KJO
pISSN: 1011-8942 eISSN: 2092-9382

Korean J Ophthalmol 2015;29(6):359-367
http://dx.doi.org/10.3341/kjo.2015.29.6.359

Special Article

An Overview of Ophthalmologic Survey Methodology in the 2008-2015 Korean National Health and Nutrition Examination Surveys

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The Korea National Health and Nutrition Examination Survey (KNHANES) is a national program designed to assess the health and nutritional status of the noninstitutionalized population of South Korea. The KNHANES was initiated in 1998 and has been conducted annually since 2007. Starting in the latter half of 2008, ophthalmologic examinations were included in the survey in order to investigate the prevalence and risk factors of common eye diseases such as visual impairment, refractive errors, strabismus, blepharoptosis, cataract, pterygium, diabetic retinopathy, age-related macular degeneration, glaucoma, dry eye disease, and color vision deficiency. The measurements included in the ophthalmic questionnaire and examination methods were modified in the KNHANES IV, V, and VI. In this article, we provide detailed information about the methodology of the ophthalmic examinations in KNHANES in order to aid in further investigations related to major eye diseases in South Korea.

Key Words: Epidemiology, Korea National Health and Nutrition Examination Survey, Methods, Ophthalmology

Received: October 5, 2015 *Accepted*: October 19, 2015

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Introduction

The Korea National Health and Nutrition Examination Survey (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 in the Ministry of Health and Welfare, to examine the health, physical, and nutritional status of the general population of South Korea. Since 2008, the first year of ophthalmic examinations, there have been several changes in the ophthalmic examination methodologies and questionnaires. Although many research articles about ocular disorders, including visual impairment [1-6], refractive errors [7-12], strabismus [1], blepharoptosis [13], cataract [14-18], pterygium [19], diabetic retinopathy (DR) [20-27], age-related macular degeneration (ARMD) [28-36], glaucoma [37-47], and dry eye disease (DED) [48-50] have been published based on the results of the KNHANES, there have not been any comprehensive overviews of the methodological changes. Therefore, in this article, we review the ophthalmic examination methodologies and their overall changes throughout the history of the KNHANES.

KNHANES Overview

The Korea Centers for Disease Control and Prevention conducted the KNHANES series (I, II, and III) in 1998, 2001, and 2005, respectively, to examine the general health and nutritional status of Koreans. Starting with the KNHANES IV (2007-2009), V (2010-2012), and VI (2013-2015), however, the survey became an annual project. The study methodology involved stratified multistage cluster-sampling to prevent subject omission or overlap. The rolling-sampling method ensured the representativeness of each annual survey of the overall Korean population, which allowed results to be merged between surveys. Specifically, the primary sample units (PSUs) were selected from a sampling frame of all census blocks or resident registration addresses. Each PSU consisted of approximately 50 to 60 households. Following PSU selection, all dwelling units in the PSU were listed, and 20 households were selected for household screening through field surveys. The final stage of selection occurred in the individual households, where all members older than one year of age were selected to participate. Approximately 10,000 individuals were sampled annually among all 192 PSUs. The target overall KNHANES response rate was 75% [51]. From July 2008, ophthalmologic interviews and examinations have been conducted. All examination and health interviews were conducted by trained teams in mobile centers that traveled to each survey location, while nutrition surveys were performed in individual households. These mobile centers provided a standardized environment and equipment. The Korea Centers for Disease Control and Prevention and the Korean Ophthalmological Society conducted team education and training programs twice yearly. The educational information included the overall purpose of epidemiological studies, cautions, machine operation, and diagnosis and classification of major eye disorders to be investigated. The quality of the ophthalmic survey was verified by the Epidemiologic Survey Committee of the Korean Ophthalmological Society. The ophthalmologists or ophthalmologic residents participating in this survey were required to complete a training course and undergo supervised practice before working in the actual survey field. In the KNHANES IV-V (2008-2012), a total of 37,982 (17,040 men and 20,942 women) participants were received an eye examinations.

