Objective: To study the prevalence and causes of blindness and visual impairment in various age categories of a large population-based study.

Methods: For the study, 6775 subjects aged 55 years or older underwent an extensive ophthalmologic screening examination, including measurements of visual acuity and the visual field and fundus photography. The causes of blindness or visual impairment were determined using all screening information and medical records.

Results: The prevalence of blindness, according to World Health Organization criteria, ranged from 0.1% in subjects aged 55 to 64 years to 3.9% in subjects aged 85 years or older; the prevalence of visual impairment ranged from 0.1% to 11.8%. For persons younger than 75 years, myopic degeneration and optic neuropathy were the most important causes of impaired vision. For persons aged 75 years or older, age-related macular degeneration was the major cause of the increased prevalence of blindness, whereas age-related cataract predominantly caused the increased prevalence of visual impairment.

Conclusions: The hierarchy of causes of blindness and visual impairment is highly determined by age. As yet, little can be done to reduce the exponential increase of blindness; however, adequate implementation of surgery to treat cataract could reduce visual impairment by one third. Underuse of ophthalmologic care is a prominent cause of the high frequency of untreated cataracts among the elderly.
SUBJECTS AND METHODS

SUBJECTS

The rationale and design of the Rotterdam Study have been described elsewhere. In brief, this population-based prospective follow-up study focuses on chronic ophthalmologic, neurologic, cardiovascular, and locomotor diseases among subjects aged 55 years or older living in Ommoord, a city district of Rotterdam, the Netherlands. Baseline data were collected between 1990 and 1993. Eligible subjects were identified by drawing names and addresses from the municipal register. During an initial home interview, demographic characteristics, medical and ophthalmologic history, the use of eye care, the attained level of education, the level of ability in daily activities, and a variety of other variables were evaluated. Subsequently, participants underwent a physical examination at the screening center. Subjects living in the 6 nursing homes of the target area were examined at their homes.

PROCEDURES AND DEFINITIONS

The ophthalmologic examination included measurements of visual acuity, ocular refraction, visual fields, and intraocular pressure; slitlamp examination; and direct and indirect ophthalmoscopy. The examination was performed by 3 ophthalmologically trained physicians (R.C.W.W., J.R.V., and Ida Dielemans, MD, PhD) who determined the presence of cornea and lens opacities and vitreous and fundus changes by using a standardized grading protocol. In addition, 20° stereoscopic fundus color transparencies were taken of the optic disc (Topcon TRC-552 stereoscopic fundus camera, Topcon Optical Company, Tokyo, Japan), and 35° color transparencies were taken of the macular area (Topcon TRV-50VT fundus camera, Topcon Optical Company). Visual acuity was measured at a 3-m distance using the Lighthouse Distance Visual Acuity Test, a modified Early Treatment Diabetic Retinopathy Study chart. To evaluate best-corrected visual acuity, optimal refraction was obtained subjectively after objective autorefraction. Screening of visual fields was performed using a modified 76-point suprathreshold perimetry test (Humphrey Visual Field Analyzer, Zeiss, Oberkochen, Germany); visual field defects were subsequently confirmed by using Goldmann perimetry. The various population-based studies evaluating blindness have used different criteria for blindness and visual impairment. We used 2 sets of criteria for blindness and visual impairment to enable comparison of our prevalence data with others. The first set of criteria was established by the World Health Organization (WHO) and used in the International Classification of Diseases; blindness is defined as a best-corrected visual acuity of less than 0.05 (Snellen, 20/400) in the better eye or a visual field no greater than 10° around central fixation, and visual impairment, as a best-corrected visual acuity of less than 0.3 (20/60) but no less than 0.05 (20/400) in the better eye. The second set of criteria is used most commonly in the United States; blindness is defined as a best-corrected visual acuity of 0.1 (20/200) or less in the better eye, and visual impairment, as a best-corrected visual acuity less than 0.3 (20/40) but better than 0.1 (20/200) in the better eye. The cause of visual loss was determined for blindness and visual impairment according to the WHO criteria. Two clinical investigators (C.C.W.K. and P.T.V.M.J.) reached consensus on the final determination of the cause of visual loss after reviewing all screening information, fundus transparencies, and, when necessary, information provided by ophthalmologists. Standard procedures and standard clinical criteria were applied. In most cases, the cause of the visual loss was a single disorder. When multiple disorders were present, we attempted to identify the disorder causing the greatest limitation of vision. In a few subjects, no primary cause of the visual loss could be identified, and visual loss was considered due to a combination of mechanisms.

