**Objective:** To determine the prevalence of visual impairment and eye abnormalities in Oklahoma Indians.

**Methods:** The cross-sectional study included 1019 Oklahoma Indians, aged 48 to 82 years; 60.2% were women. All participants gave a personal interview, and all underwent an eye examination, including the determination of best-corrected visual acuity and an ophthalmoscopic examination. In addition, two 45° fundus photographs were taken of each eye, and these photographs were graded by the Fundus Photography Reading Center at the University of Wisconsin, Madison.

**Results:** Among the 1019 participants, 77.4% had a visual acuity of 20/20 or better, 19.5% and 2.5% had visual acuities of between 20/25 and 20/40 and between 20/50 and 20/190, respectively; and 0.6% were legally blind, all in the better eye. Cataract was the most frequent contributing cause and age-related macular degeneration the second most frequent contributing cause of visual impairment. The overall prevalence proportions of age-related macular degeneration, cataract, diabetic retinopathy, and definite glaucoma were 33.6%, 39.6%, 20.1%, and 5.6%, respectively. Most of the other eye abnormalities were rare in the study participants, except for pinguecula (42.4%) and dermatochalasis (30.1%).

**Conclusions:** Oklahoma Indians have a higher prevalence of visual impairment, age-related macular degeneration, and diabetic retinopathy than other ethnic groups. The implementation of adequate treatment and prevention programs for eye diseases is indicated.

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**IN 2002, IT WAS ESTIMATED THAT VISUAL IMPAIRMENT AFFECTS MORE THAN 3.4 MILLION AMERICANS 40 YEARS AND OLDER (2.85%), AND THIS NUMBER WAS EXPECTED TO DOUBLE OVER THE NEXT 30 YEARS.\(^1\)** Poor vision is often responsible for loss of independence in older adults. In people older than 70 years, it is the third leading cause of impaired function.\(^2\) Not only are visual impairments a burden to those experiencing sight loss but also to our national economy. Visual impairments cost the federal government more than $4 billion each year in benefits and lost taxable income. For those 40 years and older, the 4 most common causes of visual impairment and blindness in the United States are age-related macular degeneration (AMD), cataracts, diabetic retinopathy (DR), and glaucoma.\(^1\) Despite the social and economic importance of these diseases, little information is available on the prevalence rates within certain minority groups, including American Indians.

Oklahoma, with 273,230 American Indians (2000 census), has the second largest American Indian population in the United States. In this population, diabetes mellitus has reached epidemic status, with prevalence rates of 40% in those aged 45 to 74 years.\(^3\) Consequently, diabetes-related eye diseases, such as DR, have received much attention. There are insufficient data, however, on other eye diseases in this population.

Vision Keepers (VK), funded by the National Eye Institute, Bethesda, Md, was a study to determine the prevalence of eye diseases in Oklahoma Indians and to determine the relationships between these eye diseases and potential risk factors. In addition to retinopathy (related to diabetes mellitus or high blood pressure), AMD, cataracts, glaucoma, eyelid abnormalities, pinguecula, pterygium, trachoma, and vascular occlusion were studied. This article focuses on the prevalence proportions and causes of visual impairment, and compares the results with those of reports from other populations. The prevalence proportions of other eye abnormalities are reported briefly.

**METHODS**

The VK study population was drawn from a cohort of adults who participated in the Strong
Heart Study (SHS), a multicenter longitudinal study of cardiovascular disease in American Indians, initiated in 1988 and funded by the National Heart, Lung, and Blood Institute. The baseline examination of the SHS (July 1989–July 1991) included a total of 4549 tribal members from 13 Indian tribes or communities in Oklahoma, Arizona, North Dakota, and South Dakota. Eligibility criteria were as follows: (1) members must be between 45 and 74 years of age at examination, (2) they must be an enrolled member of an American Indian tribe or community in the study areas, and (3) they must have resided in the area for at least 6 months. Of the 4549 participants, 1527 were from Oklahoma. The Oklahoma cohort was recruited from 7 tribes in southwestern Oklahoma: Apache, Caddo, Comanche, Delaware, Fort Sill Apache, Kiowa, and Wichita. All eligible tribal members, men and women, were invited to participate in the study, and the 1527 who participated represented 62.0% of the eligible population.

