the most frequent source of visits for eye care
- About ¼ of eye care visits was provided by ophthalmologists
- Over half of the population had never been tested for glaucoma
- About 60% of those newly diagnosed by the study had never been tested for glaucoma
- These results indicate the need to increase glaucoma testing, which may involve examination of the optic nerve at all eye care visits.

CONCLUSIONS

The Barbados Eye Studies have contributed a wealth of new information regarding the frequency and distribution of major eye diseases in a predominantly black Caribbean population. Such data are essential to allow the planning of public health and eye care delivery programs to control visual loss. Tables 4 and 5 give a summary of the prevalence and incidence rates. These results document the unusually high prevalence and incidence of OAG, as well as of age-related cataract, which are by far the most frequent causes of blindness. Both conditions should be the major target for interventions.

Table 4. Prevalence Summary

Condition	Percent prevalence
Blindness <6/120	<2
OAG	7
Lens opacities	42
Diabetic retinopathy*	29
Late AMD	<1

* among persons with diabetes mellitus

Table 5. Four-year Incidence Summary

Condition	Percent incidence
Blindness <6/120	0.6
OAG	2.2
Lens opacities	22.3
Diabetic retinopathy*	30.1
Late AMD	<0.1

* among persons with diabetes mellitus

The high prevalence of diabetes and hypertension in the population are also affecting vision, not only by leading to a high frequency of diabetic retinopathy, but also by contributing to high IOP levels and to cortical cataract. Such potential benefits should reinforce the efforts to control diabetes and hypertension.

The studies have also provided information on individual characteristics that increase the risk of having or developing various eye conditions. The high-risk groups so defined, (e.g., relatives of OAG patients, the elderly) can be targeted for early detection and treatment. In addition, data from the studies is providing insights into the etiology of eye diseases and the reasons for their higher frequency in the Caribbean region, thus contributing to scientific knowledge. Now that the information is becoming available, it is hoped that applications to the prevention and control of visual impairment will soon follow, as well as resolving scientific questions. When this occurs, the ultimate aim of the studies will be realized.

THE BARBADOS EYE STUDIES GROUP

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REFERENCES

- ¹ Kahn HA, Moorhead HB. Statistics on blindness in the model reporting area 1969-1970. U.S. Department of Health, Education, and Welfare. Publication No. (NIH)73-427.
- ² Leske MC. The epidemiology of open-angle glaucoma: a review. *Am J Epidemiol* 1983; 118:166-191.
- ³ Leske MC, Sperduto R. The epidemiology of senile cataract: a review. *Am J Epidemiol* 1983; 118:152-165.
- ⁴ Gregor Z, Joffe L. Senile macular changes in the black African. *Br J Ophthalmol* 1978;62:547-550.
- ⁵ Leske MC, Connell AMS, Troutman HT. The Barbados Eye Study. Letter to the Editor. *Arch Ophthalmol* 1989;107:169.
- ⁶ Leske MC, Connell AMS. Design of a Pilot Study of Glaucoma in Barbados. *J Nat Med Assoc* 1988;80:727-30.
- ⁷ Leske MC, Connell AMS, Kehoe R. A Pilot Project of Glaucoma in Barbados. *Br J Ophthalmol* 1989;73:365-9.
- ⁸ Leske MC, Connell AMS, Schachat AP, Hyman L and the Barbados Eye Study Group. The Barbados Eye Study: Prevalence of open angle glaucoma. *Arch Ophthalmol* 1994;112:821-829.
- ⁹ Tielsch JM, Sommer A, Witt K, Katz J, Royall RM. The Baltimore Eye Survey. Blindness and visual impairment in an American urban population. *Arch Ophthalmol*. 1990;108:282-290.
- ¹⁰ Rubin GS, West SK, Muñoz B, Bandeen-Roche K, Zeger S, Schein O, Fried LP. A comparative assessment of visual impairment in a population of older Americans, The SEE Study. *Invest Ophthalmol Vis Sci*. 1997;38:557-568.
- ¹¹ Hyman L, Wu SY, Connell AMS, Schachat A, Nemesure B, Hennis A, Leske MC for the Barbados Eye Study Group. Prevalence and Causes of Visual Impairment in the Barbados Eye Study. *Ophthalmology* 2001; 108:1751-1756.
- ¹² Thylefors B, Négrel AD, Pararajasegaram R, Dadzie KY. Global data on blindness. *Bulletin of the World Health Organization*. 1995; 73:115-121.
- ¹³ Leske MC, Wu SY, Hyman L, Nemesure B, Hennis A, Schachat A, for the Barbados Eye Studies Group. Four-year incidence of visual impairment: Barbados Incidence Study of Eye Diseases. *Ophthalmology* (in press).
- ¹⁴ Nemesure B, Wu S-Y, Leske MC. Ethnic differences in primary open-angle glaucoma. *International Ophthalmology*. American Academy of Ophthalmology. San Francisco, CA 2002;167-172.
- ¹⁵ Leske MC, Connell A, Wu S, Nemesure B, Li X, Schachat A, Hennis A, for the Barbados Eye Studies Group. Incidence of Open-Angle Glaucoma. *Arch Ophthalmol* 2001;119:89-95.
- ¹⁶ Leske MC, Connell AMS, Wu S-Y, Hyman LG, Schachat AP and the BES Group. Risk factors for Open-Angle Glaucoma. *Arch Ophthalmol* 1995;113:918-924.