To evaluate the presence of diabetes mellitus, a nonfasting oral glucose tolerance test was performed for all subjects not using antidiabetic medication. Diabetes mellitus was defined as the use of antidiabetic medication or a random or postload glucose level greater than 11 mmol/L (198 mg/dL). A screening test for cognitive function comprised the Mini-Mental State Examination; a low score indicates poor cognitive function. The attained level of education was evaluated according to the standard classification of education, which is comparable to the international standard classification of education (UNESCO, Paris, France, 1976). Four levels of education were included; the lowest was primary education and the highest, university or higher vocational education. Ability in daily activities was measured in 8 components (ie, dressing, rising, reach, hygiene, eating, walking, grip, and activity) as described previously. Moderate disability was present when subjects had difficulties in 4 of the 8 components.

DATA ANALYSIS

The prevalences of blindness and visual impairment were calculated as percentages of the total study population and stratified by age and sex. The prevalences of the causes of blindness and visual impairment were calculated as percentages of affected eyes in 3 age categories. The proportions of categorical variables and the differences in the categorical variables between groups were calculated by using multiple logistic regression analysis with adjustment for age and sex; means and differences between continuous variables were adjusted by using analysis of covariance. The sum of the age-specific prevalences of blindness and visual impairment was calculated to represent the total prevalence of poor vision (ie, blindness and visual impairment).

scores on the Mini-Mental State Examination and were more likely to have visual and other health problems. The use of antidiabetic medication was not higher among nonparticipants. By using the WHO criteria, we identified 32 subjects who were blind and 96 subjects who were visually impaired in both eyes. Table 1 gives the more specific distribution of characteristics among these subjects compared with subjects with better vision. Compared with subjects with better vision, subjects who were blind or visually impaired were significantly older (Student t test; P < .001). After adjustment for age, they were still more likely to be institutionalized (21% vs 9%; P < .001), showed more disability in daily activities (41% vs 33%; P < .001),
and had slightly lower scores on the Mini-Mental State Examination (25.0 vs 27.2; \( P < .001 \)). There were no significant differences in presence of diabetes mellitus (12% vs 11%; \( P = .1 \)).

The prevalence of blindness and visual impairment stratified by age and sex is given in Table 2. Whatever criteria were used, blindness and visual impairment showed a significant increase in prevalence in subjects aged 75 years or older. Women had a slightly higher prevalence of blindness or visual impairment in most age strata, although the differences were not statistically significant after additional adjustment for age within the age strata. Figure 1 shows a comparison of our data with prevalence data from other studies based on white populations. Compared with the results of other studies, the prevalence of blindness and visual impairment in the Rotterdam Study was low for all groups older than 55 years, although the Rotterdam Study did not have the lowest prevalence at every age point.

In most subjects, the cause of visual loss was the same for both eyes. However, in 3 (9%) of the 32 blind subjects and in 18 (19%) of the 96 visually impaired subjects, the 2 eyes had different causes of visual loss. For this reason, the prevalences of the various causes of visual loss are most clearly presented as percentages of eyes rather than percentages of subjects. Table 3 gives the causes of blindness for 3 age categories. Optic neuropathy was the most frequent cause of blindness for subjects aged 55 to 74 years. In subjects aged 75 years or older, age-related macular degeneration became the most important cause of blindness and was most apparent in the oldest age category. Primary open-angle glaucoma and cataract were the second and third most important causes of blindness, respectively. In the 2 cases of combined mechanisms, we could not determine which disorder limited vision the most, myopic macular degeneration or primary open-angle glaucoma. The rare causes included pigment dispersion syndrome with secondary glaucoma, congenital syphilis, and atrophy of the eyeball as a complication of surgery to correct a retinal detachment.

