Prevalence of Eye Diseases in South Korea: Data from the Korea National Health and Nutrition Examination Survey 2008-2009

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Purpose: The aim of this study is to report on preliminary data regarding the prevalence of major eye diseases in Korea.

Methods: We obtained data from the Korea National Health and Nutrition Examination Survey, a nation-wide cross-sectional survey and examinations of the non-institutionalized civilian population in South Korea (n = 14,606), conducted from July 2008 to December 2009. Field survey teams included an ophthalmologist, nurses, and interviewers, traveled with a mobile examination unit and performed interviews and ophthalmologic examinations.

Results: The prevalence of visual impairment, myopia, hyperopia and astigmatism in participants over 5 years of age was 0.4 ± 0.1%, 53.7 ± 0.6%, 10.7 ± 0.4%, and 58.0 ± 0.6%, respectively. The prevalence of strabismus and blepharoptosis in participants over 3 years of age was 1.5 ± 0.1% and 11.0 ± 0.8%, respectively. In participants over 40 years of age, the prevalence of cataract, pterygium, early and late age-related macular degeneration, diabetic retinopathy and glaucoma was 40.2 ± 1.3%, 8.9 ± 0.5%, 5.1 ± 0.3%, 0.5 ± 0.1%, 13.4 ± 1.5%, and 2.1 ± 0.2%, respectively.

Conclusions: This is the first nation-wide epidemiologic study conducted in South Korea for assessment of the prevalence of eye diseases by both the Korean Ophthalmologic Society and the Korea Center for Disease Control and Prevention. This study will provide preliminary information for use in further investigation, prevention, and management of eye diseases in Korea.

Key Words: Epidemiology, Eye diseases, Korea, Korea National Health and Nutrition Examination Survey, Prevalence

Epidemiological studies provide information on the prevention, treatment, and minimization of the impact of diseases on society. In the past two decades, a wide range of epidemiologic studies in ophthalmology have provided important information on the pattern of visual impairment and the major eye diseases that cause such vision loss [1]. Although several epidemiological studies of several age-related eye diseases (e.g., glaucoma, age-related macular degeneration, and cataract) have been conducted in Korea [2-4], these studies were hospital-based or were conducted primarily in urban areas. Data on the prevalence of diseases based on the number of hospital visits or surveys conducted in limited areas are easy to obtain; however, substantial differences may exist between such data and that obtained in large-scale population studies, which are more accurate and can represent entire populations.

Large-scale population-based studies conducted over the past two decades in many countries, including the United States [5-14], Western Europe [15-17], Australia [18-21], Japan [22-26], Singapore [27-30], and China [31-35], have been used to guide public health policy and plan preventive strategies. However, these studies were conducted mostly with regard to major age-related eye diseases, such as cataract, glaucoma, age-related macular degeneration, and diabetic retinopathy, which are major causes of vision loss. Nation-wide epidemiological studies of all age groups for the prevalence of common eye diseases have not been performed.

The Korea Center for Disease Control and Prevention (CDC) conducted a series of Korea National Health and Nutrition Examination Surveys (KNHANES) in 1998, 2001, 2005 and 2007-2009 for examination of the general health and nutrition status of Koreans. As of the fourth KNHANES (2007-2009), an annual total of 4,600 households were selected, and the participating household members were interviewed regarding health and nutrition and underwent a basic health examination that included blood pressure measurements, blood and urine collection, a pulmonary function test, and a dental examination. Since the Korean Ophthalmologic Society has participated in this survey since 2008, ophthalmologic interviews and examinations were also conducted with the same participants.

The purpose of this study is to investigate the national prevalence of common eye diseases in South Korea based on the survey data obtained from the KNHANES and to analyze the prevalence of diseases according to age and gender. Data

obtained from KNHANES may offer further insight into the etiology, ethnic differences, and public health impact of the most common eye diseases affecting Korean people living in Asia.

Materials and Methods

Study design and population

The KNHANES is an ongoing population-based, cross-sectional epidemiological survey conducted in South Korea. Annually, 4,000 households in 200 enumeration districts were selected by a panel to represent the civilian, non-institutionalized South Korean population using the stratified, multistage clustered sampling method based on the 2005 National Census Data. In KNHANES, sample design and size are estimated so that annual survey results represent the whole population in Korea. Therefore, annual survey results can be used as statistics to represent the overall Korean population. All members of each selected household were asked to participate in the survey, and the rate of participation in the past several cycles ranged from 79% to 84%. From July 2008, ophthalmologic interviews and examinations have been conducted. All examination and health interviews were conducted by trained teams in mobile centers, while nutrition surveys were performed in individual households.

This survey is aimed to determine the prevalence of the following vision status and common eye diseases in a population-based sample of Koreans: visual impairment and blindness, refractive errors, strabismus, blepharoptosis, cataract, pterygium, diabetic retinopathy, age-related macular degeneration (AMD), and glaucoma. The ophthalmologic survey was designed to be conducted over 5 years from 2008 to 2013. The present study includes interim data from a survey conducted from July 2008 to December 2009.