Between August 1993 and October 1995, all living participants were invited to participate in a second examination. Among the 1527 participants in Oklahoma, 122 died before the second examination took place, 111 refused to participate, 36 could not be located, and 1258 participated in the second examination. Diabetes status and many cardiovascular and diabetes risk factors were ascertained at the baseline and second examinations.

The VK examination was conducted between September 1995 and March 1998. In September 1995, 1255 of the SHS participants were alive with a known address. These 1255 SHS participants were invited to participate in the VK study. The study was approved by the University of Oklahoma Health Sciences Center Institutional Review Board. Written informed consent was obtained from each participant before the examination began.

The examination, which was conducted at a satellite clinic of the Dean A. McGee Eye Institute in Lawton, included a personal interview on medical history and a complete eye examination, including the ascertainment of best-corrected visual acuity of both eyes, an intraocular pressure determination, and a slitlamp evaluation. An ophthalmoscopic examination was performed by a general ophthalmologist (A.W.) using indirect ophthalmoscopy with a 20-diopter lens and biomicroscopy with a superfield or a 78-diopter lens. Stereoscopic 45° retinal photographs centered on the optic disc and macula (between standard fields 1 and 2) were obtained using a camera (Canon 45° CR-3) with 35-mm slide film. Pupils were pharmacologically dilated for ophthalmoscopy and fundus photography. Four fundus photographs (2 of each eye) were taken for each participant. The best photograph of each eye was sent to the University of Wisconsin, Madison, Fundus Photograph Reading Center for grading.

The best-corrected monocular visual acuity was measured for each participant using an Early Treatment Diabetic Retinopathy Study chart. To obtain the best-corrected visual acuity, the participants were first tested on the Early Treatment Diabetic Retinopathy Study chart in an area with good lighting. They were then taken back to the regular examination room and refracted with the regular chart in the room. The participants were tested again with the Early Treatment Diabetic Retinopathy Study chart for final best-corrected acuity. The “forced-choice” procedure was used. The best-corrected visual acuity was categorized into 4 levels in the better eye: 20/20 or better (normal), 20/25 to 20/40, 20/50 to 20/190, and 20/200 or worse (legally blind). If it was not possible to assign a visual acuity score, participants were grouped, according to their visual ability, into 1 of the following 4 categories: no light perception, light perception only, hand motions only, or counting fingers only.

To determine the prevalence of eye abnormalities, we used the diagnosis of the worse eye. In patients in whom only 1 eye could be graded for the specific disease, the participant was categorized according to that eye. If neither eye could be graded, the participant was eliminated from the prevalence calculation.

Age-related macular degeneration was diagnosed at the University of Wisconsin Fundus Photograph Reading Center according to the Wisconsin ARM grading system. Cataracts were diagnosed using the Age-Related Eye Disease Study system for classifying cataracts. The ophthalmologist (A.W.) graded the eyes for cataract using standardized photographs of 3 types of cataract: nuclear, cortical, and posterior subcapsular. There were 3 standardized photographs for each of the 3 types of cataract, demonstrating 3 levels of increasing severity (1, 2, and 3). Nuclear and cortical cataracts were diagnosed if the patient’s lens opacity was greater than or equal to that in the level 2 standardized photographs for the respective types of cataracts. Posterior subcapsular cataract was diagnosed if the lens opacity was greater than or equal to that in the level 1 standardized photograph for posterior subcapsular cataracts. Prevalence cases of cataracts included participants who underwent previous cataract surgery or those who were diagnosed as having nuclear, cortical, or posterior subcapsular cataracts during the VK examination.

