Visual phenotyping analysis of Korean wild mouse KWM/Hym

Munkhdelger Jamiyansharav

Department of Medicine

The Graduate School, Yonsei University

Visual phenotyping analysis of Korean wild mouse KWM/Hym

Directed by Professor Kyoung Yul Seo

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Munkhdelger Jamiyansharav

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This certifies that the Master's Thesis
of Munkhdelger Jamiyansharav
is approved.

Thesis Supervisor : Kyoung Yul Seo

Thesis Committee Member#1 : Ki Taek Nam

Thesis Committee Member#2 : Jin Woong Bok

The Graduate School
Yonsei University

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ABSTRACT

Visual phenotyping analysis of Korean wild mouse KWM/Hym

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Department of Medicine
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Laboratory mice are widely and commonly used in biomedical research by having similar genes to humans. However, they have been segregated from their free-living relatives and too far removed from natural environmental conditions for many years. For that reason, some researchers believe these animals might have been affected by selective pressures of domestication to no longer represent an entire genome of their original population.

In the last few decades, numerous efforts have been made to develop a better mouse model to overcome the limitations of laboratory inbred mouse models. As part of these efforts, in Korea, the Hallym university research team has been developing a new inbred strain of Korean wild mouse KWM/Hym. They suggested that this strain, which is derived from wild mice, might be useful for genetic research and may become a valuable tool for overcoming some limitations seen in inbred mice that are currently used in the laboratory. Therefore, for this study, I aimed to determine the visual phenotype of this unique strain-KWM/Hym, and consider whether and if they are suitable for visual research.

To analyze their visual phenotype, I performed the functional and morphological examinations in KWM/Hym mice and compared the results with laboratory mice which are the most common background strain.

As a result, KWM/Hym had a thin corneal phenotype, well-ordered retina, and normal visual function similar to control mice. Although they appeared a crack-like lesions in their fundus, there were no abnormalities observed with structural examination such as optical coherence tomography (OCT), histopathology and transmission electron microscopy (TEM). Unexpectedly, the KWM/Hym mice developed lens cataracts only at around 25 weeks old. However, according to their normal visual phenotype, particularly the electroretinography (ERG) test, their retinal cell function has not differed from laboratory wild-type mice. Therefore, we suggest Korean wild mouse KWM/Hym which originated from a wild population would be useful for visual experiments and could be an animal model of lens cataract disease in humans.

Key words: Korean wild mouse, KWM/Hym, visual phenotyping

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I. INTRODUCTION

House mice (also known as *Mus musculus*) may have the widest geographical distribution of any mammalian species with the exception of humans. Their geological origin is likely in present-day India and the expansion to the periphery of the Eurasian range, and to the rest of the world, is related to human migration and activities. Then, the breeding of house mice has begun in the late 19th and the use of them as laboratory animals with the study of genetics by scientists was in the early 20th century[1,2]. At present, they are the most widely studied and commonly used primary model organisms in biomedical research because they are economical and easy to handle, and in particular, over ninety percent of mouse genes share functions with the genes in humans. These similarities help scientists to gain information about the physiology and genetics of health and disease in the human body system, including the visual system. However, the laboratory-inbred mice have been genetically isolated from their free-living relatives and too far removed from natural environmental conditions for many years. Therefore, some scientists predict that the laboratory mice might have been affected by selective pressures of domestication to no longer represent an entire genome of their origin population[3,4]. Accordingly, over the last years, several review articles have highlighted the benefits of a wild mouse. Also, they have discussed the demands for continued research on wild mice and efforts to create new inbred strains that diversified from wild populations[5].

So recent study has shown that wild mice have diverse and complex immune systems that mimic those of adult humans, whereas laboratory mice have weaker similar to human neonate-like immune status[6]. In addition, numerous studies reported about the microbiota such as bacteria, fungi, and viruses of wild mice which are necessary for normal physiological functioning, including immune function are much different from laboratory strains. In wild mice, their natural micro-organisms results promote host fitness and survival under natural selection pressure and better resemble the immune response of humans. However laboratory mice have simpler and more controlled microbiota, and that lack of it decreases the value of laboratory mice to human translational research[7,8].