Examination procedures

Examination procedures were stratified according to age group. Participants aged 3 to 4 years old only underwent testing for strabismus and blepharoptosis. Autorefraction and visual acuity testing and testing for strabismus and blepharoptosis were performed among the participants ranging in age from 5 to 18 years old. The participants over 19 years of age underwent full ocular examinations, including autorefraction and visual acuity testing, testing for strabismus and blepharoptosis, slit lamp examinations, measurement of intraocular pressure (IOP), and fundus photographs. IOP was measured with a Goldmann applanation tonometer. For participants meeting the glaucoma suspicion criteria, frequency doubling perimetry (FDT) was carried out. Phamacological pupil dilatation was performed for participants who had a history of diabetes mellitus or random blood glucose level of 200 mg/dL or higher and/or fundus photograph suspected di-

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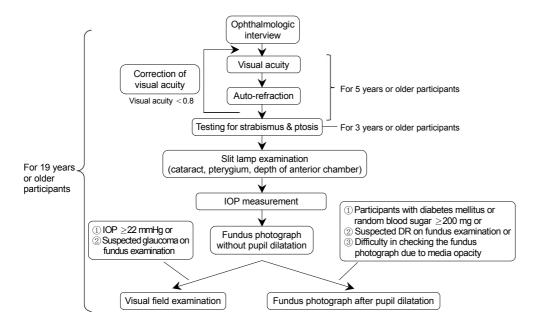
Fig. 1. Ophthalmologic examination flowchart for Korea National Health and Nutrition Examination Surveys. IOP = intraocular pressure; DR = diabetic retinopathy.

abetic retinopathy and/or difficulty obtaining a fundus photograph due to media opacity (Fig. 1). All procedures described above except for fundus photography were performed before pupil dilatation.

Examination methods and definition of eye diseases

1) Questionnaire

A detailed interviewer-administered questionnaire was administered for collection of relevant sociodemographic and medical information. Collected data included marital status, education, occupation, current housing status, lifestyle factors (including cigarette smoking history), optical symptoms, systemic medical and surgical history, and family history of eye diseases.

2) Visual acuity

Uncorrected visual acuity and/or best-corrected distance visual acuity (BCVA) were measured at a distance of 4 m using an international standard vision chart based on the LogMAR Scale (Jin's vision chart, Seoul, Korea) [36]. Visual impairment was defined as a BCVA of 0.32 or worse in the best eye. Blindness was defined as BCVA of 0.02 or worse in the right or left eye.

3) Autorefraction

An autorefractor-keratometer (KR8800; Topcon, Tokyo, Japan) was used for all measurement of refraction, which were converted to spherical equivalents calculated as the spherical value plus half of the astigmatic value. Myopia was defined as an spherical equivalents of worse than -0.75 diopters (D). Hyperopia was defined as spherical equivalents of worse than +1.0 D. Astigmatism was defined as a cylindrical error worse than +0.75 D.

4) Strabismus

Testing for strabismus included the cover-uncover test, prism and alternate cover test, and/or Krimsky test. Strabismus was defined as a manifest or latent ocular deviation at distance or near fixation with or without spectacle correction, esodeviation of 10 or more prism diopters, exodeviation of 15 or more prism diopters, or any vertical deviation.

5) Blepharoptosis

Blepharoptosis was defined as presentation of a marginal reflex distance (MRD_1) of 2 mm or less. Measurement of MRD_1 was performed as follows: Positioned at the physician's eye level, participants were asked to look straight ahead and relax while focusing at a distance target. Shining the penlight into the participant's eye, the distance from the corneal light reflex to the upper eyelid margin was measured in millimeters.

6) Slit lamp examination

A structured slit-lamp examination (Haag-Streit model BQ-900; Haag-Streit AG, Koeniz, Switzerland) was performed by study ophthalmologists. The slit lamp examination was performed for determination of diseases in the anterior segment of the eye (e.g., pterygium and cataract) and measurement of the IOP and anterior chamber depth using the Van Herick method [37]. Cataract was defined as a nuclear, cortical, or posterior subcapsular cataract in at least one eye. Pseudophakic and aphakic eyes were included as operated cataracts for the purpose of statistical analysis. A pterygium was defined as a radially oriented fibrovascular lesion crossing over the nasal or temporal limbus. Grading was based on the visibility of the underlying episcleral blood vessels [38].

7) Fundus photography

A digital nonmydriatic fundus camera (TRC-NW6S, Topcon) and a Nikon D-80 digital camera (Nikon, Tokyo, Japan) were used to obtain the digital fundus images. Digital images were captured from all participants 19 years of age and older under physiological mydriasis. For each participant, one 45° nonmydriatic digital retinal image centered on the fovea (field 2) was taken per eye (2 images per person in total). Each image was graded twice (a preliminary grade and a detailed grade) using the grading protocol of the International Age-related Maculopathy Epidemiological Study Group [39]. Optic nerve configuration and any retinal pathologic findings were recorded. Patients were defined as having early AMD if they met any one of the following criteria: (1) the presence of soft indistinct drusen or reticular drusen, or (2) the presence of hard or soft distinct drusen with pigmentary abnormalities (increased pigmentation or hypopigmentation of the retinal pigment epithelium) in the absence of signs of late AMD. Late AMD included the presence of signs of wet AMD or geographic atrophy. Wet AMD was defined as retinal pigment epithelial detachment or serous detachment of the sensory retina, subretinal or sub-RPE hemorrhages, and subretinal fibrous scars. Geographic atrophy was defined as a circular discrete area (of 175 microns in diameter) of retinal depigmentation with visible choroidal vessels, in the absence of signs of wet AMD.

In participants who had a history of diabetes mellitus or random blood glucose level of 200 mg/dL or higher and/or suspicion of diabetic retinopathy in nonmydriatic fudndus photography, 7 standard photographs from the Early Treatment for Diabetic Retinopathy Study were obtained from each eye after pharmacological pupil dilatation [40,41]. Diabetic retinopathy was defined as the presence of 1 or more retinal microaneurysms or retinal blot hemorrhages with or without more severe lesions (hard exudates, soft exudates, intraretinal microvascular abnormalities, venous bleeding, new retinal vessels, and fibroproliferations) [42,43]. The prevalence of diabetic retinopathy was estimated in persons with diabetes mellitus.

8) Visual field test

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 mmHg or a glaucomatous optic disc. FDT testing was repeated once if deemed unreliable. Patients were defined as having primary open angle glaucoma (POAG) if they met any one of the following category I or category II diagnostic criteria [44].