Because a visual field test was not performed during the VK examination, definite cases of glaucoma could only be identified if the patient was taking antiglaucoma medication, underwent previous surgery for glaucoma, or had some other history of glaucoma. Of the remaining participants, those with a high intraocular pressure (>22 mm Hg) and a large cup-disc ratio (>0.6) were diagnosed as having suspected glaucoma. If a participant was considered to have suspected glaucoma, the ophthalmologist referred the participant to another physician for a visual field test. If the participant followed through with the referral, the diagnosis was updated according to the results of the visual field test.

During the VK examination, the ophthalmologist evaluated the presence of retinopathy (DR and non-DR), and, if present, noted the retinal details. An additional diagnosis for DR or non-DR was available from the graders in Wisconsin, based on the retinal photographs using the modified Airlie House classification scheme. The definition used for diabetes mellitus was the criterion of the American Diabetes Association (fasting plasma glucose level ≥126 mg/dL [≥7.0 mmol/L]). In addition to retinopathy, participants were also screened for clinically significant macular edema (CSME) during the VK examination. Clinically significant macular edema was defined as retinal thickening at or within 500 µm of the center of the macula, hard exudates at or within 500 µm of the center of the macula if associated with thickening of the adjacent retina, or a zone of retinal thickening of 1 disc area, at least part of which was within 1 disc diameter of the center. Clinically significant macular edema was diagnosed by ophthalmoscopy and fundus photography.

Other eye diseases examined were 5 conditions affecting the eyelid (trichiasis, entropion, ectropion, dermatochalasis, and blepharitis); 2 conditions affecting the conjunctiva (pinguecula and pterygium); trachoma, a leading cause of preventable blindness worldwide; and retinal vascular occlusion (branch retinal vascular occlusion, central retinal vascular occlusion, and ischemic optic neuropathy). SAS statistical software (SAS Institute Inc, Cary, NC) was used to calculate prevalence proportions and summary statistics. Statistical methods included t tests, the χ² test, the trend test, and the Fisher exact test. P < .05 was considered statistically significant.

**RESULTS**

A total of 1255 participants of the SHS second examination were invited to participate in VK. Of these participants, 62 (4.9%) died before they could be examined.
Among the 1193 surviving participants, 73 (6.1%) did not respond to the VK invitation to participate, 73 (6.1%) chose not to participate in the VK study, 12 (1.0%) moved out of the area, and 16 (1.3%) could not be traced. The total number of participants in the VK study was, therefore, 1019 (85.4% of 1193). Of the 1019 participants, 60.2% were women; and the mean age was 62.1 years (range, 48-82 years). Of the 174 living eligible subjects who did not participate, 57.0% were women; and the mean age was also 62.1 years.

Table 1 provides a summary of the VK participants by age, sex, and best-corrected visual acuity in the better eye. Of the 1019 participants, 128 (91.2%) had a visual acuity of 20/20 or better, 199 (19.5%) had a visual acuity between 20/25 and 20/40, 25 (2.5%) had a visual acuity between 20/50 and 20/190, and 6 (0.6%) had a visual acuity of 20/200 or worse.

Table 2 gives the possible causes of visual impairment in the better eye of the 230 participants whose visual acuity was impaired (20/25 or worse). Visual impairment was caused by 1 or more of the 4 major eye diseases (cataracts, macula degeneration, glaucoma, and retinopathy). The prevalence proportion of visual impairment (20/25-20/190) increased significantly with age in men and women. Three (0.3%) of the participants had a prosthesis for the left eye, but all 3 had a visual acuity of 20/20 in the right eye. The visual acuity required to obtain an unrestricted driver's license in Oklahoma is 20/40 or better in the better eye. Although the prevalence of visual impairment with a visual acuity worse than 20/40 in the better eye in women (3.7%) was almost double that in men (2.0%), the difference was not statistically significant (P = .11). The prevalence of visual impairment with a visual acuity worse than 20/40 in the better eye increased with age from 1.6% in those 49 to 59 years old to 2.4% in those 60 to 69 years old, to 7.0% in those 70 to 83 years old (P < .001).