For these reasons, numerous efforts have been made to develop or to create better mouse strains to overcome the above limitations of laboratory inbred mice models. As part of these efforts, in Korea, Hallym university research team has been developing a new inbred strain of Korean wild mouse KWM/Hym. They suggested these KWM/Hym mice (subspecies: *Mus. Mus. Musculus*) which originated from the wild population might be useful for the research and become a valuable tool for overcoming the limitations of current laboratory inbred mice[9]. Consequently, in this study, I aimed to determine the visual phenotype of this unique KWM/Hym mouse strain to see its suitability for visual research and experiments.

II. MATERIALS AND METHODS

1. Mice

The KWM/Hym mice used in this study were provided by the Laboratory Animal Resource Center of Hallym University, Korea. The wild mice were captured between March and April of 2017 and 2018 in Chuncheon-si, Gangwon-do, Korea. Mice were kept and inbred at the Laboratory Animal Resource Center of Hallym university, in a conventional animal care facility that maintained a regular environment: 22±2℃, 55±10% relative humidity, and a 12hr light and 12hr night routine cycle. Normal rodent pellet feeds (Cargill Agri Purina, Korea) and water was provided ad libitum. The KWM/Hym mice aged 20 and 25 weeks were transferred to Abison Biomedical Research Center (ABMRC) at Yonsei University with animal transferring conditions after each mouse had been tested for their genotype and other analysis at Hallym University.

A total of sixteen KWM/Hym mice aged 20-25 weeks, 11 males and 5 females, were used for the vision phenotyping analysis. Also, twenty-two mice were (4-8 mice per group) used for cataract screening (proceeded at Hallym university, Laboratory Animal Resource Center). All animal experimental procedures are carried out by the guidelines for the Care and Use of the Laboratory Animals Committee of Yonsei University, College of Medicine, and in accordance with the Yonsei Medical Center Animal Research guidelines, which adhere to the standards articulated in the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC) guidelines. All possible steps were taken to avoid animal suffering during the experiments.

2. Fundus examination

For all experiments, a mixture of zolazepam and tiletamine (30 mg/kg; Zoletil 50®, Vibrac, Carros, France) and xylazine (10mg/kg; Rompun®, Bayer animal health) was administered intramuscularly to induce anesthesia in all mice. After anesthesia, pupils were

dilated with 0.5% tropicamide and 0.5% phenylephrine mixed eye drops (Mydrin-P, Santen Pharmaceutical Co, Ltd.,). Then, the fundus was examined using Micron® IV (Phoenix Research Labs, Pleasanton, CA, USA), with a wavelength range between 450 and 650nm, and stored the resultant images in Micron IV StreamPix software (Norpix, Inc., Montreal, QC, Canada).

3. Tonometry

Mice were anesthetized as previously described, and intraocular pressure (IOP) was measured using a rebound tonometer (Icare® TONOLAB tonometer, Colonial Medical Supply, Franconia, NH, USA). IOP measurements were performed in the left eye of mice, according to the manufacturer's instructions. At least 6 IOP readings were obtained, and average data was used for analysis.

4. Optical coherence tomography (OCT)

Optical coherence tomography (OCT) imaging was performed using Micron® IV (Phoenix Research Labs, Pleasanton, CA, USA) to determine the overall structure of the eyes. Mice were deeply anesthetized, pupils were dilated as previously described. After the mice were placed collaterally in front of the OCT camera, I focused the lens on the retina and obtained fundus photographs and retinal OCT scans.

Central corneal thickness (CCT) was determined from cross-sectional corneal OCT images that passed through the center of the pupil. We measured the linear distance between the anterior and posterior corneal surfaces in resultant images by the Insight-Animal OCT Segmentation Software (Phoenix Research Labs, USA).

Retinal cross-sectional images centered on the optic disc as the main landmark was obtained and we measured the thickness of the retinal layers of KWM/Hym mice. It was

measured in two parts, the retinal nerve fiber layer to the outer plexiform layer (RNFL-OPL) and the outer nuclear layer to retinal pigment epithelium (ONL-RPE), distanced 300μm from the optic nerve head. The thickness of individual retinal layers was determined using the same technique.

