

# Blindness and Visual Impairment in an Urban West African Population: The Tema Eye Survey

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**Objective:** To determine the prevalence, causes, and risk factors of blindness and visual impairment among persons aged 40 years or older residing in an urban West African location.

**Design:** Population-based, cross-sectional study.

**Participants:** A total of 5603 participants residing in Tema, Ghana.

**Methods:** Proportionate random cluster sampling was used to select participants aged 40 years or older living in the city of Tema. Presenting distance visual acuity (VA) was measured at 4 and 1 m using a reduced logarithm of the minimum angle of resolution tumbling E chart and then with trial frame based on autorefraction. A screening examination was performed in the field on all participants. Complete clinical examination by an ophthalmologist was performed on participants with best-corrected visual acuity (BCVA) <20/40 or failure of any screening test.

**Main Outcome Measures:** Age- and gender-specific prevalence, causes, and risk factors for blindness (VA of <20/400 in the better eye, World Health Organization definition) and visual impairment (VA of <20/40 in the better eye).

**Results:** A total of 6806 eligible participants were identified, of whom 5603 (82.3%) participated in the study. The mean age ( $\pm$  standard deviation) of participants was  $52.7 \pm 10.9$  years. The prevalence of visual impairment and blindness was 17.1% and 1.2%, respectively. After refraction and spectacle correction, the prevalence of visual impairment and blindness decreased to 6.7% and 0.75%, respectively, suggesting that refractive error is the major correctable cause of visual impairment and blindness in this population. Of 65 subjects with a VA <20/400, 22 (34%) were correctable with refraction, 21 to the level of visual impairment and 1 to normal. The remaining 43 patients (66%) had underlying pathology (cataract in 19, glaucoma in 9, nonglaucomatous optic neuropathy in 3, corneal opacities in 3, retinal disease in 3, and undetermined in 5) that prevented refractive correction. Increased age was a significant risk factor for blindness and visual impairment.

**Conclusions:** There is a high prevalence of blindness and visual impairment among those aged  $\geq 40$  years in Tema, Ghana, West Africa. Refractive error is a major cause of blindness and visual impairment in this population, followed by cataract, glaucoma, and corneal disease.

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Sub-Saharan Africa bears a disproportionate amount of the world's blindness,<sup>1,2</sup> and the proportion of people blind in this region is increasing at a faster rate than in other parts of the world.<sup>1,2</sup> Ghana is a country of approximately 24 million people<sup>3</sup> located in West Africa. It currently is in the middle stages of a demographic transition typical of many developing countries in Africa, from a high birth rate and short life expectancy to a lower birth rate and increased longevity.<sup>4</sup> Part of this demographic transition is driven by a shift from a primarily rural agrarian society (where high birth rates yield economic rewards) to an urban society (where

high birth rates have the opposite effect).<sup>5</sup> The percentage of Ghana's population that lives in urban areas has more than doubled in the past 50 years, from 23% in 1960 to 48% in 2009.<sup>6</sup> Chronic eye diseases such as cataract and glaucoma may represent a greater percentage of disease burden today because of the reduced prevalence of infectious causes of blindness, such as trachoma and onchocerciasis, from improvements in their prevention and treatment, as well as population shifts away from endemic regions<sup>1,7</sup> and increased life expectancy in developing West African countries such as Ghana.<sup>8</sup> In addition, improvements in economic status and

urbanization have led to increased obesity<sup>9</sup> and diabetes mellitus prevalence<sup>10</sup> in Ghana and other developing African countries, and the prevalence of diabetic eye disease and its impact on vision in this population is unknown.

The paucity of country-specific data regarding the prevalence of blindness and visual impairment in Africa led the World Health Organization (WHO) in 2004 to recommend additional study of the prevalence and causes of visual impairment in Sub-Saharan Africa.<sup>1</sup> The purpose of this portion of the Tema Eye Survey (TES) was to determine the age-specific prevalence and causes of, and factors associated with, blindness and visual impairment in an urban West African population.

## Materials and Methods

### Study Population

Tema is a city of the Greater Accra region in Ghana, West Africa. Approximately 17.6% of Ghana's population lives in the Greater Accra region,<sup>11,12</sup> despite the fact that this is the geographically smallest of Ghana's 10 regions. The 2005 estimated population in the Tema District was 562 291, extrapolated from census data from 2000<sup>12</sup> and known birth and death rates. As one of the busiest ports in West Africa, Tema has attracted workers from all over Ghana, making it an ethnically and economically diverse environment for study; for these reasons, Tema was chosen for the current survey.

Tema is divided into 20 communities. Five of these communities were selected for study on the basis of their ethnic diversity and lower socioeconomic status. These included Community 1, Ashiaman Southeast, Ashiaman Southwest, Bethlehem/Kakasunanka, and Tema Newtown. These communities are further divided into polling stations by the Ghanaian government for the purpose of voting and represent distinct geographic areas (analogous to neighborhoods). We used voting rolls, which contained the number (but not names) of voting-age individuals and the name of each polling station, to divide the communities into clusters. With the help of local polling officials (usually a local teacher or government official), the polling stations were mapped in each of the 5 communities selected. A sample size of 5600 was calculated using the National Center for Health Statistics standards to specifically determine the prevalence of glaucoma in subjects aged 40 years or older. The National Center for Health Statistics standard for a reliable prevalence estimate is one that has a relative standard error of  $\leq 30\%$ .<sup>13</sup>

A random cluster sampling strategy with probability of cluster selection proportionate to the size of the community under study was used to obtain a representative sample and avoid bias. Each polling station of more than 350 voting-age adults in each of the 5 communities was eligible for inclusion. Large polling stations (>600 voting-age adults) were broken down into smaller clusters of 350 to 600 voting-age individuals. Population data from the 2000 census for Ghana<sup>12</sup> indicated that 38% of voting-age individuals are aged 40 years or older and that 62% are aged 18 to 39 years. It was estimated that 190 subjects would be of an eligible age per cluster. Polling stations with less than 350 of voting-age adults were excluded because these small areas would be expected to yield too few subjects aged 40 years or older. The number of clusters selected from each of the 5 communities varied on the basis of the total estimated eligible population in each community, creating a proportional cluster sampling of the population. All eligible clusters within each community were placed in a random number generator and ordered according to the random number

order from lowest to highest. A house-to-house census was conducted in each randomly selected cluster, and residents aged 40 years or older were invited to participate in a screening eye examination (field examination) as part of a study. They were given an appointment card with a specific appointment date and time for the following week and asked to bring their glasses with them.

