A Nationwide Population-Based Study of Low Vision and Blindness in South Korea

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See the appendix for the members of the Epidemiologic Survey Committee in the Korean Ophthalmological Society.

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Purpose. To investigate the prevalence and associated risk factors of low vision and blindness in the Korean population.

Methods. This cross-sectional, population-based study examined the ophthalmologic data of 22,135 Koreans aged ≥5 years from the fifth Korea National Health and Nutrition Examination Survey (KNHANES V, 2010–2012). According to the World Health Organization criteria, blindness was defined as visual acuity (VA) less than 20/400 in the better-seeing eye, and low vision as VA of 20/60 or worse but 20/400 or better in the better-seeing eye. The prevalence rates were calculated from either presenting VA (PVA) or best-corrected VA (BCVA). Multivariate regression analysis was conducted for adults aged ≥20 years.

Results. The overall prevalence rates of PVA-defined low vision and blindness were 4.98% and 0.26%, respectively, and those of BCVA-defined low vision and blindness were 0.46% and 0.05%, respectively. Prevalence increased rapidly above the age of 70 years. For subjects aged ≥70 years, the population-weighted prevalence rates of low vision, based on PVA and BCVA, were 12.85% and 3.87%, respectively, and the corresponding rates of blindness were 0.49% and 0.42%, respectively. The presenting vision problems were significantly associated with age (younger adults or elderly subjects), female sex, low educational level, and lowest household income, whereas the best-corrected vision problems were associated with age ≥ 70 years, a low educational level, and rural residence.

Conclusions. This population-based study provides useful information for planning optimal public eye health care services in South Korea.

Keywords: blindness, low vision, South Korea, visual impairment

Visual impairment is an important public health problem and leads to decreased quality of life.[1–3] According to the report from the World Health Organization (WHO) analyzing recent surveys from 39 countries since 2000, the estimated number of visually impaired individuals worldwide is 285 million (39 million blind and 246 million with low vision); 65% of those who are visually impaired and 82% of those who are blind are aged ≥50 years, as assessed by presenting vision.[4,5] The major cause of visual impairment is uncorrected refractive errors (43%) followed by cataract (33%); the most common cause of blindness is cataract (51%), which means that the preventable causes contribute to as much as 80% of the total global burden.[5] To plan national policies for the prevention of visual impairment and treatment of visually impaired individuals, accurate information on the prevalence of and factors associated with visual impairment is required.

Several epidemiologic studies focusing on visual impairment have been conducted in many countries.[6–13] However, very few studies[14,15] have reported detailed data on the prevalence of visual impairment in the Korean population. South Korea has experienced rapid socioeconomic growth during the past several decades. With the rapid increase in life expectancy, the estimated increases in the prevalence of low vision and blindness can be a major public health and socioeconomic concern, especially in the elderly.[16] In addition, there are regional differences in the distribution of refractive errors and major vision-threatening ocular diseases. Therefore, a national investigation on visual impairment should be conducted in Korea. Korea has one of the highest prevalence rates of myopia worldwide, especially among the youth.[17,18] In the current study, we widely included subjects aged ≥5 years to comprehensively analyze low vision and blindness in the general population. Investigation of visual impairment based

on both presenting visual acuity (PVA) and best-corrected visual acuity (BCVA) may provide useful information on correctable visual impairment caused by uncorrected refractive error.

The Korea Centers for Disease Control and Prevention has been conducting the Korea National Health and Nutrition Examination Survey (KNHANES) regularly since 1998. The KNHANES is a national program designed to assess the health and nutritional status of adults and children in South Korea.[19,20] The KNHANES is a cross-sectional survey conducted every year, and its target population comprises nationally representative noninstitutionalized civilians in Korea. Each survey year includes a new sample of approximately 10,000 individuals aged 1 year and older. These data have been used to estimate the prevalence of various diseases in the entire population or to monitor trends in the prevalence and the risk behaviors in South Korea.[19,20] Since July 2008, this survey has included ophthalmologic interviews and examinations with help from the Korean Ophthalmological Society.[14] We used the ophthalmologic data acquired from KNHANES phase V, from 2010 to 2012, to analyze visual impairment in the South Korean population. The purpose of this study was to assess the prevalence of visual impairment, based on PVA and BCVA, and its demographic associations in the general population of South Korea.

Methods

Data Source and Study Population

The KNHANES is a nationwide, population-based, cross-sectional health examination and survey conducted regularly by the Division of Chronic Disease Surveillance of the Korea Centers for Disease Control and Prevention under the Ministry of Health and Welfare. The KNHANES has been conducted in 1998 (KNHANES I), 2001 (KNHANES II), 2005 (KNHANES III), 2007–2009 (KNHANES IV), and 2010–2012 (KNHANES V) (http://knhanes.cdc.go.kr; provided in the public domain by the Korea Centers for Disease Control and Prevention). The survey has three parts: health interview, health examination, and nutrition surveys. A stratified, multistage probability sampling design is used for the selection of household units that participate in the survey, so that each year's survey result represents the entire general population of South Korea. All members of each selected household were asked to participate in the survey and the participation rate between 2010 and 2012 ranged from 75.9% to 77.5%.

Our cross-sectional study included data from a representative sample of Koreans aged ≥5 years, collected in the fifth KNHANES (KNHANES V 1, 2, and 3, conducted in years 2010, 2011, and 2012, respectively) studies. From the 23,239 subjects who had completed the Health Examination Survey and underwent ophthalmologic examinations, those aged <5 years or who had no VA data were excluded ($n = 1104$); the 22,135 remaining were included in this study (Fig. 1). Tenets of the Declaration of Helsinki for biomedical research were followed, and institutional review board approval was granted by the Institutional Review Board of the Korea Centers for Disease Control and Prevention. Written informed consent was obtained from each participant. The study design was approved by the Institutional Review Board of Kim's Eye Hospital, Seoul, Korea.