- ¹⁷ Wu S-Y, Leske MC, Nemesure B and the Barbados Eye Study Group. Refractive errors in a black adult population: the Barbados Eye Study. *Invest Ophthalmol & Vis Sci* 1999; 40: 2179-2184.
- ¹⁸ Leske MC, Nemesure BB, He Q, Mendell N, Polednak A, for the Barbados Eye Study. Open-angle glaucoma and blood groups: the Barbados Eye Study. *Arch Ophthalmol* 1996; 114:205-210.
- ¹⁹ Nemesure B, Leske MC, He Q, Mendell N and the Barbados Eye Study Group. Analyses of reported family history of glaucoma: a preliminary investigation. *Ophthalmic Epidemiol* 1996;3:135-141.
- ²⁰ Leske MC, Nemesure B, He Q, Wu S-Y, Hejtmancik JF, Hennis A, for the Barbados Family Study Group. Patterns of open angle glaucoma in the Barbados Family Study. *Ophthalmology* 2001;108:1015-1022.
- ²¹ Leske MC, Connell AMS, Wu SY, Hyman L, Schachat AP for the Barbados Eye Study Group. Distribution of intraocular pressure: the Barbados Eye Study. *Arch Ophthalmol* 1997;115:1051-1057.
- ²² Leske MC, Connell AMS, Wu S-Y, Hyman L, Schachat AP and the Barbados Eye Study Group. Risk Factors for Open-angle Glaucoma: The Barbados Eye Study. *Arch Ophthalmol* 1995;113:918-924.
- ²³ Wu SY, Leske MC, the Barbados Eye Study Group. Associations with intraocular pressure in the Barbados Eye Study. *Arch Ophthalmol*. 1997;115:1572-1576.
- ²⁴ Nemesure B, Wu S-Y, Hennis A, Leske MC for the Barbados Eye Studies Group. Factors Related to the 4-Year Risk of "High" Intraocular Pressure – The Barbados Eye Studies. *Arch Ophthalmol* 2003;121:856-862.
- ²⁵ Hennis A, Wu SY, Nemesure B, Leske MC, for the Barbados Eye Studies Group. Hypertension, Diabetes and Longitudinal Changes in Intraocular Pressure. *Ophthalmology* 2003;110:908-914.
- ²⁶ Copt RP, Thomas R, Mermoud A. Corneal thickness in ocular hypertension, primary open-angle glaucoma, and normal tension glaucoma. *Arch Ophthalmol*. 1999;117:14-16.
- ²⁷ Hansen FK, Ehlers N. Elevated tonometer readings caused by thick cornea. *Acta Ophthalmol (Copenh)*. 1971;49:775-778.
- ²⁸ Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. *Acta Ophthalmol (Copenh)*. 1975;53:34-43.
- ²⁹ Nemesure B, Wu S-Y, Hennis A, Leske MC for the BISED Group. Corneal thickness and intraocular pressure in the Barbados Eye Studies. *Archives of Ophthalmology* 2003;121:240-244.
- ³⁰ Gordon MO, Beiser JA, Brandt JD, et al. The ocular hypertension treatment study: baseline factors that predict the onset of primary open-angle glaucoma. *Arch Ophthalmol*. 2002;120:714-720.
- ³¹ Nemesure B, He Q, Mendell N, Wu S-Y, Hejtmancik JF, Hennis A, Leske MC for the Barbados Family Study Group. Inheritance of Open-Angle Glaucoma in the Barbados Family Study. *Am J Med Genet* 2001;103:36-43.
- ³² Nemesure B, Jiao X, He Q, Leske MC, Wu S-Y, Hennis A, Mendell NR, Redman J, Garchon H-J, Agarwala R, Schäffer AA, Hejtmancik JF, for the Barbados Family Study Group. A genome-wide scan for primary open-angle glaucoma (POAG): The Barbados Family Study of Open-Angle Glaucoma. *Human Genetics*. 2003;112:600-609.
- ³³ Leske MC, Wu SY, Nemesure B, Hennis A, for the Barbados Eye Studies Group. Incident open-angle glaucoma and blood pressure. *Arch Ophthalmol* 2002;120:954-959.