### Field Examination

Field examinations were conducted in schools or churches within subjects' communities near their homes. After the identity, address, and eligibility of each subject was confirmed, written informed consent was obtained. An extensive health questionnaire was completed orally in the subject's native language. Subjects then underwent a screening examination that included testing of presenting visual acuity (VA) using the reduced logarithm of the minimum angle of resolution tumbling E chart<sup>14</sup> at 4 m and then at 1 m, if they were unable to see any letters at 4 m. This vision chart provides a close approximation of Early Treatment Diabetic Retinopathy Study vision but is designed specifically for countries with low literacy rates. Autorefractometry (Humphrey Autorefractor model 599, Carl Zeiss Meditec, Dublin, CA) was then performed if the presenting VA was  $<20/40$ , and the VA was rechecked with a trial frame correction using the autorefractometry results. Frequency doubling technology (FDT) perimetry (Carl Zeiss Meditec), intraocular pressure with Tonopen XL (Reichert Ophthalmic Instruments, Depew, NY), ultrasonic pachymetry (DGH Technology Inc., Exton, PA), flashlight screening for potentially occludable anterior chamber angles,<sup>15</sup> and dilated optic disc and macular photographs using a handheld digital fundus camera (Kowa Genesis D, Kowa Company, Ltd., Tokyo, Japan) were then taken. Neither slit-lamp examination nor gonioscopy was taken in the field examination. Presenting VA was defined by the VA obtained in the field with the subject's distance glasses on. The field examinations were performed by study personnel from the United States or United Kingdom, local ophthalmic nurses, and local ophthalmic technicians. An intensive 3-week training period was performed by 3 of the investigators (D.L.B., K.B., W.N.) on the correct protocol for obtaining informed consent, data collection, field examinations, and use of equipment before the study. During this training period, 2 separate 2-day field examination sessions were performed at a church and a mosque in a nearby community that was not part of the study. Subjects who tested positive on any screening tests were referred back to the clinic for complete ophthalmic examination by study investigators for the purpose of training on clinic procedures and to address the medical reasons for positive tests.

### Criteria for Referral to Clinic

Subjects were referred to clinic for complete examination for the following reasons: best-corrected visual acuity (BCVA)  $<20/40$  after spectacle correction based on autorefractometry,  $>1$  abnormal spot on the FDT Screening C20-5 program on 2 tests in either eye, intraocular pressure  $\geq 21$  mmHg on the average of 2 readings, narrow anterior chamber by flashlight testing by ophthalmic nurse, and abnormal optic disc or macular photographs as assessed by the Moorfields Eye Hospital Reading Centre. Subjects who were not able to be tested with the FDT screening mode or in whom photographs were not possible were referred to clinic for complete examination.

### Clinic Examination

Clinic examinations consisted of manifest refraction by a licensed optometrist followed by measurement of BCVA using the reduced

logarithm of the minimum angle of resolution tumbling E chart at 4 m and then at 1 m if the subject was unable to see any letter on the chart at 4 m. Next, automated static perimetry was performed using the Humphrey Visual Field Analyzer 2 with the 24-2 Swedish Interactive Threshold Algorithm (Carl Zeiss Meditec) using the subject's best correction with age-appropriate presbyopic correction. All visual fields were uploaded to a secure study Web site and evaluated by one of the study investigators (J.W.dV.). An investigator/ophthalmologist then performed a complete dilated ophthalmic examination including Goldmann applanation tonometry, gonioscopy, and fundus examination. Last, simultaneous stereoscopic optic disc and macular photographs were performed using the Nidek 3Dx camera (Nidek Co, Ltd., Gamagori, Japan). These were uploaded to a secure study Web site and evaluated in a masked fashion by the Moorfields Eye Hospital Reading Centre (London, UK). The BCVA was defined by the VA in the better eye after manifest refraction by the optometrist in the clinic. Visual data are presented for presenting VA and BCVA at the time of presentation, before any intervention, such as cataract surgery. Subjects with visually significant cataracts were referred to the ophthalmologist at the Tema Christian Eye Center for cataract surgery and referred back to the study clinic for completion of the dilated examination by a study ophthalmologist and posterior segment photographs. Subjects with closed or occludable anterior chamber angles were referred for free laser or surgical iridotomy by a study investigator and then sent back to the study clinic for completion of the dilated examination and photography. Subjects with glaucoma or other ophthalmic conditions requiring monitoring or treatment were referred to the Tema Christian Eye Center for evaluation and management by a local Ghanaian ophthalmologist. Ophthalmologist investigators were asked to determine the presence or absence of any eye disease(s) and the primary cause of the visual impairment.

### Definitions of Blindness and Visual Impairment

This study used the WHO's definitions of visual impairment and blindness<sup>16</sup> with the addition of a category for mild visual impairment (VA <20/40 to  $\geq$ 20/60) as suggested by a recent eye survey in Nigeria<sup>17</sup> and for comparison with US definitions.<sup>18,19</sup> Moderate visual impairment was used for VA <20/60 but  $\geq$ 20/200. Severe visual impairment was used for VA <20/200 but  $\geq$ 20/400. Any visual impairment was defined as VA <20/40 but  $\geq$ 20/400. Blindness was reserved for those with VA <20/400 or visual field constriction to less than 10 degrees from fixation. Anyone who had vision of  $\geq$ 20/40 was classified as normal/near normal. Data are presented for presenting VA (distance VA in the better-seeing eye with presenting correction before autorefraction and without pinhole assistance) and BCVA (distance VA in the better-seeing eye after manifest refraction by an optometrist with correction in trial frame). The cause of blindness and visual impairment for each subject was based on the WHO recommendation that the primary cause should be the pathology that is most amenable to treatment or prevention.

### Statistical Analysis

Age-specific prevalences of visual impairment and blindness were calculated by taking the number of subjects in a specific age group with blindness or visual impairment divided by the number of individuals who participated in the study in that age group. Factors associated with blindness and visual impairment were calculated using logistic regression and Mantel-Haenszel procedures. Statistical analysis was performed using PASW 18.0 (IBM Inc., Armonk, NY).