The causes of visual impairment according to the WHO criteria are listed in Table 4. Myopic macular degeneration was the predominant cause of visual impairment in subjects younger than 75 years. For subjects aged 75 years or older, cataract, as a single cause or in combination with other disorders, became the leading contributor to visual impairment. In 62 (65%) of the 96 visually impaired subjects aged 85 years or older, cataract contributed at least partially to the visual impairment. The disorder most frequently accompanying cataract as a cause of impaired vision was age-related macular degeneration, followed by primary open-angle glaucoma. The combined mechanisms included corneal dystrophy with macular hole, myopic macular degeneration with optic neuropathy, and age-related macular degeneration with primary open-angle glaucoma. The rare causes comprised hereditary macular degeneration, neuroretinitis, enucleation of the eyeball after complications of combined surgery to treat glaucoma and cataract, retinopathy without a known cause, and venous branch occlusion.

Figure 2 shows, by age, the proportions of poor vision (blindness and visual impairment, WHO criteria) caused by age-related macular degeneration, age-related cataract, and primary open-angle glaucoma. As single causes, these 3 disorders constituted the largest part of the increase in the prevalence of poor vision; combinations of these disorders and other single causes increased the prevalence of impaired vision only moderately with age.

Of the 3 major causes, age-related cataract is the only cause for which treatment may be sufficiently successful to restore vision. Cataract extraction was a common surgical procedure in our study population of 6775 subjects; its overall prevalence was 5.3% (371 subjects), ranging from 1.4% (35 subjects) in persons aged 55 to 65 years to 21.3% (87 subjects) in persons aged 85 years or older. Cataract extraction was a common surgical procedure in our study population of 6775 subjects; its overall prevalence was 5.3% (371 subjects), ranging from 1.4% (35 subjects) in persons aged 55 to 65 years to 21.3% (87 subjects) in persons aged 85 years or older.
extraction had prevented or treated possible bilateral blindness and visual impairment (as bilateral cataract extraction or unilateral extraction with blindness or visual impairment in the other eye) in 3.6% (243 subjects) of the total study population and up to 15.2% (62 subjects) of persons aged 85 years or older. Of interest is that more than half (53%) of the subjects who were blind or visually impaired owing to untreated cataract indicated that they had never visited an ophthalmologist. To identify possible reasons for not seeking appropriate care, we compared the variables listed in Table 1 between subjects who were bilaterally blind or visually impaired due solely to cataract (n = 34) and subjects who had undergone surgery to treat cataract (n = 371). Compared with subjects who had undergone surgery to treat cataract, blindness or visual impairment due to untreated cataract was associated with a higher proportion of subjects aged 85 years or older (21% vs 58%, respectively, P < .001), being homebound owing to health reasons (17% vs 33%, respectively, age-adjusted P = .03), and a higher proportion of low scores (≥20) on the Mini-Mental State Examination (6% vs 20%, respectively, age-adjusted P = .004). Differences in sex and level of education were not statistically significant; however, none of the subjects with untreated cataract had attained university or higher vocational education.

Table 3. Causes of Blindness in 64 Eyes of 32 Blind Subjects, Stratified by Age

<table>
<thead>
<tr>
<th>Cause</th>
<th>55-74 y</th>
<th>75-84 y</th>
<th>≥85 y</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(14 Eyes)</td>
<td>(18 Eyes)</td>
<td>(32 Eyes)</td>
<td>(64 Eyes)</td>
</tr>
<tr>
<td>Age-related macular degeneration</td>
<td>14 (2)</td>
<td>56 (10)</td>
<td>78 (25)</td>
<td>58 (37)</td>
</tr>
<tr>
<td>Cataract</td>
<td>0 (0)</td>
<td>11 (2)</td>
<td>6 (2)</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Primary open-angle glaucoma</td>
<td>14 (2)</td>
<td>0 (0)</td>
<td>9 (3)</td>
<td>8 (5)</td>
</tr>
<tr>
<td>Myopic degeneration</td>
<td>14 (2)</td>
<td>0 (0)</td>
<td>6 (2)</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Optic neuropathy</td>
<td>28 (4)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Retinitis pigmentosa</td>
<td>14 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>3 (2)</td>
</tr>
<tr>
<td>Rare causes</td>
<td>14 (2)</td>
<td>22 (4)</td>
<td>0 (0)</td>
<td>9 (6)</td>
</tr>
<tr>
<td>Combined mechanisms</td>
<td>0 (0)</td>
<td>11 (2)</td>
<td>0 (0)</td>
<td>3 (2)</td>
</tr>
</tbody>
</table>

*Blindness according to the World Health Organization classification, best-corrected visual acuity < .05 (Snellen, 20/400) in the better eye. Data are given as percentage (number) of eyes.