5. Electroretinography (ERG)

After anesthesia, we performed the Electroretinography (ERG) test using Micron Ganzfeld ERG (Phoenix Research Labs, Pleasanton CA, USA) to examine their cone and rod cells function, which are photoreceptor cells distributed in the retina. Before the test, mice were dark-adapted for at least 12 hours for scotopic testing and also for sedation. Pupils were dilated with 0.5% tropicamide and 0.5% phenylephrine mixed eye drops (Mydrin-P, Santen Pharmaceutical Co, Ltd.,). Once the pupils were adequately dilated, we applied 2.5% hypromellose (Goniovisc®) to lubricate the ocular surface and inserted the electrodes between the eyes, in the middle of the head, and the tail.

First, rod cell function tests (Scotopic ERGs) were recorded in a dark room under dim red illumination, according to the standard protocol provided in the manual. Scotopic ERGs were obtained in response to increasing flash intensities ranging from -1.7 log cd•s/m2 to 1.9 log cd•s/m2. Then, cone cell function tests (Photopic ERGs) were recorded on the light-acclimated mouse in a bright environment. Photopic ERGs were obtained in response to increasing flash intensities ranging from -0.5 log cd•s/m2 to 4.1 log cd•s/m2.

6. Histopathological and structural examination (Hematoxylin and Eosin staining, H&E staining)

To confirm an ocular structure more clearly, we enucleated the eyes and proceed with histopathological tests. After all experiments, mice were sacrificed by asphyxiation with carbon dioxide, and their eyes were dissected immediately. Then, place the dissected

eyes in fixation buffer (65% ethanol, 4% formaldehyde, 5% acetic acid, 3% sucrose) and stored them at 4℃. The next day, after dehydration, the eyes were embedded in paraffin and sectioned by a thickness of 5-10nm. Sections were stained with Hematoxylin and eosin and checked with a light microscope. The histopathological test was carried out by pathologic experts.

7. Transmission electron microscope (TEM)

Eyes were enucleated and fixed for 12 hours in 2% Glutaraldehyde and 2% Paraformaldehyde in 0.1M phosphate buffer (pH 7.4) and washed in 0.1M phosphate buffer. The anterior segment and vitreous humor were removed. The eyecups with the retina, RPE, and choroid were fixed with 1% osmium tetroxide in 0.1M phosphate buffer (pH7.4) for 2hr and dehydrated with an ascending ethanol series and embedded with a Poly/Bed 812 kit (Polysciences), polymerized in an electron microscope oven (TD-700, DOSAKA, Japan) at 65℃ for 12 hours. 80-nanometer ultrathin sections were cut with an ultra-microtome and placed on copper grids, double stained with 5% Uranyl acetate for 30min and 3% Lead citrate for 7min staining, and imaged with a transmission electron microscopy (HT 7800 Tokyo, Japan).

8. Statistical analysis

All statistical analysis was performed with GraphPad Prism v.5 Software (GraphPad, San Diego, CA, USA). Comparison between groups was performed with the Mann-Whitney *U* test and unpaired t-test. The result of the experiments was presented as the mean standard error of the mean. $P<0.05$ was considered significant. Pearson correlation test and linear regression analysis were used to evaluate the correlation.

III. RESULTS

In this study, a total thirty-five of Korean wild mice KWM/Hym were analyzed. Sixteen of them were used for visual phenotyping analysis and twenty-two were used for cataract screening examination. First, as for their appearance, KWM/Hym mice have an agouti-colored fur coat and they were physically smaller than laboratory mice (Fig 1A). First, we did not observe any abnormal morphologic changes in the cornea and iris (Fig1 C, D - left). However, there were crack-like lesions appeared more or less on all of their fundus image (Fig 1C, D - right).