### Protection of Human Subjects and Informed Consent

The Ethics Committee of the Ghana Ministry of Health and the individual institutional review boards of each of the investigators who examined participants approved this study. The study was conducted in accordance with protection of human subjects guidelines set forth by the Declaration of Helsinki. All study personnel having contact with subjects were required to complete Collaborative Institutional Training Initiative certification before obtaining informed consent. Each subject signed a written informed consent form approved by the Ghana Ethics Committee before conducting any study-related activity. If the subject did not read or speak English, the national language of Ghana, a translator was provided to explain the study and answer questions. On the specific recommendation of the Ethics Committee of the Ghana Ministry of Health, subjects were paid the equivalent of US\$2 for their participation in field examinations and the equivalent of US\$5 for their participation in clinic examinations. If subjects were asked to repeat clinic examinations or ancillary testing, an additional US\$5 was provided. Because the field examinations were conducted in the communities where subjects resided, no transportation to field examinations was provided. Transportation to and from the clinic was offered free of charge. Field examinations were conducted from September 2006 to August 2008, and clinic examinations continued through December 2008.

### Results

There were a total of 230 clusters identified for sampling in the 5 communities. Thirty-seven of these were randomly chosen, the number of clusters from each community (and therefore, the number of subjects) proportionate to the estimated number of people aged 40 years or older residing in each community. The house-to-house census enumerated 6806 eligible subjects, of whom 5603 came for the field examination for a participation rate of 82.3%. The field examination identified 1869 subjects (33.3%) who failed 1 or more screening examinations. Of these, 1538 came back to the clinic for complete examination by an ophthalmologist, for a participation rate at this stage of 82.2%.

The demographic characteristics of subjects in the TES are shown in Table 1. Although 30% of subjects were from the Greater Accra region, 70% were born elsewhere in Ghana; 7.7% were from outside Ghana, from nearby Mali (40), Togo (37), Nigeria (14), and Cote d'Ivoire (13). Table 2 presents the distribution of subjects enumerated in the census and examined in the field by age and gender. In all age ranges, there were more female subjects enumerated and examined than male subjects, and this difference increased with age. There were no differences, however, in the proportion of male and female subjects enumerated versus examined, demonstrating that our sample was representative of the population of this area.

The prevalence of visual impairment and blindness was higher among older participants (Tables 3 and 4). For the entire group, the prevalence of any visual impairment or blindness in presenting VA was 18.3% (95% confidence interval [CI], 17.3–19.3). The prevalence of any visual impairment or blindness based on BCVA was 7.4% (95% CI, 6.8–8.1), indicating that refractive error alone accounted for approximately 60% of the visual impairment and blindness in this population. The prevalence of blindness, defined as VA <20/400 in the better eye, was 1.2% (95% CI, 0.9–1.5) on presentation and was reduced to 0.75% (95% CI, 0.54–1.01) using BCVA.

Of the 331 subjects who were examined in the field but did not report for the clinic examination, 63.8% had been referred for

Table 1. Demographic Characteristics of Subjects in the Tema Eye Survey

Age (Mean ± SD)	52.7±10.9 Yrs (Range, 40–110 Yrs)
Gender	
Male	39.7%
Female	60.3%
Region of birth*	
Ashanti	4.8% (20.3%)
Greater Accra	29.3% (17.1%)
Eastern	15.2% (10.0%)
North	4.4% (9.5%)
Western	3.9% (10.2%)
Brong Ahafo	0.6% (9.5%)
Volta	18.5% (8.1%)
Central	14.7% (8.1%)
Upper East	0.3% (4.5%)
Upper West	0.2% (2.7%)
Other countries	7.7%
Marital status	
Married	66.2%
Single	2.7%
Divorced	11.4%
Widowed	15.5%
Unknown	4.2%
Previous eye examination	
Yes	37.8%
No	61.9%
Unknown	0.3%
History of diabetes mellitus	
Yes	4.7%
No	33.9%
Unknown	61.4%
History of systemic hypertension	
Yes	29.1%
No	31.8%
Unknown	39.1%
History of eye disease	
Yes	29.7%
No	70.3%

SD = standard deviation.

\*Approximate percentage of people residing in each of Ghana's 10 regions in 2006 given in parentheses for comparison.

failure of FDT, 29.1% for intraocular pressure >21 mmHg in either eye, 18.5% for vision <20/40, and 4.7% for inability to take fundus photographs (subjects could have been referred for >1 reason; thus, the totals are >100%). Subjects who failed to come to clinic were younger (54 vs. 60 years;  $P < 0.001$ ), had worse vision (20/60 vs. 20/50;  $P < 0.001$ ), and had slightly lower intra-

ocular pressure (18 vs. 19 mmHg;  $P < 0.001$ ) than those who came to clinic. Eight percent more women than men failed to come to the clinic examination ( $P = 0.001$ ).

Sixty-seven subjects had presenting VA <20/400, of whom 25 were correctable with refraction so that 21 still had visual impairment and the remaining 1 had normal VA. The remaining 42 subjects had underlying pathology that was not correctable with refraction: cataract in 19, glaucoma in 9, nonglaucomatous optic neuropathy in 3, corneal opacities in 3, retinal diseases in 3, and undetermined in 5 (Table 5). There were no definite cases of blindness from diabetes mellitus or age-related macular degeneration identified. Two cases of corneal opacification were thought to be secondary to trachoma and were in persons aged 68 and 75 years.

Factors associated with visual impairment (BCVA <20/40 but ≥20/400) and blindness (BCVA <20/400 or visual field <10 degrees) are shown in Tables 6 and 7, respectively. Older age and widowed marital status were significantly associated with visual impairment in the multivariate analysis, whereas age and a history of ocular disease were significantly associated with blindness in the multivariate analysis. Data on socioeconomic status were not available.

Because we were concerned about using 7 ophthalmologists to determine the cause of visual impairment and blindness, 29 subjects were examined by all investigators in a masked fashion, and the presence and cause of visual impairment or blindness were noted by each. Investigators agreed that there was no ophthalmic diagnosis in 14 of them and agreed on the same diagnoses causing visual impairment or blindness in 8. Among the other 7 patients, the examining ophthalmologists disagreed about a determination of primary open-angle glaucoma versus glaucoma suspect in 5 patients, one in whom there was a disagreement about whether there was chronic narrow-angle glaucoma present and one in whom there was a disagreement about traumatic glaucoma. However, these did not affect the presence or absence of visual disability and blindness, just the cause of these conditions in these few subjects.