Participant Data and Measurements

A detailed questionnaire was administered by trained interviewers to collect relevant demographic, socioeconomic, and medical data. Demographic variables include age, sex, educational level, monthly household income, and residential area. Area of residence was categorized as urban or rural. Among the 16 districts of South Korea, eight major cities (Seoul, Gyeonggi, Busan, Daegu, Incheon, Gwangju, Daejeoun, and Ulsan) were classified as urban areas, and the other provinces (Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju) were classified as rural areas. Monthly household income was categorized as lowest, medium-lowest, medium-highest, and highest income levels. Education was categorized into four levels: elementary-school graduation or lower education; middle-school graduation; high-school graduation; university graduation or higher education.

The ophthalmologic survey is aimed at determining the prevalence of vision status and common eye diseases nationwide in the Korean population. This was offered to all participants in the KNHANES survey. A total of 574 surveys were conducted within a time span of 144 weeks for the fifth KNHANES survey. A total of 370 ophthalmology residents or ophthalmologists from 75 training hospitals participated in this project as ophthalmologic examiners. The quality of the ophthalmic survey and fundus photograph readings was verified by the Epidemiologic Survey Committee of the Korean Ophthalmological Society. The ophthalmology residents participating in the survey are required to complete a training course and to conduct supervised practice before working in the survey field. The use of standardized protocol and the periodic training of examiners by acting staff members of the Committee helped to control the quality and validate the results. Additionally, a high degree of agreement in the grading of fundus photographs was achieved (https://knhanes.cdc.go.kr/knhanes/sub04/sub04_03_02.do; provided in the public domain by the Korea Centers for Disease Control and Prevention).

Ocular examination procedures were stratified according to age groups. Participants aged 3 to 4 years underwent testing only for strabismus and blepharoptosis. For participants aged 5 to 18 years, noncycloplegic autorefraction and testing for VA, strabismus, and blepharoptosis were performed. For adult populations older than 19 years, full ocular examinations, including slit lamp examinations, measurement of intraocular pressure, and fundus photographs, were conducted. An autorefractor-keratometer (KR 8800; Topcon, Tokyo, Japan) was used for all refraction measurements. The VA was measured for each eye at a distance of 4 m by using Jin's vision chart, which is an international standard vision chart based on the logMAR scale widely adopted for clinical use in South Korea (www.jvinstitute.net; provided in the public domain by JV Institute, Seoul, Korea).[21] The PVA was initially assessed by using the participant's usual distance correction. The VA was measured in the right eye first, and then the left eye. The participants were asked to read the numbers in the VA chart while the forced choice method was consistently applied. The VA was recorded as the smallest line in which they could read correctly more than 60% of the numbers in each line. For those who could not distinguish any letter on the chart at the 4-m distance, VA was retested at a 1-m distance. If no letters were distinguished at a 1-m distance, VA was assessed by counting fingers, using hand movements, or using light perception at a 0.4-m distance. To obtain the BCVA, the VA examination was performed with full subjective refraction by using data recorded by an autorefractometer and then repeated by applying the pinhole when the value for corrected VA with autorefractometry did not reach 0.8. Fundus photographs were obtained by using a digital nonmydriatic fundus camera (TRC-NW6S, Topcon) and a Nikon D-80 digital camera (Nikon, Tokyo, Japan) from all participants 19 years of age and older under physiologic mydriasis in the dark. One 45° nonmydriatic digital retinal image centered on fovea was taken per eye. Pharmacologic pupillary dilatation was performed for

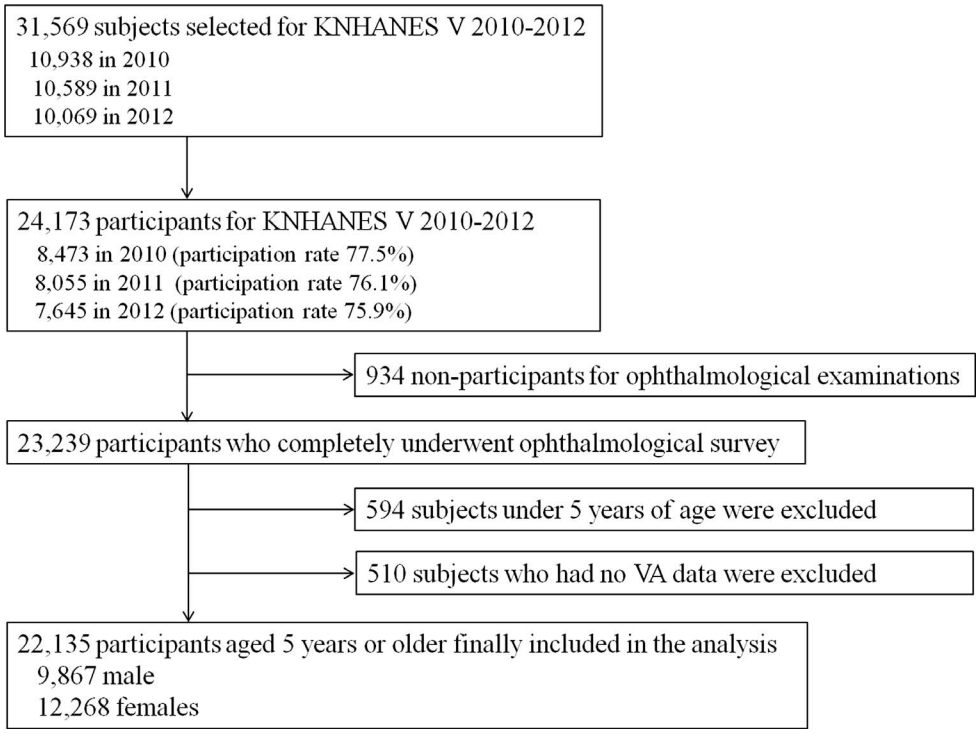

FIGURE 1. Flow diagram presenting the selection of study participants.

participants who had a history of diabetes mellitus or random blood glucose level of 200 mg/dL or higher, and/or when the fundus photographic findings were suggestive of diabetic retinopathy, and/or when it was difficult to obtain a non-mydriatic fundus photograph owing to media opacity. Additional photos were obtained under pharmacologic mydriasis in those cases.