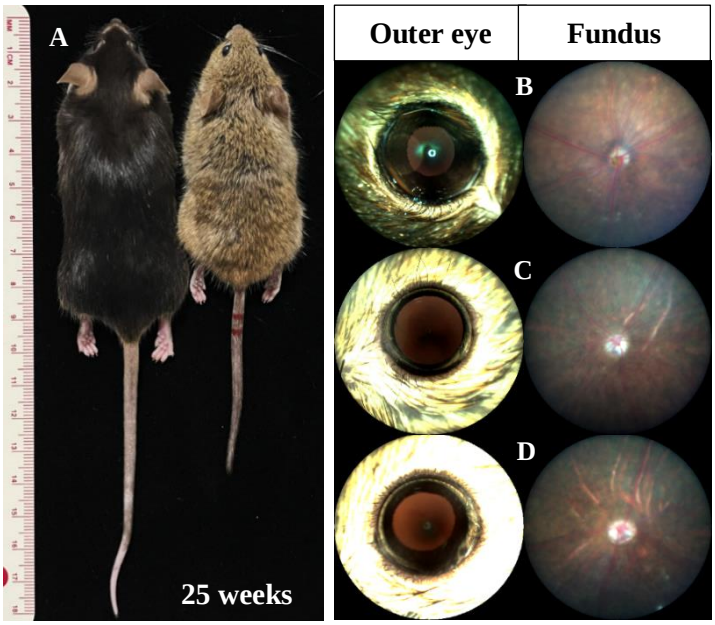

Figure 1. Physical appearance and eye images of C57BL/6N and KWM/Hym mice.

A photograph shows a comparative appearance (A) of laboratory strain C57BL/6N (left) and Korean wild mouse KWM/Hym (right). Representative outer eye and fundus images of 25 weeks aged C57BL/6N mouse (B), 20 weeks aged (C) and 25 weeks aged KWM/Hym mouse (D).

When I compared the visual and ocular measurement results of KWM/Hym mice with their age and sex groups, there is no detectable difference between 20 and 25-week-aged groups or male and female groups. Therefore, I summarized all of the data of the KWM/Hym mice and compared them with the age-matched laboratory strain mouse C57BL/6N which is the most widely used strain in biomedical research.

First, central corneal thickness (CCT) was determined from cross-sectional corneal OCT images that passed through the center of the pupil, and we measured the linear distance between the anterior and posterior corneal surfaces. KWM/Hym mice cornea was seen as normal but the mean central corneal thickness (CCT) value of KWM/Hym (71.91μm) was significantly lower than the control group (83.83μm) (Fig 2C).

Also, an intraocular pressure (IOP) was measured with a rebound tonometer and found significantly lower ($p = .0111$) in KWM/Hym (7.50 ± 0.1118mmHg) than in C57BL/6N mice (9.896 ± 0.3819 mmHg) (Fig 2D). Several studies have shown that the corneal thickness is directly correlated with IOP, which means IOP alterations are likely to depend on the corneal thickness or other conditions. In our study, there was a significant moderate positive correlation ($r=0.72$, p-value <0.0001) between IOP and CCT results (Fig 2E). To confirm whether the corneal thinness of KWM mice relates to their smaller body characteristic we checked their relation. There was also a positive correlation ($r=0.7922$, p-value <0.0001) between the body mass and measured CCT (Fig 2F). Statistical analysis was performed with the Pearson correlation test and linear regression analysis.