## Discussion

The TES is one of only a few population studies of blindness, visual impairment, and eye diseases in West Africa and perhaps the only one that has studied a purely urban population. We found a high prevalence of curable vision loss due to uncorrected refractive error or cataract. The percentage of curable visual impairment from refractive error or cataract was 39.2%, and the percentage of curable blindness from these causes was 58.3%. In addition, preventable vision loss from glaucoma was found to be a significant problem in this population.

Table 2. Age and Gender Distribution of Study Participants

Age Group (yrs)	Female				Male				Total			
	Enumerated		Examined		Enumerated		Examined		Enumerated		Examined	
	n	%	n	%	n	%	n	%	n	%	n	%
40–49	2014	50.5	1662	49.2	1270	45.1	942	42.4	3284	48.3	2604	46.5
50–59	1066	26.7	940	27.8	810	28.7	648	29.2	1876	27.6	1588	28.3
60–69	535	13.4	459	13.6	474	16.8	404	18.2	1009	14.8	863	15.4
70–79	243	6.1	211	6.2	212	7.5	186	8.4	455	6.7	397	7.1
≥80	129	3.2	109	3.2	53	1.9	42	1.9	182	2.7	151	2.7
Total	3987	58.6	3381	60.3	2819	41.4	2222	39.7	6806	100	5603	100

Table 3. Age-Specific Prevalence of Visual Impairment and Blindness in the Tema Eye Survey by Presenting Visual Acuity in the Better-Seeing Eye

	Age Categories (Yrs)					Total
	40-49	50-59	60-69	70-79	≥80	
Mild visual impairment (<20/40 and ≥20/60)	63 (2.42)	94 (5.92)	99 (11.46)	45 (11.36)	20 (13.33)	321 (5.73)
Moderate visual impairment (<20/60 and ≥20/200)	73 (2.80)	135 (8.51)	156 (18.06)	148 (37.37)	82 (54.67)	594 (10.60)
Severe visual impairment (<20/200 and ≥20/400)	3 (0.12)	8 (0.50)	14 (1.62)	10 (2.53)	6 (4.00)	41 (0.73)
Total visual impairment (<20/40 and ≥20/400)	139 (5.33)	237 (14.93)	269 (31.13)	203 (51.26)	108 (72.00)	956 (17.06)
Age-specific blindness (<20/400)	8 (0.31)	8 (0.50)	17 (1.97)	18 (4.55)	16 (10.67)	67 (1.20)
Age-specific blindness according to US definition (<20/200)	11 (0.42)	16 (1.00)	31 (3.59)	28 (7.07)	22 (14.67)	108 (1.93)
Total visual impairment or blindness (<20/40)	147 (5.64)	245 (15.44)	286 (33.10)	221 (55.81)	124 (82.67)	1023 (18.26)
Total no. of subjects	2606	1587	864	396	150	5603

Data provided as n (%).

There are several reasons why it is difficult to directly compare blindness prevalence survey results across studies. First, many different definitions of blindness and visual impairment have been used in the past. Second, studies vary widely in how they achieve BCVA. The current study used the WHO definition of blindness as presenting distance VA <20/400 and visual impairment of varying degrees from <20/60 to 20/400. It also included the category of mild visual impairment (<20/40 to ≥20/60) for comparison with a recent study in Nigeria<sup>16</sup> and the US definition of visual impairment (<20/40),<sup>17</sup> as evidenced by the legal limits for a driver's license in most US states.<sup>18,19</sup> The current study went to great lengths to provide BCVA for subjects by having them refracted by an optometrist and then retested.

There have been 2 other population surveys of the prevalence and causes of blindness in Ghana. Both were conducted in rural areas. In the early 1990s, Moll et al<sup>20</sup> surveyed 866 subjects aged 40 years or older residing in 10 villages distant from the onchocerciasis endemic area around the Black Volta River. They found a 2.4% prevalence of blindness (WHO definition, VA <20/400 in better eye) for people aged 40 years or older. In that study, nonophthalmologist observers assessed presenting and pin-hole visual acuities without refraction, slit-lamp examination, dilated fundus examination, or standardized diagnostic criteria for glaucoma. The causes of blindness and visual

impairment determined by nonophthalmologist observers were cataract (62.5%), onchocerciasis (12.5%) and corneal opacities (8.2%). More recently, Guzek et al<sup>21</sup> performed a survey of 2298 subjects aged 40 years or older in 3 districts of the rural mid-Volta region of Ghana. Three ophthalmologists and 2 optometrists performed refractions and complete dilated eye examinations. They found a 2.8% prevalence of blindness (VA <20/400), with the main causes being cataract (53.9%) and glaucoma (20.6%). These investigators did not comment on corneal blindness and found no definite cases of onchocerciasis and only 1 case of possible inactive trachoma. We found 2 cases of suspected inactive trachoma as a possible cause of corneal blindness. It is possible that there were cases of inactive onchocerciasis that were misdiagnosed as toxoplasmosis or chorioretinal scarring of indeterminate cause.

There have been several other population-based surveys of blindness and eye disease in West Africa. In the mid-1980s, Faal et al<sup>22</sup> surveyed 8174 people of all ages living in both urban and rural communities in Gambia. They found a 0.7% prevalence of blindness (VA <20/400) and a 1.4% prevalence of visual impairment (VA <20/60). The age-specific prevalence of blindness and visual impairment in adults aged 40 years or older was similar to that in the current study (Table 8, available at <http://aojournal.org>). The 3 most common causes of blindness were cataract (55%), corneal opacity (20%), and trachoma (17%). In

Table 4. Age-Specific Prevalence of Visual Impairment and Blindness in the Tema Eye Survey by Best-Corrected Visual Acuity in the Better-Seeing Eye