Table 4. Causes of Visual Impairment in 192 Eyes of 96 Visually Impaired Subjects, Stratified by Age

<table>
<thead>
<tr>
<th>Cause</th>
<th>55-74 y</th>
<th>75-84 y</th>
<th>≥85 y</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(22 Eyes)</td>
<td>(74 Eyes)</td>
<td>(96 Eyes)</td>
<td>(192 Eyes)</td>
</tr>
<tr>
<td>Age-related macular degeneration</td>
<td>5 (1)</td>
<td>28 (21)</td>
<td>27 (26)</td>
<td>25 (48)</td>
</tr>
<tr>
<td>Cataract</td>
<td>18 (4)</td>
<td>35 (26)</td>
<td>42 (40)</td>
<td>36 (70)</td>
</tr>
<tr>
<td>Cataract in combination with another cause</td>
<td>18 (4)</td>
<td>12 (9)</td>
<td>23 (22)</td>
<td>18 (35)</td>
</tr>
<tr>
<td>Primary open-angle glaucoma</td>
<td>0 (0)</td>
<td>3 (2)</td>
<td>1 (1)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Myopic macular degeneration</td>
<td>23 (5)</td>
<td>4 (3)</td>
<td>3 (3)</td>
<td>6 (11)</td>
</tr>
<tr>
<td>Optic neuropathy</td>
<td>9 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Corneal dystrophy</td>
<td>9 (2)</td>
<td>1 (1)</td>
<td>0 (0)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Diabetic retinopathy</td>
<td>9 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Rare causes</td>
<td>9 (2)</td>
<td>11 (8)</td>
<td>3 (3)</td>
<td>6 (13)</td>
</tr>
<tr>
<td>Combined mechanisms</td>
<td>0 (0)</td>
<td>5 (4)</td>
<td>1 (1)</td>
<td>3 (5)</td>
</tr>
</tbody>
</table>

*Visual impairment according to the World Health Organization classification, best-corrected visual acuity ≥ .05 (Snellen, 20/40) and < .05 (Snellen, 20/60) in the better eye. Data are given as percentage (number) of eyes.

We have presented age-specific prevalences and causes of blindness and visual impairment in a population ranging in age from 53 to 106 years. Our data indicate that age-related macular degeneration is the main contributor to the exponential increase in the prevalence of blindness in persons aged 75 years or older and that age-related cataract causes the major increase in the prevalence of visual impairment. Myopic macular degeneration, optic neuropathy, and various other less frequent disorders have important contributions to the poor vision occurring before the age of 75 years.

All population-based studies during the 1990s on the prevalence of blindness and visual impairment show an exponential increase with age. \(^2\) However, the age-specific prevalences vary considerably among studies (Figure 1).
Although the variations may be due to study design, population sampling, or differences in measuring techniques, they may indicate real geographic variation in the prevalence and course of vision-imparing disorders. This points out a need for detailed information on the age-specific causes of impaired vision.

The size of our study enables relatively precise estimates of the prevalence of blindness and visual impairment and facilitates an accurate determination of the proportions of causes. Our population was predominantly white, and because black populations are known to have higher prevalence of poor vision,26 we limited a comparison of prevalences to white populations. Our age-specific prevalences were similar to the SEE Study6 and the Melbourne Visual Impairment Project,10 but lower compared with all other studies. The Beaver Dam and Blue Mountain Eye studies showed substantially higher prevalences.2,8 This may be due in part to differences in definition because those 2 studies included a visual acuity of 0.5 (20/40) in the definition of visual impairment. When comparing only legal blindness, the prevalences were still higher, but closer to our data (data not shown).

A major concern in prevalence studies is nonparticipation. The Rotterdam Study had a reasonable response, but the evaluation of differences between participants and nonparticipants indicated that nonresponse was selective and may have produced an underestimate of the prevalences of blindness and visual impairment. A higher proportion of nonparticipants among the oldest subjects is a general problem in the studies of elderly populations, as is the higher nonresponse among subjects with poor physical or mental health. Our study consisted of more subjects aged 85 years or older than the other studies, and especially for this age group, the true prevalence must be even higher. We consider it unlikely that nonresponse influenced the proportions of causes of blindness and visual impairment.