9) Category I diagnosis

The presence of FDT testing results, fixation error and false positive error $\leq$1: (1) elevated IOP $\geq$22 mmHg or (2) glaucomatous optic disc (loss of neuroretinal rim with vertical or horizontal cup-disc ratio $\geq$0.6 or presence of optic disc hemorrhage or presence of retinal nerve fiber layer defect or asymmetry of vertical cup-disc ratio $\geq$0.2), (3) the presence of an abnormal FDT testing result (at least one location of reduced sensitivity) and (4) the presence of an open angle (peripheral anterior chamber depth >1/4 corneal thickness)

10) Category II diagnosis

Absence of FDT testing results or fixation error or false positive error $\geq$2, (1) the presence of an open angle (peripheral anterior chamber depth >1/4 corneal thickness) and (2) loss of neuroretinal rim with vertical cup-disc ratio $\geq$0.9, (3) asymmetry of vertical cup-disc ratio $\geq$0.3 or (4) the presence of retinal nerve fiber layer defect and violation of the ISNT rule.

Normal tension glaucoma (NTG) was defined using the same criteria for POAG with IOP $\leq$21 mmHg. Primary angle closure glaucoma (PACG) was diagnosed when all of the following four criteria were met: (1) the presence of a narrow, occludable angle (peripheral anterior chamber depth <1/4 corneal thickness), (2) elevated IOP $\geq$22 mmHg, (3) glaucomatous optic disc (loss of neuroretinal rim with vertical or horizontal cup-disc ratio $\geq$0.6 or the presence of optic disc hemorrhage or retinal nerve fiber layer defect), and (4) the presence of an abnormal FDT testing result (at least one location of reduced sensitivity) and fixation error, false positive error $\leq$1.

Quality control and data analysis

A total of 308 surveys were conducted by four survey teams within a time span of 77 weeks. Each survey team included one ophthalmologist, one otolaryngologist, one dentist, three nurses, two interviewers, and one coordinator. The team moved with a mobile examination unit to pre-assigned locations and performed surveys for three days. A total of 199 ophthalmology residents or ophthalmologists from 66 training hospitals participated in this project as ophthalmologic examiners.

The quality of the survey was verified by the Epidemiologic Survey Committee of the Korean Ophthalmologic Society. Training of participating residents was periodically performed by acting staff members of the National Epidemiologic Survey Committee of the Korean Ophthalmologic Society. Data were collected using a combination of paper and digital formats. Imaging data, including fundus photographs, were retrieved directly from the imaging equipment and stored in their respective computers. All variables of interest were entered into a password-protected Microsoft Office Access database by a data entry clerk. For all digital information, original data were copied into external hard disks daily and written onto DVDs for storage.

Statistical analyses were performed using SAS ver. 9.2 (SAS Institute, Cary, NC, USA). All estimates were obtained using the sample weight adjusted for oversampling, nonresponse and the Korean population in 2008 to 2009, and standard errors of estimates were estimated accounting for the complex design of the survey. Prevalence estimates for all outcomes were performed for the overall sample and then

in age- and gender-stratified groups. Chi-square tests were used for analysis of differences in prevalence between genders. Logistic regression was used for analysis of differences in prevalence among age groups.

Results

During the period from July 2008 to December 2009, a total of 14,606 participants from 5,986 households were recruited and underwent an eye examination. Ages of the study participants ranged from 3 to 95 years of age: 6,580 were men and 8,026 were women. Table 1 shows the age and gender distributions of the study population.

Visual impairment and blindness

The overall prevalence of visual impairment was $0.4 \pm 0.1\%$ ($0.3 \pm 0.1\%$ in males, $0.5 \pm 0.1\%$ in females) (Table 2), while that in participants over 40 years of age was $0.9 \pm 0.1\%$ ($0.6 \pm 0.1\%$ in males, $1.1 \pm 0.2\%$ in females) and was higher in females than males ($p = 0.04$). The prevalence of visual impairment in participants over 70 years of age was $3.8 \pm 0.7\%$ ($2.9 \pm 0.8\%$ in males, $4.4 \pm 0.9\%$ in females) and showed a significant increase with age ($p < 0.01$). The prevalence of blindness in either eye of participants over 65 years of age was $0.2 \pm 0.1\%$ ($0.3 \pm 0.2\%$ in males, $0.1 \pm 0.1\%$ in fe-

males), and there were no statistically significant differences in relation to gender ($p > 0.05$).

Refractive errors

The overall prevalence of myopia was $53.7 \pm 0.6\%$ ($54.3 \pm 0.8\%$ in males, $53.1 \pm 0.7\%$ in females) (Table 3). The prevalence of myopia in the group of participants ranging in age from 12 to 18 was $78.8 \pm 1.3\%$ ($77.9 \pm 1.7\%$ in males, $79.9 \pm 1.7\%$ in females) and was highest among the age groups ($p < 0.01$). The prevalence of myopia was higher in females than in males in the 19 to 29 and over 70 years age groups ($p < 0.05$ for both).

The overall prevalence of hyperopia was $10.7 \pm 0.4\%$ ($9.4 \pm 0.4\%$ in males, $12.0 \pm 0.5\%$ in females) (Table 3). In the group of participants ranging in age from 5 to 11, the prevalence of hyperopia was $5.3 \pm 0.6\%$ and then decreased with age. From the group of participants ranging in age from 40 to 49, the prevalence of hyperopia again increased with age. The prevalence of hyperopia in the group of participants ranging in age from 60 to 69 and in the age group over 70 years was $43.8 \pm 1.4\%$ and $47.1 \pm 1.5\%$, respectively. In all age groups, there was no statistically significant difference in relation to gender ($p > 0.05$).