	Age Categories (Yrs)					Total
	40-49	50-59	60-69	70-79	≥80	
Mild visual impairment (<20/40 and ≥20/60)	12 (0.46)	29 (1.83)	44 (5.09)	53 (13.38)	24 (16.00)	162 (2.89)
Moderate visual impairment (<20/60 and ≥20/200)	21 (0.81)	25 (1.58)	54 (6.25)	59 (14.90)	45 (30.00)	204 (3.64)
Severe visual impairment (<20/200 and ≥20/400)	1 (0.04)	1 (0.06)	4 (0.46)	1 (0.25)	1 (0.67)	8 (0.14)
Total visual impairment (<20/40 and ≥20/400)	34 (1.30)	55 (3.47)	102 (11.81)	113 (28.54)	70 (46.67)	374 (6.67)
Age-specific blindness (<20/400)	5 (0.19)	4 (0.25)	9 (1.04)	11 (2.78)	13 (8.67)	42 (0.75)
Age-specific blindness according to US definition (<20/200)	6 (0.23)	5 (0.32)	13 (1.50)	12 (3.03)	14 (9.33)	50 (0.89)
Total visual impairment or blindness (<20/40)	39 (1.50)	59 (3.72)	111 (12.85)	124 (31.31)	83 (55.33)	416 (7.42)
Total no. of subjects	2606	1587	864	396	150	5603

Data provided as n (%).

Table 5. Nonrefractive Causes of Visual Impairment and Blindness in the Tema Eye Survey

Cause	Visual Impairment*	Blindness <sup>†</sup>	Blindness*
Cataract	198 (53.4)	19 (44.2)	20 (43.5)
Glaucoma	52 (14.0)	9 (20.9)	10 (21.7)
Corneal opacification	28 (7.5)	4 (9.3)	4 (8.7)
Nonglaucomatous optic atrophy	9 (2.4)	3 (7.0)	3 (6.5)
Retinal disease <sup>§</sup>	26 (7.0)	3 (7.0)	4 (8.7)
Others	14 (3.8)	0	0
Undetermined	44 (11.9)	5 (11.6)	5 (10.9)
Total	371	43	46

Data provided as n (%).

\*Visual impairment defined as best-corrected visual acuity (BCVA) <20/40 but ≥20/400 in the better-seeing eye.

<sup>†</sup>Blindness defined as BCVA <20/400 in the better-seeing eye.

\*Blindness defined as BCVA <20/400 in the better-seeing eye or visual field less <10%.

<sup>§</sup>Retinal degeneration, chorioretinal scar of indeterminate cause, age-related macular degeneration, central retinal artery occlusion, and macular hole.

1990, Kortlang et al<sup>23</sup> surveyed 5871 rural residents of all ages residing in Mali and found a 1.7% prevalence of both blindness (VA <20/400) and visual impairment (VA <20/60). However, only 719 subjects (12.2%) were aged ≥50 years. The most frequent causes of blindness in that study were cataract (69%), trachoma (23%), and glaucoma (9%). In 1993, Whitworth et al<sup>24</sup> examined 1625 subjects of all ages residing in 6 rural villages in Sierra Leone in an area known to be hyperendemic for onchocerciasis. The preva-

lence of blindness (VA <20/200 in better eye) in this population was 1.3%, and the prevalence of visual impairment (VA <20/60 but >20/200) was 4.3%. Again, the prevalence of blindness and visual impairment was understandably lower in that study than in ours because of the lower age of the study population. Onchocerciasis was the leading cause of blindness (48%), followed by cataracts (19%), corneal opacity (14.3%), and glaucoma (9.5%). In 1996 Wilson et al<sup>25</sup> surveyed 10 647 subjects of all ages (2183 aged ≥40 years) in both rural and urban areas in the northern province of Cameroon. They found a combined prevalence of blindness (VA <20/200) of 3.7% for all age groups and 15.9% for people aged 40 years or older. The leading causes of blindness in all age groups were cataract (55%), glaucoma (12%), refractive error (9.7%), and trachoma (7.4%). Most recently, the Nigerian National Blindness and Visual Impairment Survey<sup>17</sup> studied 13 599 subjects aged 40 years or older. The strength of that survey was that it sampled both rural and urban communities throughout Nigeria. By using the same definitions for visual impairment and blindness as our study, the authors found a prevalence of blindness (BCVA <20/400) of 3.4% and a prevalence of visual impairment (BCVA<20/40) of 14%. Table 8 (available at <http://aaojournal.org>) summarizes the prevalence of visual impairment and blindness in the current study compared with other prevalence studies performed in Ghana and West Africa.

Table 9<sup>27-37</sup> (available at <http://aaojournal.org>) summarizes the prevalence of blindness and visual impairment from previous studies that reported age-specific data with an emphasis on ethnicity. Comparison with

Table 6. Risk Factors for Visual Impairment in the Tema Eye Survey (N = 371)

Risk Indicator	Univariate		Multivariate	
	Odds Ratio (95% CI)	P Value	Odds Ratio (95% CI)	P Value
Age (yrs)				
40-49	Reference	<0.001	Reference	<0.000
50-59	2.67 (1.73-4.12)		2.53 (1.62-3.97)	1
60-69	10.04 (6.75-14.94)		9.10 (6.01-13.80)	
70-79	31.37 (20.96-46.94)		28.09 (18.33-43.06)	
≥80	78.88 (49.00-126.98)		66.58 (39.79-111.39)	
Gender				0.941
Female	Reference	0.420		
Male	0.92 (0.74-1.14)			
Marital status				
Married	Reference	<0.000	Reference	<0.000
Single	1.10 (1.51-2.39)	1	1.97 (0.86-4.48)	1
Widowed	4.79 (3.78-6.08)		1.81 (1.38-2.38)	
Divorced	1.72 (1.22-2.42)		1.43 (0.99-2.07)	
History of ocular disease	1.28 (1.02-1.60)	0.03		0.1
History of hypertension				
No	Reference	<0.000		0.06
Yes	2.42 (1.82-3.23)	1		
Unknown	1.71 (1.28-2.30)			
History of diabetes				
No	Reference	<0.01		0.32
Yes	2.14 (1.38-3.31)			
Unknown	1.26 (1.00-1.61)			

CI = confidence interval.