To define the prevalence of ocular comorbidities, the presence of various ocular disorders was determined in each subject. The severity of the eye conditions was not assessed. The diagnostic criteria of ocular disorders used in this study are described elsewhere and summarized as follows.[14] Applying spherical equivalents (SE), calculated as the spherical value plus half of the cylindrical value, myopia and hyperopia were defined as an SE $\leq$ −0.75 diopters (D) and SE $\geq$ +1.0 D, respectively. Cylindrical powers were recorded as negative values, and astigmatism was recorded as a cylinder $\leq$ −0.75 D. Strabismus was defined as a manifested or latent ocular deviation at a distance or near fixation with or without spectacle correction, which included esodeviation of $\geq$10 prism diopters (PD), exodeviation of $\geq$15 PD, and any vertical deviations. Regarding cataract, the presence of lens opacity was evaluated and its subtype was classified as a nuclear, cortical, or posterior subcapsular cataract, without grading of lens opacity. The determination of diabetic retinopathy and age-related macular degeneration (ARMD) was made on the basis of the fundus photographs. Diabetic retinopathy was defined as the presence of one or more retinal microaneurysms or retinal blot hemorrhages with or without more severe lesions, such as hard exudates, soft exudates, intraretinal microvascular abnormalities, new retinal vessels, and fibroproliferations, in at least one eye.[22,23] Age-related macular degeneration was defined as the presence of signs of early or late ARMD and geographic atrophy in at least one eye, on the basis of the grading protocol of the international Age-Related Maculopathy Epidemiological Study Group.[24] Regarding glaucoma assessment, frequency doubling perimetry (FDT, Humphrey Matrix; Carl Zeiss Meditec, Inc., Dublin, CA, USA) testing with the screening program N-30-1 was performed if the participants had elevated IOP ($\geq$22 mm Hg) or a glaucomatous optic disc (loss of neuroretinal rim with vertical or horizontal cup-to-disc ratio $\geq$ 0.6, or presence of optic disc hemorrhage, or presence of retinal nerve fiber layer defect, or asymmetry of vertical cup-to-disc ratio $\geq$ 0.2). Glaucoma was defined as primary open-angle glaucoma (POAG), normal-tension glaucoma (NTG), or primary angle-closure glaucoma in at least one eye, based on the combinations of IOP, glaucomatous optic disc configuration, and the presence of an abnormal FDT testing result.[25] On the basis of IOP, open-angle glaucoma was classified into POAG (IOP $\geq$ 22 mm Hg) or NTG (IOP $\leq$ 21 mm Hg). Because of the limitation in the design of the KNHANES, several eye diseases can exist in one subject simultaneously and the presence of comorbid eye disease does not necessarily mean that the disease is the direct cause of the subject's visual impairment; the specific cause of the visual impairment could not be determined in this study.

Definitions

Low vision and blindness were defined on the basis of the standard WHO criteria. Blindness was defined as VA worse than 20/400 in the better-seeing eye, and low vision as VA 20/60 or worse but 20/400 or better in the better-seeing eye. Visual impairment included both low vision and blindness. The prevalence rates of low vision and blindness were calculated on the basis of PVA and BCVA, separately.

Statistical Analysis

The overall and age- and sex-specific prevalence rates for low vision and blindness were expressed as percentages of the study population, with the 95% confidence interval (CI), based on the PVA and BCVA. Since KNHANES V included weights to compensate for the complex sampling design and to allow

Table 1. Baseline Characteristics of Study Participants

	Participants, $n = 22,135$		Nonparticipants, $n = 2038$		
	No.	Weighted % (95 % CI)	No.	Weighted % (95 % CI)	*P* Value
Age, y					
5–19	4,394	19.0 (18.2–19.9)	113	12.7 (9.0–16.4)	<.0001
20–29	1,892	14.6 (13.7–15.6)	57	11.2 (8.2–14.2)	
30–39	3,275	17.0 (16.1–17.8)	128	20.1 (15.8–24.5)	
40–49	3,161	17.8 (17.0–18.5)	133	23.1 (19.0–27.2)	
50–59	3,445	15.0 (14.3–15.7)	89	12.9 (9.6–16.3)	
60–69	3,081	8.8 (8.3–9.3)	65	5.5 (3.6–7.4)	
≥70	2,887	7.8 (7.3–8.3)	167	14.4 (10.8–18.0)	
Mean (95% CI)		39.5 (39.1–40.0)		21.7 (19.88–23.43)	
Sex					
Male	9,867	50.1 (49.4–50.8)	1008	50.9 (48.5–53.4)	0.5109
Female	12,268	49.9 (49.2–50.6)	1030	49.1 (46.6–51.5)	
Education					
Elementary or less	7,808	28.1 (27.1–29.0)	1484	73.3 (67.9–78.7)	<.0001
Middle school	2,635	12.9 (12.3–13.6)	56	4.0 (2.7–5.3)	
High school	5,929	32.7 (31.7–33.7)	132	12.0 (9.1–15.0)	
University or more	5,236	26.3 (25.2–27.4)	132	10.7 (7.5–13.8)	
Monthly household income					
Lowest	5,334	27.5 (26.2–28.9)	501	31.5 (28.0–35.0)	0.0521
Medium-lowest	5,486	25.6 (24.5–26.8)	503	34.9 (22.3–27.6)	
Medium-highest	5,518	24.3 (23.2–25.4)	514	23.5 (20.9–26.0)	
Highest	5,505	22.6 (21.3–23.8)	481	20.1 (17.7–22.6)	
Residential area					
Urban	17,789	80.6 (77.2–83.9)	1696	80.7 (75.8–85.6)	0.9482
Rural	4,346	19.4 (16.1–22.8)	342	19.3 (14.4–24.2)	