The overall prevalence of astigmatism was $58.0 \pm 0.6\%$ ($57.6 \pm 0.8\%$ in males, $58.4 \pm 0.7\%$ in females) (Table 3), while that in the 70 years or older age group was $92.0 \pm 0.8\%$ ($92.9 \pm 1.2\%$ in males, $91.5 \pm 1.1\%$ in females), illustrating a significant increase with age ($p < 0.01$). In the group of participants ranging in age from 30 to 39, the prevalence of astigmatism was higher in males than in females ($p < 0.01$).

Strabismus

The overall prevalence of strabismus was $1.5 \pm 0.1\%$ ($1.5 \pm 0.2\%$ in males, $1.5 \pm 0.2\%$ in females) (Table 4). The prevalence of strabismus in participants over 40 years of age was $1.4 \pm 0.2\%$ ($1.5 \pm 0.2\%$ in males, $1.2 \pm 0.2\%$ in females). In the group of participants ranging in age from 3 to 5 years, the prevalence of strabismus was $1.8 \pm 0.7\%$ ($0.5 \pm 0.4\%$ in

Table 1. Number of participants according to age and gender

Age group (yr)	Male	Female	Total
3-4	203	174	377
5-18	1,608	1,458	3,066
19-29	692	869	1,561
30-39	905	1,254	2,159
40-49	954	1,265	2,219
50-59	804	1,062	1,866
60-69	784	1,023	1,807
≥70	630	921	1,551
Total	6,580	8,026	14,606

Table 2. Prevalence of visual impairment according to age and gender

Age group (yr)	Total			Male			Female			p-value
	No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE	
Total	13,702	0.4	(0.1)	6,171	0.3	(0.1)	7,531	0.5	(0.1)	
5-18	2,993	0.0	(-)	1,571	0.0	(-)	1,422	0.0	(-)	
19-29	1,530	0.0	(-)	679	0.0	(-)	851	0.0	(0.1)	
30-39	2,117	0.2	(0.1)	88	0.3	(0.2)	1,230	0.1	(0.1)	0.08
40-49	2,178	0.1	(0.1)	936	0.2	(0.1)	1,242	0.0	(-)	
50-59	1,824	0.3	(0.2)	790	0.3	(0.2)	1,034	0.4	(0.2)	0.82
60-69	1,717	1.2	(0.3)	746	0.9	(0.3)	971	1.5	(0.4)	0.18
≥70	1,343	3.8	(0.7)	562	2.9	(0.8)	781	4.4	(0.9)	0.17

Visual impairment was defined as a best-corrected distance visual acuity of 0.32 or worse in the best eye.
No = number of participants; Prev = prevalence; SE = standard error.

Table 3. Prevalence of refractive errors according to age

Age group (yr)	Myopia			Hyperopia			Astigmatism		
	No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE
Total	13,636	53.7	(0.6)	13,636	10.7	(0.4)	13,636	58.0	(0.6)
5-11	1,560	50.0	(1.5)	1,560	5.3	(0.6)	1,560	38.7	(1.4)
12-18	1,429	78.8	(1.3)	1,429	2.5	(0.4)	1,429	61.6	(1.6)
19-29	1,529	75.3	(1.2)	1,529	1.9	(0.4)	1,529	53.9	(1.4)
30-39	2,091	67.4	(1.2)	2,091	1.1	(0.3)	2,091	49.5	(1.3)
40-49	2,147	51.1	(1.3)	2,147	3.1	(0.4)	2,147	51.8	(1.4)
50-59	1,786	29.3	(1.3)	1,786	16.5	(1.0)	1,786	63.0	(1.3)
60-69	1,702	18.2	(1.1)	1,702	43.8	(1.5)	1,702	79.4	(1.1)
≥70	1,392	28.4	(1.2)	1,392	47.1	(1.5)	1,392	92.0	(0.8)

Myopia was defined as spherical equivalents of worse than -0.75 diopter. Hyperopia was defined defined as spherical equivalents of worse than +1.0 diopter. Astigmatism was defined as a cylindrical error worse than +0.75 diopter.
No = number of participants; Prev = prevalence; SE = standard error.

Table 4. Prevalence of strabismus according to age and gender

Age group (yr)	Total			Male			Female			*p*-value
	No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE	
Total	14,464	1.5	(0.1)	6,517	1.5	(0.2)	7,947	1.5	(0.2)	0.93
3-5	583	1.8	(0.7)	314	0.5	(0.4)	269	3.4	(1.4)	0.01
6-11	1,385	1.8	(0.3)	725	1.7	(0.4)	660	1.9	(0.6)	0.75
12-18	1,448	1.9	(0.4)	756	1.7	(0.6)	692	2.1	(0.5)	0.65
19-29	1,543	1.5	(0.4)	687	1.1	(0.4)	856	2.0	(0.6)	0.18
30-39	2,138	1.7	(0.3)	898	2.1	(0.5)	1,240	1.2	(0.3)	0.09
40-49	2,197	1.0	(0.2)	942	1.0	(0.3)	1,255	0.9	(0.3)	0.86
50-59	1,852	1.4	(0.3)	797	1.5	(0.4)	1,055	1.3	(0.4)	0.68
60-69	1,787	1.6	(0.3)	776	2.2	(0.5)	1,011	1.1	(0.4)	0.07
≥70	1,531	1.9	(0.5)	622	2.2	(0.7)	909	1.8	(0.6)	0.69

Strabismus was defined as a heterotropia at distance and/or near fixation with or without spectacle correction, esodeviation of 10 or more prism diopters, exodeviation of 15 or more prism diopters, or any vertical deviation.
No = number of participants; Prev = prevalence; SE = standard error.