Ophthalmic Examinations According to Age Group

Examination procedures were stratified according to age group. Participants aged three to four years underwent testing only for strabismus and blepharoptosis. Autorefraction, visual acuity (VA) measurement, and testing for strabismus and blepharoptosis were performed among participants ranging in age from five to 18 years. Participants aged 19 years or older underwent full ocular examinations, including autorefraction and VA measurement, testing for strabismus and blepharoptosis, slit lamp examinations, intraocular pressure (IOP) measurement, and fundus photography. IOP was measured with a Goldmann applanation tonometer. For participants meeting the glaucoma suspicion criteria, frequency doubling technology perimetry was carried out. Pharmacological pupil dilatation was performed for participants with a history of diabetes mellitus (DM) or random blood glucose level of 200 mg/dL or higher and/or fundus photographs suggestive of DR and/or difficulty obtaining fundus photographs due to media opacity (Fig. 1) [1]. All procedures described above except for fundus photography were performed before pupil dilatation.

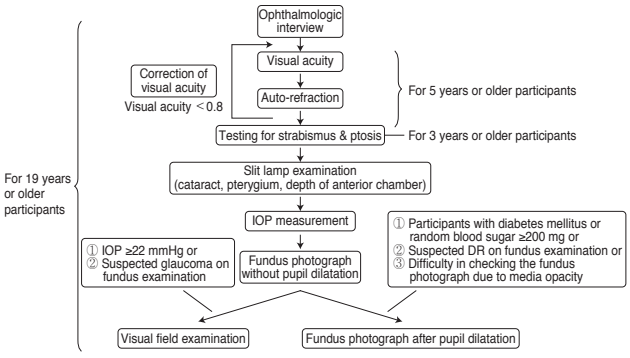

Fig. 1. Representative progression chart for the Korea National Health and Nutrition Examination Survey including ophthalmologic interview, visual acuity testing, slit lamp examination, IOP measurement, fundus photograph, and visual field examination. IOP = intraocular pressure; DR = diabetic retinopathy. From Yoon KC, et al. *Korean J Ophthalmol* 2011;25:421-33, according to the Creative Commons license [1].

Questionnaire and Ophthalmic Disease Examination Methods

Ophthalmic questionnaire

The ophthalmic questionnaires included history of ocular examinations; recent ocular examinations; family history of eye diseases; history of cold extremities and migraines; UV exposure time; ophthalmic surgery history; history of diagnosis by ophthalmologist including DED, cataract, ARMD, and glaucoma; symptoms of DED; current treatment for glaucoma; causes of visual impairment in cases of Snellen VA less than 0.32; near work duration; and parental history of myopia. The time points and age groups subjected to the questionnaire survey varied by year and are described in Table 1. Briefly, in KNHANES IV-V (2008-2012), ophthalmologic investigators queried participants about their history regarding ocular examination, cold extremities, migraines, and UV exposure time. The possible responses for UV exposure time included: "<5 hours" or "≥5 hours" in the KNHANES IV (2008-2009) and "<2 hours," "two-five hours," or "≥5 hours" in the KNHANES V (2010-2012). History of recent ocular examination and family history of eye disease were evaluated in KNHANES IV to VI (2008-2015), and history of ophthalmic surgery was investigated during KNHANES V-VI (2010-2015). In the KNHANES V (2010-2012), subjects were asked about a history of diagnosis of DED, cataract, ARMD, and glaucoma by ophthalmologists. To make data collection more accurate, subjects were also asked about symptoms they had experienced related to DED such as dryness, foreign body sensation, or burning and about the current status of medical treatment for glaucoma in the KNHANES V (2010-2012). In the cases of Snellen VA less than 0.32, interviews were conducted about the causes of visual impairment in the last year of KNHANES V (2012). Questions about near-work duration and parental history of myopia were added to the questionnaire in the KNHANES VI (2013-2015).