P values were calculated by using χ^2 test.

approximations of the Korean population, weighted analyses were performed with SAS software (version 9.3; SAS Institute, Cary, NC, USA).[19,20] Rao-Scott χ^2 tests were used for analysis of differences in the prevalence of low vision and blindness between the sexes. For Korean adults aged ≥20 years, the associations of age, sex, education level, monthly household income, and residential area with visual impairment were analyzed by using multivariable logistic regression and odds ratios (ORs), and 95% CIs were calculated. Adjusted OR was used to assess the mutually confounding effect of these variables on the risk of visual impairment. Prevalence rates of comorbid ocular disorders were described by using percentages for each ocular disorder. A P value < 0.05 indicated statistical significance.

Results

Baseline Characteristics

A total of 22,135 eligible Koreans aged ≥5 years, representative of 45,655,919 Koreans, were examined. Table 1 shows the distributions of age, sex, education level, monthly household income, and residential area of the study population. The mean age of study participants was 39.5 years (95% CI: 39.1–40.0). Nonparticipants including 934 subjects who did not undergo ophthalmologic examinations and 1104 subjects who were excluded from this study were analyzed. The nonparticipants were more likely to be in the older age group and less educated than the participants. However, the distributions of sex, household income, and residential area were not different from those of the participants.

Prevalence Rates for Low Vision and Blindness

Table 2 describes the prevalence rates of low vision and blindness, stratified by age and sex according to the WHO criteria based on PVA. The overall prevalence rates of low vision and blindness were 4.98% (95% CI: 4.54%–5.43%) and 0.26% (95% CI: 0.18%–0.34%), respectively. The prevalence of visual impairment was higher among the elderly populations, with population-weighted prevalence rates of 12.85% (95% CI: 11.12%–14.58%) for low vision and 0.49% (95% CI: 0.22%–0.77%) for blindness in subjects aged ≥70 years. The prevalence rates of low vision and blindness, based on BCVA, are presented in Table 3. Compared with the results based on PVA, the overall population-weighted prevalence rates based on BCVA decreased to 0.46% (95% CI: 0.35%–0.57%) for low vision and 0.05% (95% CI: 0.03%–0.07%) for blindness. For the adult participants, the age-specific prevalence of low vision and blindness showed a steep increase in subjects aged ≥70 years, with prevalence rates of 3.87% (95% CI: 2.90%–4.83%) for low vision and 0.42% (95% CI: 0.16%–0.67%) for blindness.

Sex difference in the prevalence of low vision and blindness is summarized in Table 4. Significant sex differences were noted in the prevalence of PVA-defined low vision and blindness, with higher prevalence in females. Females tended to demonstrate a higher prevalence of BCVA-defined visual impairment; however, the sex differences did not reach statistical significance in the prevalence rates of low vision and blindness. This tendency of sex differences remained after age adjustment.

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TABLE 2. Prevalence of Low Vision and Blindness by Age and Sex Based on Presenting Visual Acuity

	Examined Subjects			Low Vision						Blindness					
				Men			Women			Men			Women		
Age, y	Men	Women	Total	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)
5–19	2315	2,079	4,394	112	5.75 (4.42–7.08)	146	6.92 (5.44–8.41)	258	6.30 (5.21–7.40)	2	0.15 (0.00–0.35)	9	0.67 (0.18–1.16)	11	0.40 (0.14–0.65)
20–29	777	1,115	1,892	38	5.28 (3.44–7.12)	73	7.15 (5.28–9.01)	111	6.16 (4.88–7.44)	3	0.19 (0.00–0.46)	6	0.58 (0.09–1.08)	9	0.38 (0.10–0.65)
30–39	1344	1,931	3,275	22	1.72 (0.89–2.55)	70	3.83 (2.75–4.91)	92	2.75 (2.06–3.44)	2	0.11 (0.00–0.28)	4	0.29 (0.00–0.58)	6	0.20 (0.03–0.37)
40–49	1379	1,782	3,161	24	2.39 (1.25–3.53)	63	4.19 (3.07–5.30)	87	3.28 (2.44–4.12)	2	0.15 (0.00–0.36)	4	0.17 (0.00–0.37)	6	0.16 (0.01 −0.30)
50–59	1435	2,010	3,445	24	1.93 (0.90–2.97)	65	3.62 (2.56–4.67)	89	2.78 (2.05–3.51)	1	0.02 (0.00–0.07)	4	0.12 (0.00–0.26)	5	0.07 (0.00–0.15)
60–69	1376	1,705	3,081	41	2.97 (1.83–4.11)	101	6.25 (4.86–7.64)	142	4.70 (3.78–5.61)	2	0.09 (0.00–0.23)	5	0.25 (0.03–0.48)	7	0.18 (0.04–0.31)
≥70	1241	1,646	2,887	122	10.47 (8.35–12.60)	225	14.41 (12.01–16.81)	347	12.85 (11.12–14.58)	7	0.64 (0.13–1.16)	8	0.39 (0.09–0.70)	15	0.49 (0.22–0.77)
Total	9867	12,268	22,135	383	3.87 (3.32–4.41)	743	6.10 (5.53–6.68)	1126	4.98 (4.54–5.43)	19	0.16 (0.07–0.25)	40	0.36 (0.23–0.49)	59	0.26 (0.18–0.34)
P value*				<.0001		<.0001		<.0001		0.0533		0.0704		0.0292	
≥40	5431	7,143	12,574	211	3.40 (2.74–4.05)	454	6.27 (5.54–6.99)	665	4.89 (4.35–5.43)	12	0.16 (0.06–0.27)	21	0.21 (0.11–0.32)	33	0.19 (0.12–0.26)
≥60	2617	3,351	5,968	163	6.16 (5.00–7.32)	326	10.35 (8.92–11.79)	489	8.52 (7.49–9.55)	9	0.33 (0.09–0.56)	13	0.32 (0.14–0.51)	22	0.33 (0.18–0.47)

Prevalence is expressed as estimated percentage with 95% CI.