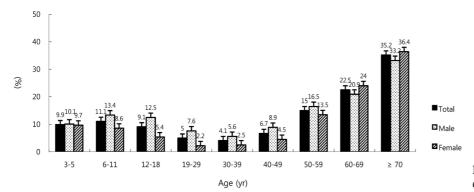**Table 5.** Prevalence of blepharoptosis according to age and gender

Age group (yr)	Total			Male			Female			*p*-value
	No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE	
Total	14,489	11.0	(0.8)	6,530	12.1	(0.9)	7,959	10.0	(0.8)	<0.01
3-5	580	9.9	(1.6)	313	10.1	(2.1)	267	9.7	(2.3)	0.01
6-11	1,387	11.1	(1.6)	726	13.4	(2.0)	661	8.6	(1.5)	<0.01
12-18	1,451	9.1	(1.2)	757	12.5	(1.7)	694	5.4	(0.9)	<0.01
19-29	1,546	5.0	(0.9)	687	7.6	(1.4)	859	2.2	(0.7)	<0.01
30-39	2,141	4.1	(0.7)	899	5.6	(1.0)	1,242	2.5	(0.5)	<0.01
40-49	2,203	6.7	(0.9)	946	8.9	(1.3)	1,257	4.5	(0.8)	<0.01
50-59	1,853	15.0	(1.5)	798	16.5	(1.7)	1,055	13.5	(1.9)	0.16
60-69	1,791	22.5	(1.7)	778	20.9	(2.0)	1,013	24.0	(1.9)	0.16
≥70	1,537	35.2	(2.3)	626	33.2	(2.8)	911	36.4	(2.6)	0.26

Blepharoptosis was defined as a marginal reflex distance 1 of 2 mm or less.
No = number of participants; Prev = prevalence; SE = standard error.

males, 3.4 ± 1.4% in females), and it was higher in females than in males ($p < 0.01$). There were no significant differences in relation to age ($p > 0.05$). The overall prevalence of esodeviation, exodeviation and vertical deviation was 0.2 ± 0.0%, 1.1 ± 0.1% and 0.3 ± 0.0%, respectively.

Blepharoptosis

The overall prevalence of blepharoptosis was 11.0 ± 0.8% (12.1 ± 0.9% in males, 10.0 ± 0.8% in females) (Table 5 and Fig. 2). The prevalence of blepharoptosis in participants over
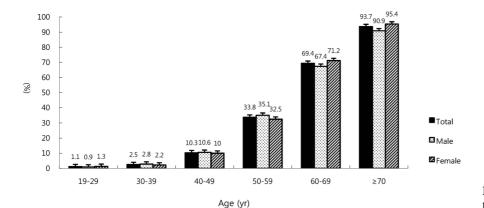
Fig. 2. Prevalence of blepharoptosis according to age and gender.

Table 6. Prevalence of cataract according to age and gender

Age group (yr)	Total			Male			Female			p-value
	No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE	
Total	11,037	24.1	(0.9)	4,718	21.9	(1.0)	6,319	26.2	(1.0)	<0.01
19-29	1,542	1.1	(0.3)	685	0.9	(0.4)	857	1.3	(0.5)	0.49
30-39	2,137	2.5	(0.4)	898	2.8	(0.7)	1,239	2.2	(0.4)	0.34
40-49	2,198	10.3	(1.1)	943	10.6	(1.3)	1,255	10.0	(1.3)	0.66
50-59	1,850	33.8	(2.0)	797	35.1	(2.7)	1,053	32.5	(2.2)	0.31
60-69	1,785	69.4	(2.1)	774	67.4	(2.7)	1,011	71.2	(2.2)	0.12
≥70	1,525	93.7	(0.8)	621	90.9	(1.6)	904	95.4	(0.8)	<0.01

Any cataract in at least one eye: pseudophakic and aphakic eyes were also included as cataract.
No = number of participants; Prev = prevalence; SE = standard error.

Fig. 3. Prevalence of cataract according to age and gender.

40 years of age was 16.2 ± 1.1%. From the age of 40, the prevalence of blepharoptosis was increased with age, and it was highest in the age group over 70 years (35.2 ± 2.3%, *p* < 0.01). The prevalence of blepharoptosis was higher in males than in females in participants from 6 to 49 years of age (*p* < 0.05).

Cataract

The prevalence of cataract in participants over 19 years of age was 24.1 ± 0.9% (21.9 ± 1.0% in males, 26.2 ± 1.0% in females) (Table 6 and Fig. 3), that in participants over 40 years of age was 40.2 ± 1.3% (37.5 ± 1.5% in males, 42.6 ± 1.3% in females), and that in participants over 60 years of age

was 80.5 ± 1.3% (76.9 ± 1.8% in males, 83.2 ± 1.3% in females). These results indicate that prevalence of cataract tended to increase with age (*p* < 0.01). The prevalence of cataract in participants over 40 years of age was higher in females than in males (*p* < 0.01).
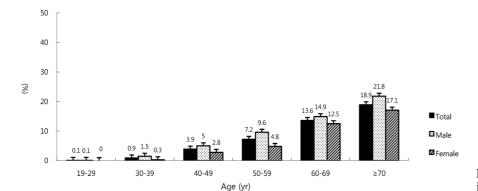
Pterygium

The prevalence of pterygium in participants over 19 years of age was 5.4 ± 0.3% (6.1 ± 0.5% in males, 4.7 ± 0.3% in females) (Table 7 and Fig. 4). The prevalence of pterygium in participants over 40 years of age was 8.9 ± 0.5% (10.1 ± 0.8% in males, 7.7 ± 0.5% in females), while that in participants over 60 years of age was 16.0 ± 0.8% (17.7 ± 1.3% in