Table 7. Risk Factors for Blindness in the Tema Eye Survey (N = 46)

Risk Indicator	Univariate		Multivariate	
	Odds Ratio (95% CI)	P Value	Odds Ratio (95% CI)	P Value
Age (yrs)				
40–49	Reference	<0.001	Reference	<0.0001
50–59	1.64 (0.48–5.67)		1.66 (0.48–5.7)	
60–69	7.32 (2.57–20.86)		6.68 (2.31–19.29)	
70–79	14.86 (5.14–43.01)		14.66 (5.06–42.49)	
≥ 80	49.36 (17.35–140.44)		43.68 (15.10–126.32)	
Gender				
Female	Reference	0.70		0.90
Male	0.89 (0.49–1.62)			
Marital status				
Married	Reference	<0.000		0.106
Single	2.73 (0.63–11.88)	1		
Widowed	3.84 (1.95–7.56)			
Divorced	2.59 (1.12–5.98)			
History of ocular disease	1.28 (1.02–1.60)	0.03	2.76 (1.50–5.07)	0.001
History of hypertension				
No	Reference	0.22		0.1
Yes				
Unknown				
History of diabetes				
No	Reference	0.77		0.81
Yes	1.42 (0.41–4.92)			
Unknown	0.92 (0.49–1.73)			

CI = confidence interval.

previous studies suggests that people of African descent residing in Africa, the Caribbean, the United Kingdom, and the United States have a higher prevalence of visual impairment and blindness than other ethnic groups with the exception of Indian Asians, although direct comparison of these studies is difficult because of the difference between age-specific and age-adjusted data. Age is the strongest risk factor for eye disease in all epidemiologic studies, and the life expectancy in the United States, United Kingdom, and Caribbean (mid-70s) is approximately 20 years more than in West Africa (mid-50s). The US, UK, and Caribbean populations, which have a higher percentage surviving to older ages, would thus be expected to have a higher prevalence of eye diseases, blindness, and visual impairment.

### Study Limitations

This study has several limitations. Firstly, it would have been ideal to have determined the prevalence of visual impairment and blindness in people of all ages. However, the prevalence of eye disease is low in those aged younger than 50 years of age, and the larger sample size needed to draw any meaningful conclusions from prevalence data in younger age groups would have been financially prohibitive. We chose to study people aged 40 years or older, rather than 50 years or older, to attempt to capture the phenomenon of a younger age of onset of glaucoma previously reported in people of African descent. The prevalence of glaucoma in this population will be elucidated and compared with that in non-Africans in a separate report.

Secondly, a limitation of this study is that we did not collect data on the prevalence of blindness and visual impairment in rural Ghana, so we cannot generalize the results of the TES to the entire country. However, the first population survey of eye disease, the Baltimore Eye Survey,<sup>26</sup> studied only urban-dwelling blacks and whites, and these data have been used to generalize to urban and rural black and white Americans for 2 decades. In addition, there have been 2 population-based surveys in rural Ghana<sup>20,21</sup> and several in rural Africa.<sup>17,22–25</sup> Also, because 50% of Ghanaians currently live in urban areas and increasing urbanization is projected, it made sense to collect blindness and disease prevalence estimates from an urban setting. Surveying only rural subjects, as done previously, may overestimate the prevalence of blindness and visual impairment due to the high rates of infectious diseases, such as trachoma and onchocerciasis, and underestimate the prevalence of chronic diseases, such as cataract and glaucoma. We realize that the opposite phenomenon is a limitation of the current study, namely, that surveying only urban Ghanaians results in a lower prevalence estimate of trachoma and onchocerciasis. The Nigerian National Survey data<sup>17</sup> show the unadjusted blindness prevalence for urban and rural areas to be 3.8% (95% CI, 3.1–4.7) and 4.5% (95% CI, 3.8–4.8) ( $P = 0.18$ ), respectively. However, after adjusting for age and sex, the relative risk was 1.0.

We considered performing this survey in 5 or 6 different urban and rural regions of Ghana and determined that this was not feasible for budgetary and logistic reasons. The Tema district was chosen partly because of its ethnic diversity. The study population was diverse in that most of the

subjects were born in regions outside of the study area. We recognize, however, that the results may not be generalizable to the rest of Ghana or all of West Africa because African populations may be the most genetically diverse in the world.<sup>38–40</sup> Also, environmental factors and gene–environment interactions may affect the phenotypic expression of complex diseases such as glaucoma.<sup>38–40</sup> However, recent genetic studies suggest that at least 3 prominent West African populations demonstrate striking “genetic homogeneity.”<sup>41–45</sup> These West African ethnic groups are part of the linguistically similar Niger-Kordofanian “macrofamily,” which covers more of Africa than any other ethnolinguistic macrofamily and is believed to have expanded to the west from the current border area of Niger and Cameroon and then to central and southern Africa.<sup>38,46,47</sup> So perhaps generalization of genetically determined eye diseases such as glaucoma is possible from this study.

A third practical limitation of this study is that participants were examined by 7 different ophthalmologists rather than by the same ophthalmologist. The ophthalmologists examining subjects undoubtedly had different diagnostic criteria and might have been biased toward the disease of their subspecialty. Most of the investigators were comprehensive ophthalmologists or glaucoma specialists with many years of experience diagnosing anterior segment, optic nerve, and retinal diseases. In addition, most diagnoses, such as glaucoma and retinal diseases, were made solely on the basis of visual fields read by a masked glaucoma specialist and fundus photographs read by masked readers. Other diagnoses, such as corneal opacification and cataract, are so obvious that we doubt this influenced the results of the study. Thus, we do not believe this to be much of a limitation. Furthermore, using multiple examiners seemed to be the best approach because of the impracticality of a single ophthalmologist examining all 5600 subjects over 2 years and 4 months.

As with virtually all similar population surveys, the TES had more female than male participants. There may be several reasons for this. First, more women are available during weekdays to participate, particularly in developing countries where fewer women work outside the home. Second, the life expectancy is longer in women than men, and because most eye surveys study people aged 40 years or older, it is not surprising that one finds more female than male participants. In the oldest age group ( $\geq 80$  years), for instance, there were 129 women enumerated compared with only 53 men. This simply reflects the earlier age of death of men compared with women. In addition, the 2010 Ghana census showed that men constituted 48.7% of the population and women constituted 51.3% of the population of all ages.

This study chose to sample subjects in poor areas of Tema. This was done to increase participation rates, because people with middle- to upper-class incomes are less likely to participate in free eye screenings because they have the means to pay for and access to good eye care. The effect of this is that most surveys, like this one, probably overestimate the prevalence of visual impairment and blindness from curable conditions such as cataract and preventable blindness from diseases such as glaucoma.