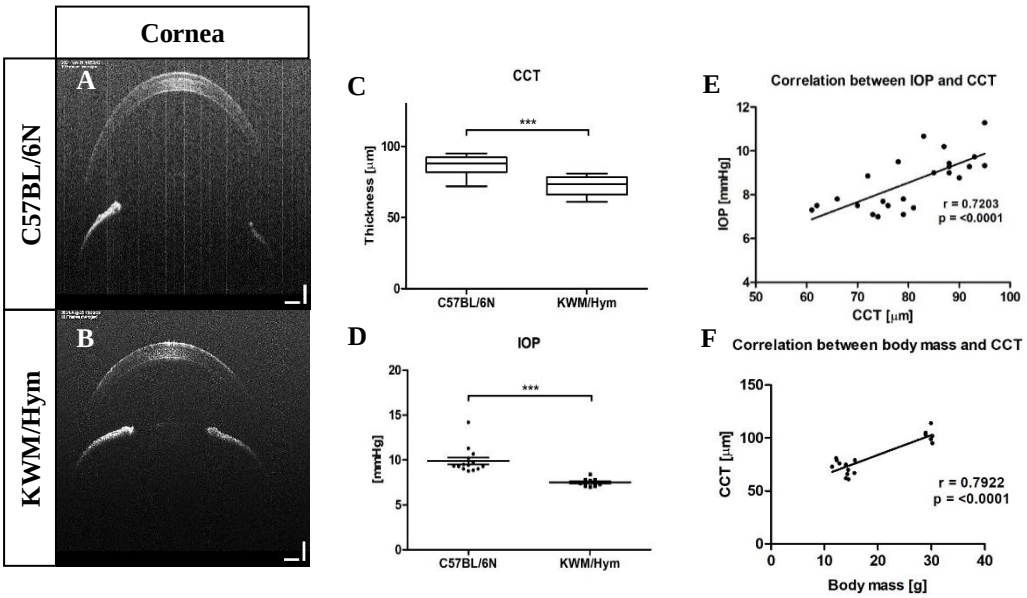

Figure 2. Average CCT and IOP and their correlation.

Representative corneal images of C57BL/6N (A) and KWM/Hym mice (B). Comparison of mean CCT value (C) and the average IOP (D) between two groups. A scatter plot graphs shown a significant positive correlation between CCT and IOP (E**)**, and body weight (F).

CCT, Central corneal thickness; IOP, Intraocular pressure. Scale bar - 100μm

Retinal thickness was measured along the cross-sectional OCT image distanced 300μm from the optic nerve and averaged for two parts from the retinal nerve fiber layer to the outer plexiform layer (RNFL-OPL), and the outer nuclear layer to the retinal pigmented epithelium (ONL-RPE). Following the result obtained with OCT, KWM/Hym mice were characterized by well-ordered retinal layers. However, a significant reduction of retinal thickness was observed in KWM/Hym mice (Fig 3C) measured as totally (168.0±0.7945μm) and individual sublayers (Fig 3D), compared to control C57BL6/N mice (210.6±1.119 μm).

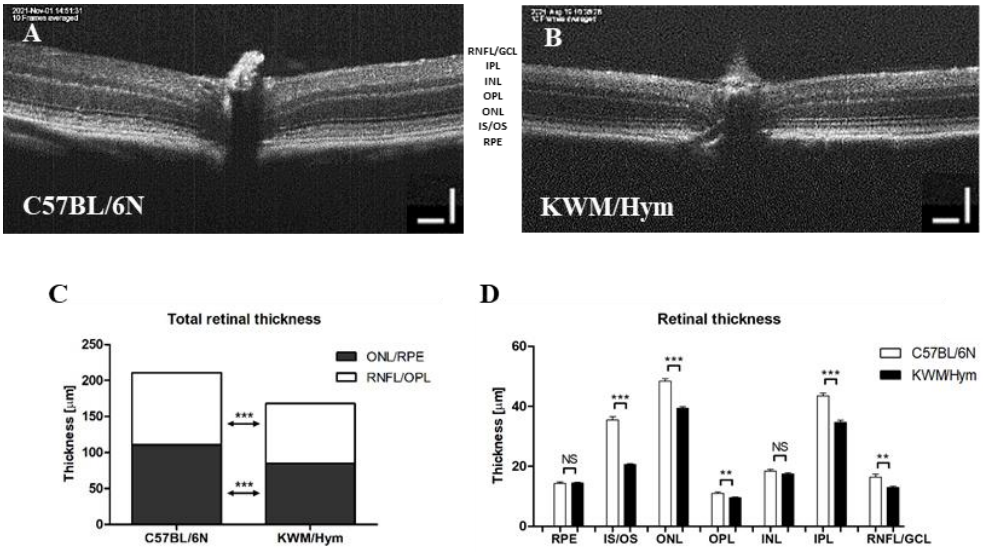

Figure 3. Comparison of the retinal thickness between the C57BL/6N and KWM/Hym mice. Representative images from the retinal OCT scan of C57BL/6N (A) and KWM/Hym mouse (B). Reduced retinal thickness of KWM/Hym mice is shown as totally (C) and particularly (D).