Ophthalmic disease examination methods

A list of all examination procedures according to age group and test period is shown in Table 2. Uncorrected VA and/or best-corrected distance VA were measured at a distance of 4 meters using an international standard vision chart based on the Snellen scale (Jin's vision chart, Seoul, Korea) [52]. Participant VA was measured in each eye, right side followed by left side. Each participant was asked to read numbers in the 0.2 line of the VA chart and to proceed to the next line if he or she correctly read at least three of the five letters. Participant VA was defined as the line with the smallest numbers in which the participant accurately read more than three characters. For those participants who presented with VA score lower than 0.8, corrected VA was measured using autorefraction. Automated refraction was performed using an autorefractive keratometer (KR8800; Topcon, Tokyo, Japan), followed by VA retesting using a pinhole in patients with Snellen VA lower than 0.8. Spherical equivalent refractive error was calculated as sphere +1 / 2 cylinder. These examinations were carried out throughout the KNHANES IV-VI (2008-2015).

Strabismus testing conducted from 2008 to 2011 included the cover-uncover test, prism and alternative 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.

Blepharoptosis was determined by measuring the marginal reflex distance 1 in the KNHANES IV and V (2010-2015). Participants were positioned at physician eye level and instructed to look straight ahead and relax while focusing on a distant target. After shining a penlight into the participant's eye, the distance from the corneal light reflex

Table 1. List of ophthalmologic questionnaires in KNHANES according to age group and test period

Questionnaire		Age (yr)		KNHANES IV		KNHANES V			KNHANES VI		
		IV-V	VI	2008	2009	2010	2011	2012	2013	2014	2015
History of ocular examination (visual acuity test)		≥2	-	○	○	○	○	○	-	-	-
History of recent ocular examination		≥12	19-49	○	○	○	○	○	○	○	○
Family history of eye diseases		≥12	19-49	○	○	○	○	○	○	○	○
History of cold extremities and migraine		≥12	-	○	○	○	○	○	-	-	-
Ultraviolet exposure time		≥19	-	○	○	○	○	○	-	-	-
History of ophthalmic surgery		≥19	19-49	-	-	○	○	○	○	○	○
Dry eye disease	Diagnosis by ophthalmologist	≥19	-	-	-	○	○	○	-	-	-
	Symptom experience	≥19	-	-	-	○	○	○	-	-	-
Cataract	Diagnosis by ophthalmologist	≥19	-	-	-	○	○	○	-	-	-
Age-related macular degeneration	Diagnosis by ophthalmologist	≥19	-	-	-	○	○	○	-	-	-
Glaucoma	Diagnosis by ophthalmologist	≥19	-	-	-	○	○	○	-	-	-
	Current treatment	≥19	-	-	-	○	○	○	-	-	-
Causes of visual impairment	Snellen visual acuity <0.32	≥19	-	-	-	-	-	○	-	-	-
Near-work duration	-	≥19	19-49	-	-	-	-	-	○	○	○
History of parental myopia	Father, mother, or both	≥19	19-49	-	-	-	-	-	○	○	○

KNHANES = the Korea National Health and Nutrition Examination Survey.

Table 2. List of examination methods and output indexes of prevalence of ophthalmic diseases in KNHANES according to age group and test period

Examination method	Prevalence	Age (yr)		KNHANES IV		KNHANES V			KNHANES VI		
		IV-V	VI	2008	2009	2010	2011	2012	2013	2014	2015
Visual acuity test	Visual impairment	≥5	19-49	○	○	○	○	○	○	○	○
Autorefractometer	Refractive errors	≥5	19-49	○	○	○	○	○	○	○	○
Strabismus test	Strabismus	≥3	-	○	○	○	○	-	-	-	-
Blepharoptosis test	Blepharoptosis	≥3	-	○	○	○	○	○	-	-	-
Slit lamp biomicroscopy	Cataract	≥19	-	○	○	○	○	○	-	-	-
	Pterygium	≥19	-	○	○	○	○	-	-	-	-
Fundus photography	Diabetic retinopathy	≥19	-	○	○	○	○	○*	-	-	-
	Age-related macular degeneration	≥19	-	○	○	○	○	○	-	-	-
Intraocular pressure, fundus examination, visual field test	Glaucoma	≥19	-	○	○	○	○	○†	-	-	-
Hardy-Rand-Rittler test	Color vision deficiency	-	19-49	-	-	-	-	-	○	○	○

KNHANES = the Korea National Health and Nutrition Examination Survey.
*Without pharmacological pupil dilation in every diabetes mellitus participants; †All participants aged 40 years or more.

to the upper eyelid margin was measured in millimeters. Differential diagnosis of blepharoptosis was made with particular attention to pseudoptosis associated with eyebrow ptosis and dermatochalasis. Blepharoptosis was de-

fined as a marginal reflex distance 1 of 2 mm or less.