The exact cause of visual impairment was unknown.
Table 3. Age-Specific Prevalence of Visual Impairment in the US Population and in the Vision Keepers Participants (American Indians)*

<table>
<thead>
<tr>
<th>Age, y</th>
<th>US Population†</th>
<th>Vision Keepers Participants‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-49</td>
<td>0.31</td>
<td>0 (15)</td>
</tr>
<tr>
<td>50-54</td>
<td>0.40</td>
<td>0.48 (207)</td>
</tr>
<tr>
<td>55-59</td>
<td>0.56</td>
<td>2.84 (211)</td>
</tr>
<tr>
<td>60-64</td>
<td>0.88</td>
<td>2.39 (209)</td>
</tr>
<tr>
<td>65-69</td>
<td>1.47</td>
<td>2.45 (163)</td>
</tr>
<tr>
<td>70-74</td>
<td>2.60</td>
<td>7.32 (123)</td>
</tr>
<tr>
<td>75-79</td>
<td>5.03</td>
<td>6.33 (79)</td>
</tr>
<tr>
<td>≥80</td>
<td>23.73</td>
<td>8.33 (12)</td>
</tr>
<tr>
<td>Total</td>
<td>2.76</td>
<td>3.04 (1019)</td>
</tr>
</tbody>
</table>

*Data are given as percentage in each group. Visual impairment was defined as a best-corrected visual acuity worse than 20/40 in the better eye. †Data were estimated based on several population-based studies. ‡Data in parentheses are the number of participants.

Information on eye disease in American Indians is lacking. To our knowledge, this is the first population-based eye study in American Indians in Oklahoma that considered diseases other than DR. There have been only a handful of similar studies in other American Indian populations, including the Navajo and Sioux Indians. Although the 1527 SHS participants were not a random sample, they represent 62.0% of the eligible study population. A few major cardiovascular disease risk factors (smoking, hypertension, diabetes status, and body mass index) were compared between participants and nonparticipants, and no significant differences were found in the Oklahoma cohort. Therefore, we considered the SHS participants representative of the study population.

In a recent article, the prevalence of visual impairment (or low vision, defined as a best-corrected visual acuity of <20/40 in the better eye) in the United States was estimated using data from several population-based eye studies in the United States, Australia, and Europe, including the Barbados Eye Study (BES), the Beaver Dam Eye Study (BDES), the Blue Mountains Eye Study (BMES), and the Proyecto Vision and Evaluation Research (PVER). Table 3 compares the age-specific prevalence proportions of visual impairment of the American Indians in the VK study with those estimated for the US population. Except for the first and last age groups, in which the numbers of VK participants were small, the prevalence of visual impairment in the VK study is higher than that of the US population, especially in those between the ages of 55 and 74 years.
Table 4 and Table 5 compare the age-specific and age-standardized prevalence proportions of visual impairment from the 4 eye studies previously mentioned with those from the VK study. Two of these studies, the BDES and the BMES, included predominantly white participants, while the BES contained predominantly black participants and the PVER focused on a Mexican American population. In these 4 studies, 2 different definitions of visual impairment were used.\textsuperscript{10-22} The BES and the PVER defined visual impairment as a best-corrected visual acuity of worse than 20/40 (Table 4), whereas the BDES and the BMES defined visual impairment as a best-corrected visual acuity of 20/40 or worse (Table 5). The age ranges of the participants in all 4 studies were similar to the age range of the participants in the VK study, although there were more younger participants in the BES and PVER than in the other studies.

The age-standardized (using 1990 US census data) prevalence of visual impairment in the BES was by far the highest of the 5 studies. The overall proportion was more than 3 times higher than that in the VK study. The age-standardized proportions in the BDES and BMES were lower than that of the VK study, and the age-standardized proportion in the PVER was similar to that of the VK study. Although not shown in the tables, the proportions of blindness in these studies followed a similar trend, with the BES reporting the highest (3.0%) and the remaining studies reporting proportions from 0.3% to 0.7%. The proportion of blindness in the VK study was 0.6%. The proportions of visual impairment increased with age in all studies. The BDES, the BMES, and the VK study also found that women had a significantly or nearly significantly higher proportion of a more severe level of visual impairment or blindness than men. The PVER reported the same relationship, but only in those older than 50 years.