* *P* values were calculated by using χ^2 test.

Factors Associated With Low Vision and Blindness

For Korean adults aged ≥20 years, a multivariate logistic regression model was constructed by using visual impairment, including low vision and blindness, as the dependent variables and using age, sex, educational level, monthly household income, and residential area as the explanatory covariates (Table 5). Subjects of older age, with a lower educational level, and with a lower monthly household income had higher risks for visual impairment, based on PVA or BCVA (*P* for trend <0.0001 for age, educational level, and monthly household income). As compared with adults aged 20 to 49 years as a reference group, the multivariate OR of visual impairment in adults aged ≥70 years was 1.92 (95% CI: 1.45–2.53) based on PVA and 8.09 (95% CI: 2.93–22.29) based on BCVA. Younger adults aged 20 to 49 years had a higher risk of PVA-defined visual impairment than adults aged 50 to 69 years (OR ratio for adults aged 50–69 years: 0.61; 95% CI: 0.47–0.79). Women had a 55% higher risk than men for the presenting vision impairment (OR: 1.55; 95% CI: 1.28–1.89), but not for the best-corrected vision impairment (OR: 0.84; 95% CI: 0.54–1.32). Regarding educational level, adults who were high-school graduate, or elementary school graduate or with a lesser education level, had a higher risk of visual impairment, based on PVA (OR: 1.51, 95% CI: 1.15–1.99 for high school; and OR: 2.30, 95% CI: 1.63–3.24 for elementary school or lesser education) than those who were university graduates or had higher education. The association between elementary school educational level and the best-corrected vision impairment was notable (OR: 6.16; 95% CI: 1.59–23.90). Subjects living in rural areas were more likely to have BCVA-defined visual impairment (OR 1.95; 95% CI: 1.23–3.08).

Comorbid Eye Diseases in Patients With Visual Impairment

Table 6 shows the prevalence of various ophthalmic disorders for subjects with or without visual impairment. More than 89% of the subjects with PVA-defined visual impairment were not included in the BCVA-defined visual impairment group, which means their VA was improved with optimal refractive correction. The subjects with PVA-defined visual impairment had a significantly higher prevalence rate for myopia than the control group (80.0% vs. 46.2%, $P < 0.0001$), whereas the myopia prevalence in subjects with BCVA-defined visual impairment was similar to that in normal subjects (51.0% vs. 46.2%, $P = 0.44$). Subjects with BCVA-defined visual impairment had much higher prevalence rates of cataract (64.3% vs. 20.4%, $P < 0.0001$), glaucoma (10.8% vs. 2.4%, $P < 0.0001$), corneal opacity (9.2% vs. 1.7%, $P = 0.0001$), diabetic retinopathy (8.8% vs. 1.1%, $P < 0.0001$), and ARMD (15.7% vs. 2.9%, $P < 0.0001$) than subjects with normal VA.

DISCUSSION

This study was a nationwide, large-scale, population-based epidemiologic study of visual impairment in Korea. Using the WHO criteria, among Koreans aged ≥5 years, the overall prevalence rates of the BCVA-defined low vision and blindness were 0.46% and 0.05%, respectively, and those of the PVA-defined low vision and blindness were 4.98% and 0.26%, respectively. The higher prevalence of the BCVA-defined visual impairment was prominent in subjects aged ≥70 years (3.87% for low vision and 0.42% for blindness). Based on demographics from the 2005 Korean National Census, approximately 208,381 and 22,732 Korean individuals are estimated to have low vision and blindness, respectively, based on BCVA.

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TABLE 3. Prevalence of Low Vision and Blindness by Age and Sex Based on Best-Corrected Visual Acuity

	Examined Subjects			Low Vision						Blindness					
				Men			Women			Men			Women		
Age, y	Men	Women	Total	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)
5–19	2315	2,079	4,394	3	0.14 (0.00–0.31)	0	0	3	0.07 (0.00–0.16)	0	0	0	0	0	0
20–29	777	1,115	1,892	1	0.31 (0.00–0.92)	0	0	1	0.16 (0.00–0.48)	0	0	0	0	0	0
30–39	1344	1,931	3,275	2	0.14 (0.00–0.36)	0	0	2	0.07 (0.00–0.18)	0	0	0	0	0	0
40–49	1379	1,782	3,161	2	0.28 (0.00–0.67)	2	0.02 (0.00–0.05)	4	0.15 (0.00–0.35)	0	0	0	0	0	0
50–59	1435	2,010	3,445	2	0.05 (0.00–0.14)	3	0.17 (0.00–0.38)	5	0.11 (0.00–0.23)	0	0	3	0.09 (0.00–0.22)	3	0.05 (0.00–0.11)
60–69	1376	1,705	3,081	7	0.31 (0.06–0.56)	19	1.07 (0.52–1.62)	26	0.71 (0.39–1.03)	2	0.09 (0.00–0.23)	3	0.14 (0.00–0.30)	5	0.12 (0.01–0.22)
≥70	1241	1,646	2,887	35	3.20 (1.87–4.52)	65	4.30 (2.94–5.66)	100	3.87 (2.90–4.83)	5	0.50 (0.04–0.97)	7	0.36 (0.06–0.65)	12	0.42 (0.16–0.67)
Total	9867	12,268	22,135	52	0.38 (0.23–0.53)	89	0.53 (0.38–0.68)	141	0.46 (0.35–0.57)	7	0.04 (0.01–0.07)	13	0.06 (0.02–0.10)	20	0.05 (0.03–0.07)
P value*				<.0001			<.0001		<.0001						
≥40	5431	7,143	12,574	46	0.59 (0.36–0.83)	89	1.04 (0.75–1.33)	135	0.82 (0.64–1.01)	7	0.08 (0.02–0.15)	13	0.12 (0.05–0.19)	20	0.10 (0.05–0.15)
≥60	2617	3,351	5,968	42	1.54 (0.95–2.13)	84	2.69 (1.94–3.45)	126	2.19 (1.69–2.69)	7	0.27 (0.05–0.48)	10	0.25 (0.08–0.42)	17	0.26 (0.13–0.39)