Investigators also conducted structured slit-lamp examinations (Haag-Streit model BQ-900; Haag-Streit AG, Koeniz, Switzerland) to test for diseases in the anterior segment of the eye, such as pterygium (2008-2011) and cataract (2008-2012), and to measure the IOP (2008-2012) and anterior chamber depth using the Van Herick method (2008-2012) [53]. Standardized Lens Opacities Classification System (LOCS) III photographic images were used to assess cataracts. Cataract was defined as nuclear (LOCS III score ≥4 for nuclear opalescence or nuclear color), cortical (LOCS III score ≥2 for cortical cataracts), posterior subcapsular (LOCS III score ≥2 for posterior subcapsular), or mixed (more than one type per eye) based on comparison with these standard photographs [54]. Pseudophakic and aphakic eyes were also documented. Pterygium was defined as a radially-oriented fibrovascular lesion crossing the nasal or temporal limbus. Grading was based on the visibility of the underlying episcleral blood vessels [55]. IOP was measured once in each eye from the right side to left side by a trained ophthalmologist with a Goldmann applanation tonometer (Haag-Streit AG).

A digital nonmydriatic fundus camera (TRC-NW6S; Topcon) and Nikon D-80 digital camera (Nikon, Tokyo, Japan) were used to obtain digital fundus images throughout the KNHANES IV and V (2008-2012). Digital images were captured under physiological mydriasis in all participants 19 years of age or older. For each participant, one 45° nonmydriatic digital retinal image centered on the fovea was taken per eye (two images per person). Optic nerve configuration and any retinal pathologic findings were recorded. Patients were considered to have early ARMD if they demonstrated presence of soft indistinct drusen or reticular drusen or 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 ARMD. Late ARMD included the signs of wet ARMD or geographic atrophy. Wet ARMD was defined as retinal pigment epithelial detachment or serous detachment of the sensory retina, subretinal or sub-retinal pigment epithelium hemorrhages, and subretinal fibrous scars. Geographic atrophy was defined as a circular discrete area (175 microns in diameter or greater) of retinal depigmentation with visible choroidal vessels, in the absence of signs of wet ARMD [56]. In participants with a history of DM or random blood glucose level of 200 mg/dL or higher and/or suspicion of DR in nonmydriatic fundus photography findings, seven standard field photographs were obtained from each eye after pharmacological pupil dilatation, as per the Early Treatment for Diabetic Retinopathy Study protocol, throughout years 2008 to 2011 [57]. On the other hand, in the last year of the KNHANES V (2012), fundus photography was performed for every participant with DM without pharmacological pupil dilatation. DR was identified in the presence of any characteristic lesion determined by the Early Treatment for Diabetic Retinopathy Study severity scale: microaneurysms, hemorrhages, hard exudates, cotton wool spots, intraretinal microvascular abnormalities, venous beading, and retinal new vessels [58,59]. The prevalence of DR among individuals with DM was estimated. Each fundus image was graded twice. First, preliminary grading was conducted onsite by ophthalmologists or ophthalmologic residents trained by the Korean Ophthalmologic Society. Retinal specialists with expertise in DR grading and ARMD diagnosis then performed detailed final grading using protocols from the Early Treatment for Diabetic Retinopathy Study and International Age-related Maculopathy Epidemiological Study Group.