This study has implications for preventable visual impairment and blindness in Ghana and similar developing countries in Sub-Saharan Africa. First, refractive error represented a significant cause of needless visual impairment in this low-income population. In this study, the prevalence of visual impairment and blindness was reduced from 18.3% to 7.4% with manifest refraction alone. We recognize that these data are based on presenting VA, which assumes subjects brought their glasses to the field examination place as instructed. However, one would think that subjects with significant visual impairment who owned glasses would have worn them on a regular basis, including walking to our field examination location from their homes. The WHO’s “Vision 2020: The Right to Sight” report<sup>48</sup> has made the correction of refractive error a priority in their Global Initiative for the Elimination of Avoidable Blindness because it is so cost-effective. The results of this study support the need for initiatives to increase the examination rate and provision of glasses in countries like Ghana.

The second important public health implication of this study is that much of the visual impairment and blindness in this population are due to chronic, rather than infectious, eye diseases, primarily cataract and glaucoma. This finding is consistent with the most recent WHO meta-analysis of causes of blindness and visual impairment worldwide conducted in 2002.<sup>1</sup> An updated analysis is due to be published shortly (Bourne R, personal communication, 2012). The current study of 5600 Africans did not identify any definite cases of onchocerciasis and found few cases of trachoma, a legacy of the successful intervention programs for these disorders conducted over the past 20 years.<sup>7</sup> Although ongoing efforts are still needed in these areas, they do not help the approximately 50% of people residing in urban areas of Sub-Saharan Africa who have noninfectious eye diseases. With increased urbanization of this region and improved longevity, developing countries in Africa must recognize the importance of chronic eye diseases of the elderly, such as cataract and glaucoma. This is different from the causes of blindness and visual impairment found in white populations of developed countries, where age-related macular degeneration and diabetic retinopathy contribute significantly to the burden of blindness. In addition, this study argues for renewed focus on the prevention of avoidable blindness in urban populations by increasing the number of ophthalmologists and improving access to ophthalmic care. For instance, Ghana currently has approximately 40 ophthalmologists to care for its 24 million people, a ratio of approximately 1 ophthalmologist for every 600 000 people. This compares with a ratio of at least 1 ophthalmologist for every 10 000 inhabitants in the United States<sup>49</sup> and 1 for every 41 000 in the United Kingdom,<sup>50</sup> which has the lowest number of ophthalmologists per person of any European country.<sup>50</sup>

In conclusion, ministries of health should be encouraged to direct resources to prevent or cure visual impairment and blindness with increased rates of general ophthalmic care and cataract surgery, including earlier diagnosis and appropriate management of glaucoma.