Table 7. Prevalence of pterygium according to age and gender

Age group (yr)	Total			Male			Female			p-value
	No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE	
Total	11,014	5.4	(0.3)	4,716	6.1	(0.5)	6,298	4.7	(0.3)	<0.01
19-29	1,543	0.1	(0.1)	685	0.1	(0.1)	858	0.0	(0.0)	-
30-39	2,130	0.9	(0.2)	896	1.5	(0.4)	1,234	0.3	(0.1)	<0.01
40-49	2,192	3.9	(0.6)	943	5.0	(0.9)	1,249	2.8	(0.6)	0.03
50-59	1,845	7.2	(0.9)	797	9.6	(1.5)	1,048	4.8	(0.7)	<0.01
60-69	1,780	13.6	(1.0)	773	14.9	(1.6)	1,007	12.5	(1.4)	0.07
≥70	1,524	18.9	(1.3)	622	21.8	(2.2)	902	17.1	(1.5)	0.07

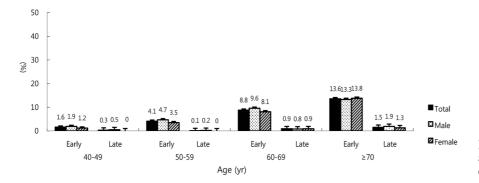No = number of participants; Prev = prevalence; SE = standard error.

Fig. 4. Prevalence of pterygium according to age and gender.

Table 8. Prevalence of age-related macular degeneration according to age and gender

Age group (yr)	Early AMD										Late AMD									
	Total			Male			Female			p-value	Total			Male			Female			p-value
	No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE		No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE	
Total	6,453	5.1	(0.3)	2,737	5.2	(0.5)	3,716	5.0	(0.4)	0.76	6,453	0.5	(0.1)	2,737	0.6	(0.2)	3,716	0.4	(0.1)	0.19
40-49	2,071	1.6	(0.3)	885	1.9	(0.5)	1,186	1.2	(0.4)	0.23	2,071	0.3	(0.1)	885	0.5	(0.3)	1,186	0.0	(-)	-
50-59	1,706	4.1	(0.5)	737	4.7	(0.9)	969	3.5	(0.6)	0.31	1,706	0.1	(0.1)	737	0.2	(0.2)	969	0.0	(-)	0.14
60-69	1,527	8.8	(0.9)	660	9.6	(1.4)	867	8.1	(1.1)	0.42	1,527	0.9	(0.3)	660	0.8	(0.3)	867	0.9	(0.5)	0.84
≥70	1,149	13.6	(1.2)	455	13.3	(1.8)	694	13.8	(1.5)	0.82	1,149	1.5	(0.4)	455	1.9	(0.7)	694	1.3	(0.4)	0.38

Patients were defined as having early AMD if they met any one of the following criteria: 1) the presence of soft indistinct drusen or reticular drusen or, 2) the presence of hard or soft distinct drusen with pigmentary abnormalities (increased pigmentation or hypopigmentation of the retinal pigment epithelium) in the absence of signs of late AMD.
AMD = age-relaged macular degeneration; No. = numberof participants; Prev = prevalence; SE = standard error.

Fig. 5. Prevalence of early and late age-related macular degeneration according to age and gender.

males, 14.8 ± 1.1% in females). The prevalence of pterygium increased with age ($p < 0.01$). The prevalence of pterygium in participants over 40 years of age was higher in males than females ($p < 0.01$).

Age-related macular degeneration

The overall prevalence of early AMD over 40 years of age was $5.1 \pm 0.3\%$ ($5.2 \pm 0.5\%$ in males, $5.0 \pm 0.4\%$ in females) (Table 8 and Fig. 5). The prevalence of early AMD in participants over 60 years of age was $10.9 \pm 0.7\%$ ($10.9 \pm 1.2\%$ in males, $10.8 \pm 0.9\%$ in females). The overall prevalence of late AMD over 40 years of age was $0.5 \pm 0.1\%$ ($0.6 \pm 0.2\%$ in males, $0.4 \pm 0.1\%$ in females). The prevalence of late AMD in participants over 60 years of age was $1.1 \pm 0.2\%$ ($1.2 \pm 0.3\%$ in males, $1.1 \pm 0.3\%$ in females). The prevalence of AMD increased with age ($p < 0.01$). There were no statistically significant differences in relation to gender ($p > 0.05$).

Diabetic retinopathy

The prevalence of diabetic retinopathy in participants over 19 years of age was $13.4 \pm 1.5\%$ ($12.0 \pm 1.9\%$ in males, $15.1 \pm 2.2\%$ in females) (Table 9 and Fig. 6). The prevalence of diabetic retinopathy in participants over 40 years of age was $13.4 \pm 1.5\%$ ($12.6 \pm 2.0\%$ in males, $14.3 \pm 2.3\%$ in females) (Table 9). The prevalence of diabetic retinopathy in participants over 65 years of age was $13.1 \pm 2.4\%$ ($11.0 \pm 3.0\%$ in males, $14.5 \pm 3.4\%$ in females). There were no statistically significant differences in the prevalence of diabetic retinopathy in relation to age or gender ($p > 0.05$).

Glaucoma

The prevalence of glaucoma in participants over 19 years of age was $1.4 \pm 0.1\%$ ($1.6 \pm 0.2\%$ in males, $1.1 \pm 0.2\%$ in females) (Table 10 and Fig. 7) and was higher in males than in females ($p < 0.05$). The prevalence of glaucoma in participants over 40 years of age was $2.1 \pm 0.2\%$ ($2.5 \pm 0.3\%$ in males, $1.7 \pm 0.2\%$ in females). The prevalence of glaucoma in participants over 60 years of age was $3.3 \pm 0.4\%$ ($3.7 \pm 0.6\%$ in males, $3.0 \pm 0.5\%$ in females). In participants over 40 years of age, the prevalence of POAG, PACG and NTG was $2.0 \pm 0.2\%$, $0.1 \pm 0.1\%$ and $1.9 \pm 0.2\%$, respectively. The prevalence of glaucoma increased with age ($p < 0.01$). The prevalence of glaucoma was higher in males than in females in participants aged 30 to 49 ($p < 0.05$).
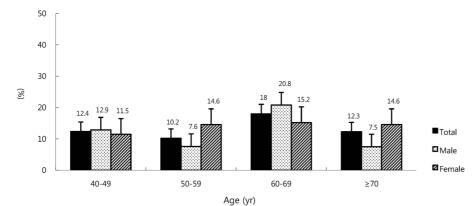
Discussion