Prevalence is expressed as estimated percentage with 95% CI.

* *P* values were calculated by using χ^2 test.

Prevalence rates of visual impairment in the pediatric patients aged <20 years have rarely been reported.[26–30] In this study, for pediatric patients aged 5 to 19 years, the prevalence rates of PVA- and BCVA-defined low vision were 6.30% and 0.07%, respectively. Because visual impairment, especially blindness, in children is rare, a very large sample size is needed for population-based surveys designed to estimate its prevalence.[31] Few surveys have been reported for the visual impairment in children.[29,30] The KNHNAES was not planned specifically for children in evaluating visual impairment. A relatively small sample size of children and the absence of cycloplegic refraction were limitations. Despite these limitations, our study has significance as the first reference on the visual impairment in the Korean pediatric population. In particular, a higher prevalence of PVA-defined visual impairment, which has been emphasized in recent years as a correctable visual impairment, compared with that in other pediatric populations, should be noted.[27–30]

For subjects aged ≥40 years, the prevalence rates of the BCVA-defined low vision and blindness were 0.82% and 0.10%, respectively. It is difficult to directly compare the prevalence rates of visual impairment from our study with those from other studies owing to the methodologic differences in the inclusion criteria, definition of visual impairment used, and age distribution of participants; however, if we do compare our data with those from other studies, using the same WHO criteria in the adult populations, the prevalence rate for low vision in our study is lower than that in the Beijing Chinese population (1.1%), Singaporean Chinese population (1.1%), and Taiwanese population (2.75%), but higher than that in the suburban (0.37%) or rural (0.58%) Japanese populations.[6–10]

Generally, age was the universal risk factor associated with visual impairment. The rates of visual impairment and blindness have been reported to sharply increase with age, beginning at about 60 to 70 years, as demonstrated in Figure 2.[6–8,12,32] A similar trend was also detected in our results. For the elderly, in particular, the prevalence rates of the BCVA-defined low vision (3.87%) and blindness (0.42%) showed a steep increase in adults aged ≥70 years. This result is similar to that reported recently in the elderly Japanese population aged ≥80 years: 3.55% for low vision and 0.71% for blindness.[7] Considering this age-dependent increase in the prevalence of low vision and blindness and the growing elderly population in Korea, the number of visually impaired elderly individuals may increase in the near future in Korea, and this could lead to a major public health problem.

To the best of our knowledge, our study is the first to investigate PVA-defined visual impairment in the Korean population. The overall population-weighted prevalence rates of low vision, based on BCVA, decreased to 0.46% from 4.98% based on PVA. The discrepancy between the PVA- and BCVA-defined prevalence rates indicates that a significant number of subjects in the visually impaired population can restore their eyesight by accurate refractive correction only. There was a notable discrepancy in the PVA- and BCVA-defined low vision prevalence rates in the three age groups: the pediatric population aged 5 to 19 years (6.30%, weighted *N* 547,840 based on PVA; 0.07%, weighted *N* 6177 based on BCVA), young adults aged 20 to 29 years (6.16%, weighted *N* 411,418 based on PVA; 0.16%, weighted *N* 10,947 based on BCVA), and the elderly aged ≥70 years (12.85%, weighted *N* 457,318 based on PVA; 3.87%, weighted *N* 137,235 based on BCVA). Applying our estimates from the 2005 Korean National Census, approximately 540,000 children and adolescents, 400,000 young adults, and 300,000 visually impaired elderly individuals aged ≥70 years could have their eyesight restored by accurate refractive correction.

Table 4. Sex Differences in the Prevalence of Low Vision and Blindness

	PVA-Defined Visual Impairment		BCVA-Defined Visual Impairment	
	Low Vision	Blindness	Low Vision	Blindness
Sex				
Men	3.87% (3.32–4.41)	0.16% (0.07–0.25)	0.38% (0.23–0.53)	0.04% (0.01–0.07)
Women	6.10% (5.53–6.68)	0.36% (0.23–0.49)	0.53% (0.38–0.68)	0.06% (0.02–0.10)
P value*	<.0001	0.0151	0.1598	0.3685
P value†	<.0001	0.0176	0.8545	0.8652

* *P* value by χ^2 test.
† *P* value by logistic regression analysis with age adjustment.