The BMES was also the only study of the 4 to report prevalence information on pinguecula.\textsuperscript{23} This condition was more prevalent in the white population of the BMES (69.5%) than in the American Indians of the VK study (42.4%). The BMES reported an age-related increase in the prevalence of pinguecula for all age groups, except those 80 years or older, who had a lower prevalence than the previous age group. On the contrary, the results of the VK study showed a slight age-related decrease. The age-specific prevalence in participants younger than 60 years (and 70-79 years) was 58.8% and 45.0% (and 79.0% and 35.2%), respectively, in the BMES and the VK study. This could be because there were more older participants in the BMES than in the VK study. In both studies, men had a higher prevalence (76.3% in BMES and 55.2% in the VK study) than women (66.3% in BMES and 34.0% in the VK study). The prevalence proportion of pterygium in the black population of the BES (23.4% and 21.9%, including and excluding previous surgery, respectively) is much higher than in the white population of the BMES (7.3%, excluding previous surgery) and the American Indian population of the VK study (7.5% and 7.8%, including and excluding previous surgery, respectively).\textsuperscript{23,24} Because pterygium has been linked to extreme exposure to the sun, a higher rate of this disease in residents of Barbados is expected.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Barbados Eye Study (Black Participants)</th>
<th>PVER (Mexican American Participants)</th>
<th>Vision Keepers Study (American Indian Participants)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-49</td>
<td>1.5</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>50-59</td>
<td>3.2</td>
<td>0.6</td>
<td>1.7</td>
</tr>
<tr>
<td>60-69</td>
<td>11.5</td>
<td>2.6</td>
<td>2.4</td>
</tr>
<tr>
<td>70-79</td>
<td>29.7</td>
<td>5.2</td>
<td>6.9</td>
</tr>
<tr>
<td>≥80</td>
<td>49.5</td>
<td>18.1</td>
<td>8.3</td>
</tr>
<tr>
<td>Crude value</td>
<td>11.8</td>
<td>2.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Age-standardized value</td>
<td>11.7</td>
<td>2.9</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Abbreviation: PVER, Proyecto Vision and Evaluation Research. *Data are given as percentage in each group.

In a study primarily involving full-blooded Navajo Indians,\textsuperscript{14} 1543 clinical records were reviewed for patients examined at the Gallup Indian Medical Center in New Mexico from July 1966 to March 1971. The age range of the patients was not reported. In this study, trachoma was found in 33% of the patients, cataract in 18%, and pterygium in 10%. In recent years, trachoma has been near eradication in the United States. It was not a surprise that we found only historical cases of trachoma and no active disease. The difference in age between the Navajo and the Oklahoma Indian groups most likely explains the difference in the prevalence of cataracts. Because age is not reported in the Navajo study, it is more likely that a representation of all ages was included, and because cataracts are considered an age-related condition, this would affect the prevalence rate. The prevalence proportions of pterygium in the Navajos and Oklahoma Indians are fairly similar, with a slightly lower rate found in the Oklahoma Indians.

Another study\textsuperscript{15} of the American Indians involved 1886 full-blooded Sioux Indians living on 2 reservations in North Dakota and South Dakota. The patients either were seen voluntarily in an optometry clinic in 1980 or participated in a school vision program during the same year.
Therefore, many of the participants were school-aged children and the age differences made the comparison difficult. The study reported more participants (4%) with a best-corrected visual acuity worse than 20/40 than the VK study. This may have been because many of the participants were from an optometry clinic.

In conclusion, the prevalence of visual impairment in Oklahoma Indians was lower than in the black subjects in the BES, but higher than in the white subjects in the BDES and the BMES and the Mexican American subjects in the PVER. In the 55- to 79-year-old group, the Oklahoma Indians had a much higher prevalence of visual impairment than the US population. Cataract and AMD were the leading causes of visual impairment. The data indicate that implementation of adequate treatment and prevention programs for these eye diseases is urgent to reduce visual impairment in this population.

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