Knowledge of the age-specific causes of blindness and visual impairment elucidates the increase in the prevalence of impaired vision and may facilitate adequate management. In this study, most of the disorders responsible for blindness and visual impairment were age related, mostly of unknown cause, and, as yet, unpreventable. We confirm the observation that age-related macular degeneration is the leading cause of blindness among white populations,5,8,15 but this was true only for subjects aged 75 years or older. Then it became the main contributor to the steep increase in the prevalence of blindness, leading to bilateral blindness as a single cause in 12 (3%) of 408 subjects aged 85 years or older in the present study. In common with other studies, age-related cataract was the most important cause of bilateral visual impairment5,8 and the second most frequent cause of blindness. The visual-imparing effect of cataract was highly associated with age, causing a larger proportion of visual impairment with increasing age. Successful treatment for this disorder is readily available; cataract extraction is one of the most frequent surgical procedures in the Netherlands (Netherlands Foundation of Information Systems for Health Care [SIG-Zorginformatie], National Medical Registration, Utrecht, the Netherlands; written communication; August 9, 1997). If adequate facilities and personnel are not a logistic constraint to treatment, why does cataract still impair vision to such a great extent in the elderly? Before we enlarge on this issue, we emphasize that 62 (15%) of 408 subjects aged 85 years or older were “saved” from bilateral blindness or visual impairment by cataract extraction, a much greater proportion than the 32 (8%) who were blind or visually impaired by cataract. Most of the subjects in the latter category received no eye care. Our study provides limited information on possible barriers, but old age, unawareness of treatment possibilities, and comorbidity (with other disabling disorders) seem to hamper access to appropriate care. Policies to implement referrals on a more uniform basis are needed, for even in the very old or disabled, the restoration of visual function may improve the quality of life and reduce the nursing care required.

Diabetes mellitus was a frequent disorder in our population, but diabetic retinopathy rarely led to poor vision. Although findings from studies of subjects with diabetes suggest a larger influence of diabetes on visual loss,21,22 diabetic retinopathy was not a major cause of blindness in any of the other population studies of older white populations.18-20 As described by Stolk et al,22 active proliferative retinopathy was not observed in the Rotterdam Study. In addition, a low frequency of laser photocoagulation scars indicated that the absence of active proliferative retinopathy did not directly result from ocular treatment. Selective nonresponse of subjects with diabetes with known complications may have occurred, but the similar frequencies of the use of antidiabetic medication between participants and nonparticipants make this assumption unlikely. Possible explanations for the small effect of diabetes on vision in this relatively old population are selective mortality of persons with diabetes with severe systemic complications, the uncommon progression from background retinopathy to proliferative retinopathy in the elderly,21,24 and the intensified control of hyperglycemia in persons with diabetes.25,26

Our data indicate that age must be specified when determining the frequency of causes of visual loss. Ap-
propriate medical care to further reduce the prevalence of blindness is not available, but improving accessibility to surgery for the treatment of cataract among the old and disabled will help diminish the number of untreated cataracts that still leads to visual impairment.

Accepted for publication January 28, 1998.

This work was supported by the Nestor program (Ministry of Health and Ministry of Education), The Hague, the Netherlands; the Netherlands Organization for Scientific Research (Nederlandse organisatie voor Welenschappelyk Onderzoek), The Hague; Topcon Europe BV, Capelle aan de Yssel, the Netherlands; the Netherlands Society for Prevention of Blindness, Amsterdam, the Netherlands; Stichting Fondsenwervingsacties Volksgezondheid, The Hague; Haagsch Oogheelkundig Fonds, The Hague; Landelijke Stichting voor Blinden en Slechtzienden, Utrecht, the Netherlands; G. Ph. Verhugen Stichting, Rotterdam, the Netherlands; Stichting Physiotherapeutisch Instituut, Rotterdam; and Stichting ROOS, Rotterdam.

We thank Ida Dielemans, MD, PhD; Ada Hooghart; and Coriina Brussee for their assistance in data collection; Caroline van Rossum for providing data on education; and Raan Ramrattan, MD, and Jacqueline Assink, MD, for review of the manuscript.

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