In the KNHANES IV-V (2008-2012), automated visual field testing (Humphrey Matrix frequency-doubling perimeter; Carl Zeiss Meditec Inc., Dublin, CA, USA) with the N-30-1 screening program was performed on participants with any of the following five conditions: (1) elevated IOP (≥22 mmHg), (2) horizontal or vertical cup-to-disc ratio ≥0.5, (3) presence of optic disc hemorrhage, (4) presence of retinal nerve fiber layer defect, or (5) violation of the inferior-superior-nasal-temporal rule. Frequency doubling technology was repeated once if the initial results were deemed unreliable. Patients were considered to have primary open angle glaucoma if they met any one of the category I or II diagnostic criteria previously described [60]. In 2012, however, frequency doubling technology perimetry was conducted for all participants aged 40 years or older, regardless of glaucoma suspicion.

The Hardy-Rand-Rittler pseudoisochromatic color vision test was performed throughout the KNHANES VI (2013-2015) [61]. There were six screening plates, four for protan-deutan deficiencies and two for tritan deficiencies. If all six boxes showed correct responses, the patient had normal color vision, and no more testing was conducted. If the fifth or sixth plates were not noted, the patient was

considered to have defective blue-yellow vision, and the examiner proceeded to show plates 21 to 24. If any of the boxes corresponding to plates 7 to 10 were not noted, the patient had defective red-green vision, and the examiner proceeded to show plates 11 to 20. After testing was complete, the total numbers in each column were summed in the spaces under the responses for plates 20 and 24. Participants were diagnosed as protan or deutan if the total numbers of marks in the protan or deutan columns, respectively, was greater than that in the opposite column. In cases of blue-yellow deficiency, participants were diagnosed as tritan or tetartan if the number of errors in the tritan or tetartan columns, respectively, was greater than that in the other column. Participants were diagnosed as having unclassified red-green or blue-yellow defects if the number of marks were the same in the protan and deutan or tritan and tetartan columns or if errors were made only in the screening plates. Color vision deficiency was graded as mild, medium, or strong, depending on whether the participants saw the symbols on the more saturated plates. There were 10 grading plates for protan/deutan defects: patients who made one or more errors in the two plates with the most saturated colors were graded as severe, and those who made an error in the next three most saturated plates were graded as medium. Those who made errors only in the five least-saturated plates were graded as mild. Similar interpretation was performed in the case of blue-yellow deficiency (Fig. 2).

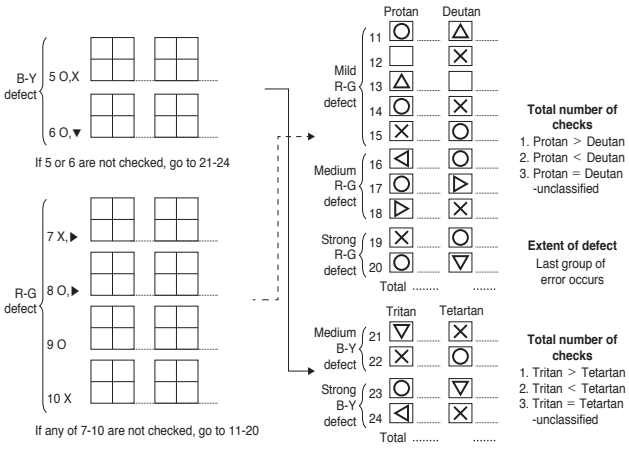

Fig. 2. Diagnostic flow diagram showing use of Hardy-Rand-Rittler pseudoisochromatic plates to detect, classify, and estimate the degree of defective color vision.

Conclusion

The KNHANES survey provides objective, standardized data on the prevalence of a wide range of diseases including major ophthalmic disorders, comorbidity, and risk factors in the noninstitutionalized population in Korea. The KNHANES data can be used to establish, develop, monitor, and evaluate national health programs and policies for eye diseases. However, because the survey components and methods varied partly by year, data users should be aware of changes in the detailed survey methods and questionnaires of concerned variables. The present report highlights the ophthalmologic methodology and the detailed changes in questionnaires and examination procedures according to survey periods of KNHANES (2008-2015). Therefore, this article can be used as a useful reference in various types of research using KNHANES data in order to assess the prevalence and risk factors of ophthalmologic disorders.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgements

The authors thank the Korea Centers for Disease Control and Prevention, which performed the KNHANES.

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