Korea has one of the highest myopia prevalence rates worldwide. A recent study[18] reports that the prevalence of myopia <–0.5 D and high myopia <–6.0 D in 19-year-old Korean men is 96.5% and 21.6%, respectively. The high prevalence of undercorrected refractive errors might be associated with an epidemic of myopia and cultural reluctance to wear spectacles among the Korean youth. Although myopia is easily correctable with spectacles, many children and adolescents are not appropriately managed for myopia. In the elderly population, uncorrected refractive error associated with cataract-related refractive changes and the increase of cylindrical power could be the major correctable causes of decreased PVA.[33] Adequate correction of refractive errors may enhance the quality of life and contribute to greater independent living in the elderly.[33]

Regarding visual impairment and biological sex, the prevalence rates of low vision and blindness were generally higher in women than in men in this study. This finding was consistent with those of other studies.[7,10,34] Sex differences were noticed in the prevalence of both PVA- and BCVA-defined visual impairment in this study. However, the difference in BCVA-defined visual impairment did not reach statistical significance. Worldwide, women bear approximately two-thirds of the burden of severe visual impairment and blindness.[35,36] Sex inequality in prevalence of visual impairment has been noted in high- and low-income countries.[34,36–38] Especially in poorer countries, far lesser utilization of eye care services by women is the main cause of this phenomenon.[35] In our study, it is unclear why women had a higher prevalence of visual impairment, especially based on PVA, than men. Further research is required to address sex differences in the pattern of eye health care utilization and in the proportion of ocular pathologic conditions leading to visual impairment.

Multivariate logistic regression analysis showed that the risk of PVA- and BCVA-defined visual impairment increased significantly with older age, lower educational level, and lower monthly household income. The presenting vision problems were associated with age (younger subjects or elderly subjects aged ≥70 years), female sex, low educational level, and lowest household income, whereas the best-corrected vision problems were associated with age ≥70 years, low educational level, and rural residence. These findings highlight the need for targeted education to increase awareness of uncorrected refractive error among youth aged <29 years and elderly aged ≥70 years, especially among

Table 5. Risks of Visual Impairment (Including Low Vision and Blindness) in Korean Population

	PVA-Defined Visual Impairment			BCVA-Defined Visual Impairment		
	OR	95% CI	*P* for Trend	OR	95% CI	*P* for Trend
Age, y			<0.0001			<0.0001
20–49	Reference			Reference		
50–69	0.61	0.47–0.79		1.12	0.42–2.95	
≥70	1.92	1.45–2.53		8.09	2.93–22.29	
Sex						
Female	1.55	1.28–1.89		0.84	0.54–1.32	
Male	Reference			Reference		
Educational level			<0.0001			<0.0001
Elementary or less	2.30	1.63–3.24		6.16	1.59–23.90	
Middle school	1.24	0.81–1.92		1.09	0.21–5.67	
High school	1.51	1.15–1.99		1.78	0.37–8.62	
University or more	Reference			Reference		
Monthly household income			<0.0001			<0.0001
Lowest	1.37	1.03–1.82		1.08	0.57–2.074	
Medium-lowest	1.16	0.88–1.55		0.72	0.39–1.33	
Medium-highest	1.03	0.76–1.39		1.01	0.44–2.35	
Highest	Reference			Reference		
Residential area						
Urban	Reference			Reference		
Rural	1.21	0.96–1.53		1.95	1.23–3.08	

Table 6. Ocular Comorbidities in Subjects With Visual Impairment: Comparison of PVA and BCVA

	Group 1 PVA-Defined Visual Impairment No. (%) ($N = 1185$)	Group 2 BCVA-Defined Visual Impairment No. (%) ($N = 161$)	Group 3 Normal Visual Acuity No. (%) ($N = 20,950$)	*P* Value†	*P* Value‡
Myopia ≤ -0.75 D	806 (80.0)	60 (51.0)	8541 (46.2)	<0.0001	0.4444
Hyperopia $\geq +1.0$ D	200 (11.8)	28 (19.5)	2403 (8.2)	<0.0001	<0.0001
Astigmatism ≤ -0.75 D	705 (59.4)	107 (79.6)	9936 (45.2)	<0.0001	<0.0001
Strabismus	26 (3.1)	9 (7.9)	167 (1.2)	0.0002	<0.0001
Ptosis	198 (12.8)	59 (35.4)	2007 (7.8)	<0.0001	<0.0001
Cataract	450 (35.9)	110 (64.3)	4741 (20.4)	<0.0001	<0.0001
Pterygium	52 (5.7)	19 (14.8)	502 (3.3)	0.0021	<0.0001
Corneal opacity	10 (5.3)	8 (9.2)	13 (1.7)	0.0042	0.0001
Glaucoma	49 (4.4)	10 (10.8)	482 (2.4)	0.0015	<0.0001
Diabetic retinopathy	22 (2.1)	9 (8.8)	235 (1.1)	0.0380	<0.0001
Age-related macular degeneration	68 (5.4)	19 (15.7)	668 (2.9)	<0.0001	<0.0001

† Comparison between group 1 and group 3 (*P* value by χ^2 test).
‡ Comparison between group 2 and group 3 (*P* value by χ^2 test).

women. Regular eye health care services and blindness-prevention programs should be conducted for populations at a high risk for visual impairment.

We investigated the prevalence of comorbid ocular disorders in all subjects. The results were interpreted with the limitation of being unable to determine the direct causal relationships between ophthalmic disorders and visual impairment. The discrepancy between PVA- and BCVA-defined visual impairment is explained by uncorrected refractive error, which exists in 89.8% of subjects with PVA-defined visual impairment. This result is supported by our finding of a much higher prevalence rate of myopia, which is an easily correctable disease, in the subjects with PVA-defined visual impairment than in the control group; subjects with BCVA-defined visual impairment had significantly higher prevalence rates of ocular diseases with less easily correctable vision loss, such as cataract, corneal opacity, glaucoma, diabetic retinopathy, and ARMD, than subjects with normal VA. In addition, strabismus and blepharoptosis were more prevalent in the subjects with PVA- or BCVA-defined visual impairment than in subjects with normal VA.