- ³⁴ Chylack LT Jr, Leske MC, McCarthy D, Khu P, Kashiwagi T, Sperduto R. Lens Opacities Classification System II (LOCS II). *Arch Ophthalmol* 1989;107:991-997.
- ³⁵ Leske MC, Connell AMS, Wu S-Y, Hyman L, Schachat AP for the Barbados Eye Study Group. Prevalence of Lens Opacities in the Barbados Eye Study. *Arch Ophthalmol* 1997;115:105-111.
- ³⁶ Leske MC, Wu SY, Nemesure B, Li X, Hennis A, Connell AMS, for the Barbados Eye Studies Group. Incidence and progression of lens opacities in the Barbados Eye Studies. *Ophthalmology* 2000; 107:7:1267-1273.
- ³⁷ Leske MC, Wu SY, Nemesure B, et al. 9-year Incidence of Lens Opacities in the Barbados Eye Studies. *Ophthalmology* (In press).
- ³⁸ Leske MC, Wu S-Y, Connell AMS, Hyman L, Schachat AP and the Barbados Eye Study Group. Lens Opacities, Demographic Factors and Nutritional Supplements in the Barbados Eye Study. *Int J Epidemiol* 1997;26:1314-1322.
- ³⁹ Leske, MC, Wu SY, Hennis A, Connell AMS, Hyman L, Schachat AP, for the Barbados Eye Study Group. Diabetes, Hypertension, and Central Obesity as Cataract Risk Factors in a Black Population: The Barbados Eye Study. *Ophthalmology* 1999;106:35-41.
- ⁴⁰ Hennis A, Wu SY, Li X, Nemesure B, Leske MC, for the Barbados Eye Studies Group. Lens opacities and mortality: The Barbados Eye Study. *Ophthalmology* 2001;108:498-504.
- ⁴¹ Leske MC, Wu SY, Nemesure B, Hennis A. Risk factors for incident nuclear opacities. *Ophthalmology* 2002;109:1303-1308.
- ⁴² Hennis A, Wu SY, Nemesure B, Leske MC. Risk factors for incident cortical and posterior subcapsular lens opacities in the Barbados Eye Studies. *Arch Ophthalmol* (in press)
- ⁴³ Hennis A, Wu SY, Nemesure B, Li X, Leske MC for the Barbados Eye Studies Group. Diabetes in a Caribbean Population: Epidemiologic Profile and Implications. *Int J Epidemiol* 2002;31:234-239.
- ⁴⁴ Leske MC, Wu S-Y, Hyman L, Li X, Hennis A, Connell AMS, Schachat A and the Barbados Eye Study Group. Diabetic Retinopathy in a Black Population – The Barbados Eye Study. *Ophthalmology* 1999;106:1893-1899.
- ⁴⁵ Leske MC, Wu S-Y, Hennis A, Nemesure B, Hyman L, Schachat A, for the Barbados Eye Studies Group. Incidence of Diabetic Retinopathy in the Barbados Eye Studies. *Ophthalmology* 2003;110:941-947.
- ⁴⁶ Schachat A, Hyman L, Leske MC, Connell AMS, Wu S-Y and the Barbados Eye Study Group. Features of Age-Related Macular Degeneration in a Black Population. *Arch Ophthalmol* 1995;113:728-735.
- ⁴⁷ Schachat A, Hyman L, Leske MC, Connell AMS, Wu S-Y and the Barbados Eye Study Group. Features of Age-Related Macular Degeneration in a Black Population. *Arch Ophthalmol* 1995;113:728-735.
- ⁴⁸ Luthra R, Nemesure B, Wu SY, Xie SH, Leske MC. Frequency and risk factors for pterygium in the Barbados Eye Study. *Arch Ophthalmol* 2001;119:1827-1832.