In the past two decades, several epidemiologic studies have reported on the prevalence of common eye diseases in many countries [2-35,42,43,45-65]. Most of these population-based studies have been conducted in the United States among predominantly White, mixed White and African-American, or Hispanic populations [5-14] or in other countries, including Europe [15-17] and Australia [18-21]. There are a growing number of new population-based studies in Asia, including

Table 9. Prevalence of diabetic retinopathy in persons with diabetes mellitus according to age and gender

Age group (yr)	Total			Male			Female			p-value
	No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE	
Total	746	13.4	(1.5)	352	12.0	(1.9)	394	15.1	(2.2)	0.27
19-29	8	-	-	3	-	-	5	-	-	
30-39	33	-	-	14	-	-	19	-	-	
40-49	100	12.4	(3.6)	59	12.9	(5.0)	41	11.5	(5.1)	0.85
50-59	160	10.2	(2.6)	83	7.6	(2.8)	77	14.6	(5.2)	0.21
60-69	269	18.0	(2.8)	127	20.8	(4.2)	142	15.2	(3.2)	0.26
≥70	176	12.3	(3.1)	66	7.5	(3.6)	110	14.6	(4.3)	0.23

Diabetic retinopathy was defined as the presence of 1 or more retinal microaneurysm or retinal blot hemorrhages with or without more severe lesions (hard exudates, soft exudates, intraretinal microvascular abnormalities, venous bleeding, retinal new vessels, and fibroproliferations). No = number of participants; Prev = prevalence; SE = standard error.
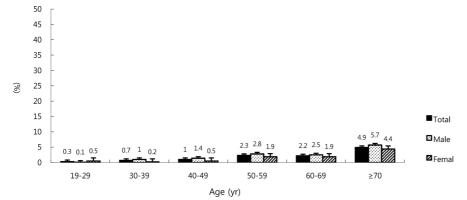

Fig. 6. Prevalence of diabetic retinopathy in persons with diabetes mellitus according to age and gender.

Table 10. Prevalence of glaucoma according to age and gender

Age group (yr)	Total			Male			Female			*p*-value
	No	Prev (%)	SE	No	Prev (%)	SE	No	Prev (%)	SE	
Total	10,035	1.4	(0.1)	4,284	1.6	(0.2)	5,751	1.1	(0.2)	<0.05
19-29	1,457	0.3	(0.1)	646	0.1	(0.1)	811	0.5	(0.3)	0.22
30-39	2,017	0.7	(0.2)	848	1.0	(0.4)	1,169	0.2	(0.1)	<0.01
40-49	2,095	1.0	(0.2)	898	1.4	(0.4)	1,197	0.5	(0.2)	<0.05
50-59	1,720	2.3	(0.4)	737	2.8	(0.7)	983	1.9	(0.5)	0.20
60-69	1,585	2.2	(0.4)	682	2.5	(0.7)	903	1.9	(0.5)	0.41
≥70	1,161	4.9	(0.7)	473	5.7	(1.2)	688	4.4	(0.9)	0.40

No = number of participants; Prev = prevalence; SE = standard error.

Fig. 7. Prevalence of glaucoma according to age and gender.

Japan [22-26,48,56], Singapore [27-30], China [31-35,46] and Taiwan [61,62]. However, even within a single Asian country, significant racial/ethnic variations may exist. The present study is the first investigating the prevalence of eye diseases in South Korea based on nationally representative data.

The 10th Revision of the World Health Organization International Statistical Classification of Diseases, Injuries and Causes of Death defines visual impairment as a BCVA less than 20 / 60 but 20 / 400 or better in the best eye, and blindness is defined as a BCVA of worse than 20 / 400 in the best eye. The United States criteria define visual impairment as a BCVA of less than 20 / 40 but better than 20 / 200, and blindness as a BCVA of 20 / 200 or worse. Using the United States standard, the prevalence of visual impairment was 0.97% to 2.34% in White Americans over 40 years of age [10] and 5.3% in African Americans over 65 years of age [8]. In a Japanese population of subjects over 40 years of age, the prevalence of visual impairment and blindness were 1.28% and 0.15%, respectively [25]. The prevalence of visual impairment and blindness in China was reported as 1.1 % and 0.3 %, respectively, in subjects over 40 years of age, according to the World Health Organization definition [31]. In our study, when we defined visual impairment and blindness as a BCVA of 0.32 or worse and 0.01 or worse, respectively, the prevalence of visual impairment and blindness in the subjects over 40 years of age was 0.9% and 0.1%, respectively, similar to the prevalence reported from China.

The prevalence of myopia has been reported as 25% in Western Europe [45], 26% in the United States [45], 38% among Chinese individuals [46], and 41% to 43 % in Japan [47,48]. In the present study, the prevalence of myopia in adult Koreans over 40 years of age was 35.7%, which was higher than those of Western Europe and United States and similar to those reported in China and Japan. Changes in the prevalence and value of refractive errors do occur with age starting in childhood [49]. Many studies have reported a decrease of the prevalence of myopia and a simultaneous increase in the prevalence of hyperopia with increasing age [50-52]. Results of our study were in agreement with those findings.