Our study has limitations. First, the definite causes of visual impairment in Korea could not be clarified in the current study. We were able to analyze only the coexistence of various ocular diseases in subjects with visual impairments (Table 6). The absence of severity data in the assessment of ocular morbidity might explain the relatively high prevalence of ocular disease in individuals with normal acuity. The results should be interpreted in light of these limitations. The causal relationship between low vision and blindness in the Korean populations will be analyzed in the upcoming KNHANES survey. Second, the application of maximally corrected VA with full correction of autorefraction measurement, followed by pinhole application, may have slightly underestimated the prevalence of visual impairment. Third, the absence of cycloplegic refraction was an obstacle to the accurate assessment of BCVA, especially in children, and may have resulted in overestimation of the visual impairment in children. Further studies using cycloplegic refraction, especially in younger age groups, are required to yield clear answers on epidemiology of visual impairment in the Korean population. Fourth, the KNHANES response rate ranged from 75.9% to 77.5% between 2010 and 2012. The

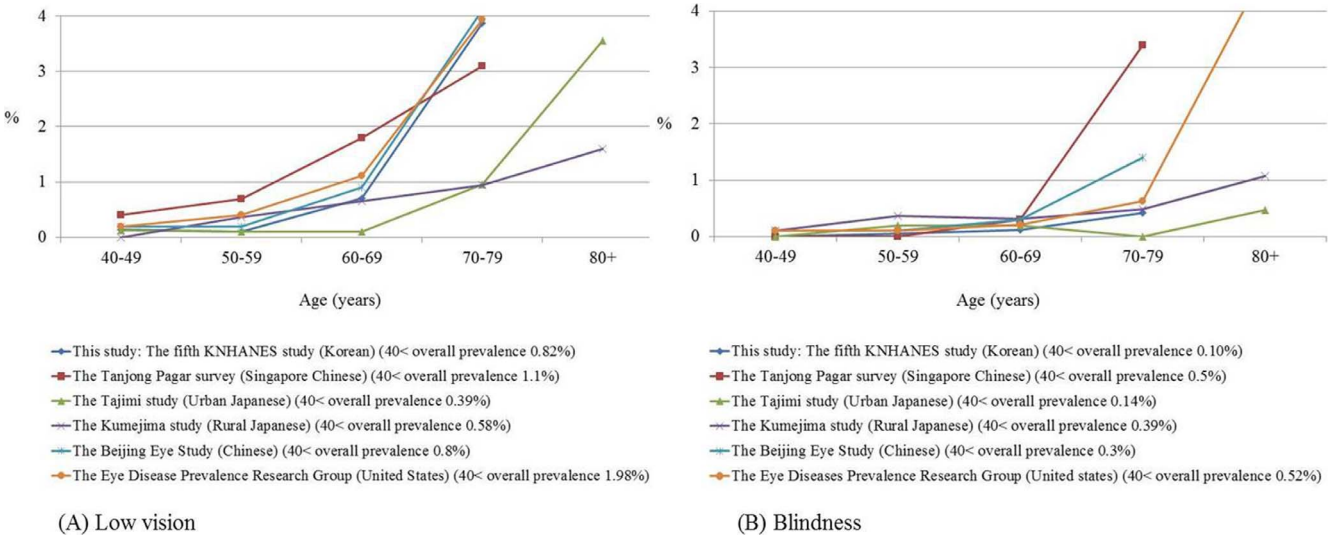

Figure 2. Prevalence of (**A**) low vision and (**B**) blindness by 10-year age groups in selected population-based studies. The rates of low vision and blindness sharply increase with age, beginning at approximately 60 to 70 years. Data from all studies except low vision in the Eye Diseases Prevalence Research Group were based on the World Health Organization criteria. Low vision in the Eye Diseases Prevalence Research Group in the United States was defined as the BCVA less than 6/12 in the better-seeing eye, based on the US definition.

significantly different characteristics of the nonrespondents and the respondents could lead to biased estimates. A way to reduce the nonresponse bias should be developed and implemented in the KNHANES data analysis. Fifth, Comparison of our study participants and nonparticipants revealed significant differences; the nonparticipants were more likely to be in the older age group and be less educated than the participants. These differences in age and education between the participants and the nonparticipants in our study may underestimate the prevalence of visual impairment. Nevertheless, our results still showed that the risk of visual impairment was highest in the oldest population (age $\geq$ 70 years, OR: 15.04) and also in the least educated group (elementary school or less, OR: 5.08). Finally, although thousands of participants were included in each age group, the frequency of visual impairment, especially in younger age groups, was very low, which led to unstable results. A larger number of participants, spanning many more years, would be required to provide more informative results. However, despite these limitations, a notable strength of this study was the relatively large sample size ($n = 22,135$) that covered the entire general South Korean population of all ages. The use of standardized protocol and the periodic training of examiners by acting staff members of the Epidemiologic Survey Committee of the Korean Ophthalmological Society helped to control the quality and validate the results. Our results could help to characterize visual impairment in different age groups in South Korea.

In conclusion, this study deepens our understanding of the distribution and determinants of visual impairment in the Korean population. The population-weighted prevalence rates for presenting low vision and blindness according to the WHO criteria were 4.98% and 0.26%, respectively, for Koreans aged $\geq$5 years; the corresponding prevalence rates for low vision and blindness, based on BCVA, were 0.46% and 0.05%, respectively. This study confirmed the association of visual impairment with increasing age, a lower education level, and a lower monthly household income. Interestingly, presenting vision problems were highly prevalent in the pediatric population (5–19 years) and young adults (20–29 years) in Korea, which emphasizes the need for targeted education and appropriate refractive correction of uncorrected refractive error. Our findings will help in planning optimal public eye health care services in South Korea.

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Appendix

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