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## References

- Thylefors B, Négrel AD, Pararajasegaram R, Dadzie KY. Global data on blindness. *Bull World Health Organ* 1995;73:115–21.
- Resnikoff S, Pascolini D, Etya'ale D, et al. Global data on visual impairment in the year 2002. *Bull World Health Organ* 2004;82:844–51.
- Ghana Statistical Service. Ghana provisional census results 2010. Available at: <http://www.ghana.gov.gh/census/phc2010.pdf>. Accessed on April 5, 2012.
- Caldwell JC, Caldwell P. The cultural context of high fertility in sub-Saharan Africa. *Popul Dev Rev* 1987;13:409–37.
- Caldwell JC. Demographic theory: a long view. *Popul Dev Rev* 2004;30:297–316.
- World Bank. Ghana at a glance. Updated February 2011. Available at: [http://devdata.worldbank.org/AAG/gha\\_aag.pdf](http://devdata.worldbank.org/AAG/gha_aag.pdf). Accessed April 5, 2012.
- Schwab L. Eye Care in Developing Nations. In: Schwab L, ed. *Onchocerciasis*. 4th ed. London: Manson; 2007:117, 143.
- Ghana Statistical Service. Ghana Demographic and Health Survey 2008. Calverton, MD: ICF Macro; 2009:3
- Biritwum RB, Gyapong J, Mensah G. The epidemiology of obesity in Ghana. *Ghana Med J* 2005;39:82–5.
- Amoah AG, Owusu SK, Adjei S. Diabetes in Ghana: a community based prevalence study in Greater Accra. *Diabetes Res Clin Pract* 2002;56:197–205.
- Ghana Statistical Service. Greater Accra region. Available at: [http://www.statsghana.gov.gh/greater\\_accra.html](http://www.statsghana.gov.gh/greater_accra.html). Accessed August 1, 2010
- Ghana Statistical Service. Ghana-population and housing census 2000 [database online]. Accra. Available at: <http://www.statsghana.gov.gh/nada/index.php/ddibrowser/3>. Accessed April 5, 2012.
- Klein RJ, Proctor SE, Boudreault MA, Turczyn KM. Healthy People 2010 criteria for data suppression. *Healthy People 2010 Stat Notes* 2002;(24):1–12. Available at: <http://www.cdc.gov/nchs/data/statnt/statnt24.pdf>. Accessed April 5, 2012.
- Bourne RR, Rosser DA, Sukudom P, et al. Evaluating a new logMAR chart designed to improve visual acuity assessment in population-based surveys. *Eye (Lond)* 2003;17:754–8.
- Patel KH, Javitt JC, Tielsch JM, et al. Incidence of acute angle-closure glaucoma after pharmacologic mydriasis. *Am J Ophthalmol* 1995;120:709–17.
- World Health Organization. ICD update and revision platform: change the definition of blindness. Available at: <http://www.who.int/blindness/Change%20the%20Definition%20of%20Blindness.pdf>. Accessed August 1, 2010.
- Kyari F, Gudlavalleti MVS, Sivsubramaniam S, et al, Nigeria National Blindness and Visual Impairment Study Group. Prevalence of blindness and visual impairment in Nigeria: the National Blindness and Visual Impairment Survey. *Invest Ophthalmol Vis Sci* 2009;50:2033–9.
- Eye Diseases Prevalence Research Group. Causes and prevalence of visual impairment among adults in the United States. *Arch Ophthalmol* 2004;122:477–85.
- Summary of medical advisory board practices in the United States. June 18, 2003. Available at: <http://www.mdsupport.org/drivingsummary.pdf>. Accessed August 15, 2010.
- Moll AC, van der Linden AJ, Hogeweg M, et al. Prevalence of blindness and low vision of people over 30 years in the Wenchi district, Ghana, in relation to eye care programmes. *Br J Ophthalmol* 1994;78:275–9.
- Guzek JP, Anyomi FK, Fiadoyor S, Nyongator F. Prevalence of blindness in people over 40 years in the Volta region of Ghana. *Ghana Med J* 2005;39:55–62.
- Faal H, Minassian D, Sowa S, Foster A. National survey of blindness and low vision in The Gambia: results. *Br J Ophthalmol* 1989;73:82–7.
- Kortlang C, Koster JC, Coulibaly S, Dubbeldam RP. Prevalence of blindness and visual impairment in the region of Ségou, Mali: a baseline survey for a primary eye care programme. *Trop Med Int Health* 1996;1:314–9.
- Whitworth JA, Gilbert CE, Mabey DM, et al. Visual loss in an onchocerciasis endemic community in Sierra Leone. *Br J Ophthalmol* 1993;77:30–2.
- Wilson MR, Mansour M, Ross-Degnan D, et al. Prevalence and causes of low vision and blindness in the Extreme North Province of Cameroon, West Africa. *Ophthalmic Epidemiol* 1996;3:23–33.
- Tielsch JM, Sommer A, Witt K, et al, Baltimore Eye Survey Research Group. Blindness and visual impairment in an American urban population: the Baltimore Eye Survey. *Arch Ophthalmol* 1990;108:286–90.
- Hyman L, Wu SY, Connell AM, et al, Barbados Eye Study Group. Prevalence and causes of visual impairment in the Barbados Eye Study. *Ophthalmology* 2001;108:1751–6.
- Munoz B, West SK, Rubin GS, et al, SEE Study Team. Causes of blindness and visual impairment in a population of older Americans: the Salisbury Eye Evaluation Study. *Arch Ophthalmol* 2000;118:819–25.
- Varma R, Ying-Lai M, Klein R, et al, Los Angeles Latino Eye Study Group. Prevalence and risk indicators of visual impairment and blindness in Latinos: the Los Angeles Latino Eye Study. *Ophthalmology* 2004;111:1132–40.
- Muñoz B, West SK, Rodriguez J, et al. Blindness, visual impairment and the problem of uncorrected refractive error in a Mexican-American population: Proyecto VER. *Invest Ophthalmol Vis Sci* 2002;43:608–14.
- Klein R, Klein BE, Linton KL, De Mets DL. The Beaver Dam Eye Study: visual acuity. *Ophthalmology* 1991;98:1310–5.
- Attebo K, Mitchell P, Smith W. Visual acuity and the causes of visual loss in Australia: the Blue Mountains Eye Study. *Ophthalmology* 1996;103:357–64.
- Xu L, Wang Y, Li Y, et al. Causes of blindness and visual impairment in urban and rural areas in Beijing: the Beijing Eye Study. *Ophthalmology* 2006;113:1134–41.
- Iwano M, Nomura H, Ando F, et al. Visual acuity in a community-dwelling Japanese population and factors associated with visual impairment. *Jpn J Ophthalmol* 2004;48:37–43.
- Thulasiraj RD, Nirmalan PK, Ramakrishnan R, et al. Blindness and vision impairment in a rural south Indian population: the Aravind Comprehensive Eye Survey. *Ophthalmology* 2003;110:1491–8.
- Taylor HR, Livingston PM, Stanislavsky YL, McCarty CA. Visual impairment in Australia: distance visual acuity, near vision, and visual field findings of the Melbourne Visual Impairment Project. *Am J Ophthalmol* 1997;123:328–37.
- Baasanhu J, Johnson G J, Burendei G, Minassian DC. Prevalence and causes of blindness and visual impairment in Mongolia: a survey of populations aged 40 years and older. *Bull World Health Organ* 1994;72:771–6.
- Tishkoff SA, Reed FA, Friedlaender FR, et al. The genetic structure and history of Africans and African Americans. *Science* 2009;324:1035–44.
- Campbell MC, Tishkoff SA. African genetic diversity: implications for human demographic history, modern human ori-

- gins, and complex disease mapping. *Annu Rev Genomics Hum Genet* 2008;9:403–33.
40. Kosoko-Lasaki O, Gong G, Haynatzki G, Wilson MR. Race, ethnicity and prevalence of primary open-angle glaucoma. *J Natl Med Assoc* 2006;98:1626–9.
  41. Adeyemo AA, Chen G, Chen Y, Rotimi C. Genetic structure in four West African population groups. *BMC Genetics* [serial online] 2005;6:38. Available at: <http://www.biomedcentral.com/1471-2156/6/38>. Accessed April 5, 2012.
  42. Reed FA, Tishkoff SA. African human diversity, origins and migrations. *Curr Opin Genet Dev* 2006;16:597–605.
  43. Sikora M, Laayouni H, Calafell F, et al. A genomic analysis identifies a novel component in the genetic structure of sub-Saharan African populations. *Eur J Hum Genet* 2011;19:84–8.
  44. Bryc K, Auton A, Nelson MR, et al. Genome-wide patterns of population structure and admixture in West Africans and African Americans. *Proc Natl Acad Sci U S A* 2010;107:786–91.
  45. Rosa A, Ornelas C, Jobling MA, et al. Y-chromosomal diversity in the population of Guinea-Bissau: a multiethnic perspective. *BMC Evol Biol* [serial online] 2007;7:124. Available at: <http://www.biomedcentral.com/1471-2148/7/124>. Accessed April 5, 2012.
  46. Scheinfeldt LB, Soi S, Tishkoff SA. Working toward a synthesis of archaeological, linguistic, and genetic data for inferring African population history. *Proc Natl Acad Sci U S A* 2010;107(Suppl):8931–8.
  47. Campbell MC, Tishkoff SA. The evolution of human genetic and phenotypic variation in Africa. *Curr Biol* 2010;20:R166–73.
  48. Pizzarello L, Abiose A, Ffytche T, et al. VISION 2020: The Right to Sight: a global initiative to eliminate avoidable blindness. *Arch Ophthalmol* 2004;122:615–20.
  49. West S, Sommer A. Prevention of blindness and priorities for the future. *Bull World Health Organ* 2001;79:244–8.
  50. Resnikoff S, Felch W, Gauthier T-M, Spivey B. The number of ophthalmologists in practice and training worldwide: a growing gap despite more than 200 000 practitioners. *Br J Ophthalmol* 2012;96:783–7.

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