In this study, the overall prevalence of strabismus in the 3 to 5 and 6 to 11 year age groups was 1.8% in South Korea. The prevalence of strabismus has been reported as 2.3% in subjects 2 to 5 years of age in the United Kingdom [53], 3.1% in subjects 4 to 7 years of age in the United States [54], 2.7% in subjects under the age of 7 years in Sweden [55], and 1.3% in subjects 6 to 12 years of age in Japan [56]. There is a significant ethnic component influencing the distribution of strabismus: Studies in Asian populations have reported an esotropia to exotropia ratio of less than 1, while in European populations, the ratio was greater than 1 [53-56]. Our study demonstrated an esotropia to exotropia ratio of less than 1, similar to results from other Asian countries [56].

Blepharoptosis, drooping of the upper eyelid, is one of the most common upper eyelid diseases. Symptoms relate to im-

pairment of the superior visual field and central vision in severe cases. Even though blepharoptosis is generally known to exist below 4 to 5 mm of MRD_1 in Western populations, there are no accurate definitions and available data on the prevalence of blepharoptosis, particularly among Asians. Except for Nigeria, the prevalence of blepharoptosis has not been reported. In the Nigeria study, blepharoptosis was defined as the amount of the cornea covered by more than 2 mm by the upper eyelid, and the prevalence of blepharoptosis among school children under the age of 16 years was 1.2% [57]. There are no accurate diagnostic criteria about blepharoptosis for Asian or Korean populations. However, depending on race, there are many differences in facial anatomy. Therefore, we defined blepharoptosis as less than 2 mm of MRD_1 with consideration for anatomical differences of the eyelids and orbit. In our study, the prevalence of blepharoptosis in the 3 to 5, 6 to 11 and 12 to 18 age groups were 9.9%, 11.1% and 9.1%, respectively, higher than prevalences reported in Nigeria. One of the main objectives of this study is to estimate the prevalence of blepharoptosis in Koreans. In future studies, appropriate diagnostic criteria should be established for use in Korean people.

The prevalence of cataract has been reported as 22.3% in the United States [29], 40.4% in Myanmar [55] and 35.0% in China [28]. In the present study, the prevalence of cataract in adult Korean over 40 years of age was 40.2%. The prevalence of cataract was similar to those reported in Myanmar and China, where no statistically significant differences in prevalence were observed in relation to gender. However, in the United States and Korea, females showed a significantly higher prevalence of cataract than males.

Several population-based studies have examined the prevalence of pterygium and have indicated a prevalence ranging from 1.2% in a White population in urban Australia [21] to 33.0% in a Chinese population of subjects 50 years or older in Doumen County, Southern China [58]. In our study, the prevalence of pterygium in subjects over 40 years of age was 8.9%. Differences in prevalence of pterygium were observed among these studies. However, dominance in male gender and old age associated with formation of pterygium were similar to those observed in other studies.

Large-scale population-based studies have been conducted over the past two decades in order to identify the prevalence and risk factors of AMD [2,6,12,15-19,26,32,60]. Studies have demonstrated variations in the prevalence and risk factors of AMD. In the Blue Mountains Eye Study, the prevalence of early AMD was 8.7%, and the prevalence of late AMD was 1.1% [19]. In the Beijing Eye Study, the prevalence of early AMD and late AMD was 5.1% and 0.3%, respectively [32]. In addition, the prevalence of early AMD and late AMD was 3.5% and 0.5% in the Funagata Study [26]. In the present study, the prevalence of early AMD and late AMD was 5.1% and 0.5%, respectively. Our study showed a low prevalence of AMD compared to those in White populations. In addition, the prevalence of AMD in

our study was similar to those of Chinese and Japanese populations.

The prevalence of diabetic retinopathy in the United States was reported as 28.5% to 40.3% [13,14]. There are many population-based data on the prevalence of diabetic retinopathy in Asia [61-63]. In Taiwan, 35% of 527 diabetic subjects over 40 years of age had diabetic retinopathy based on clinical examination [61]. However, recent studies in India indicate a much lower prevalence of diabetic retinopathy [62,63]. In the present study, the prevalence of diabetic retinopathy (subjects over 40 years of age) was 13.4%, much lower than the prevalence reported in the United States or Taiwan. This relatively low prevalence of diabetic retinopathy may be due to a short duration of diabetes in our study population.

Glaucoma is believed to be the leading global cause of surgically irremediable blindness [64]. In the Baltimore Eye Survey, the prevalence of POAG was approximately four times higher in black people (4% to 5%) than in white people (1.1%) [65]. In recent years, several studies have been conducted on the epidemiology of glaucoma in Asian people [22-24,27,66]. The prevalence ranges of POAG and PACG have been reported as 1.6% to 3.9% and 0.4% to 1.0%, respectively. In this study, the prevalence of POAG and PACG was 2.0% and 0.1%. The prevalence of POAG was similar to those reported in other Asian countries [22-24,27,66]. In contrast, the prevalence of PACG was lower than those reported in other Asian countries [22-24,27,66]. Results of this study might have been underestimated as only the Van Herick method was used in the diagnosis of PACG.

Accurate epidemiological information may contribute to the proper delivery of health care, preventive screenings, and rehabilitative services to individuals with eye diseases. This study provides standardized protocols for examination of ocular diseases and improvement of ocular examination capacity through education and quality control. Databases containing results from examination of eye diseases and results of quality control can be utilized in future clinical studies. In addition, methodology used in this survey can be utilized as a guideline for use in new population-based studies which will be performed in the nation.

In summary, our nation-wide study demonstrated the prevalence of major eye diseases and potential ocular disease-vulnerable groups in Korea. To the best of our knowledge, this is the first nation-wide epidemiologic study conducted by both the Ophthalmologic Society and the CDC and is a powerful tool for use in investigation of the national prevalence of disease conditions. Further studies are needed using on-going surveys in order to better understand the etiologic or risk factors that may be associated with ophthalmologic diseases and to evaluate proper interventions aimed at prevention of disease-related disabilities.

Conflict of Interest

No potential conflict of interest relevant to this article was

reported.

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