RNFL, retinal nerve fiber layer; IPL, inner plexiform layer; INL, inner nuclear layer; OPL, outer plexiform layer; ONL, outer nuclear layer; IS, inner segment; OS, outer segment; RPE, retinal pigmented epithelium.

Scale bar - 100μm Control group, n=6; KWM/Hym group, n=13

Next, we analyzed the retinal cell function by recording electroretinography (ERG) a- and b-waves in both scotopic and photopic conditions across a series of increasing flash intensities. Typically, the ERG waveform consists of the A-wave (indicates the function of the photoreceptors in the outer retina), and the B-wave (indicates the bipolar cells in the inner retina).

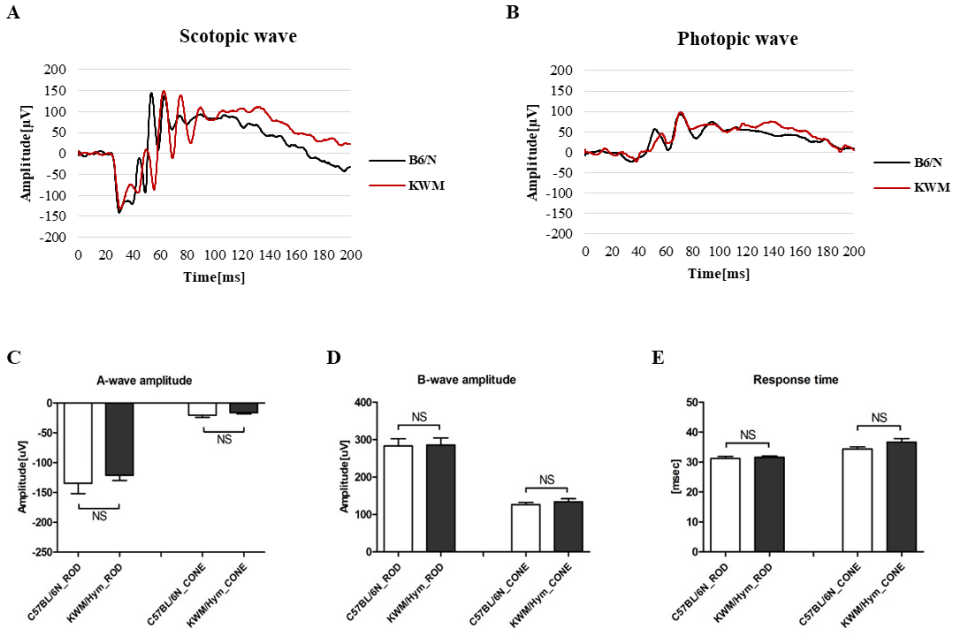

Figure 4. Comparison of the retinal cell function between C57BL/6N and KWM/Hym mice.

Representative scotopic (A) and photopic (B) ERG waveforms obtained from control (black) and KWM/Hym mice (red). Comparison of the average ERG amplitude of A-wave (B) and B-wave (C) in each group shown no significant differ. An average time of their retinal cells response to the light exposure (D) were not different.

ERG, Electroretinography; NS, not significant. Control group, n=6; KWM/Hym group, n=13

In accordance with results obtained with ERG, there was no difference between amplitudes of dark or light-adapted A, B-wave, which means a retinal rod cell (responsible for vision in the dark environment), cone cell (activated in the high light levels), and bipolar cells in KWM/Hym mice showed the same results with age-matched control C57BL/6N mice (Fig 4C, D) as functionally. Also, in their reaction rate, no significant differences were observed (Fig 4E).

Unexpectedly, the lens cataract was observed as frequently among the 25 weeks aged KWM/Hym mice (Fig 5C, D), whereas the age-matched laboratory strain C57BL/6N mice developed any abnormal change in the lens (Fig5A, B). The lens opacity (yellow box) was detected with a high reflection by the outer eye imaging (Fig 5C) and anterior segment OCT (Fig 5D). We found that 53.8% of 25-week-aged KWM/Hym mice had developed the lens cataract (Fig 5E). Therefore I checked the lens cataract development percentage among

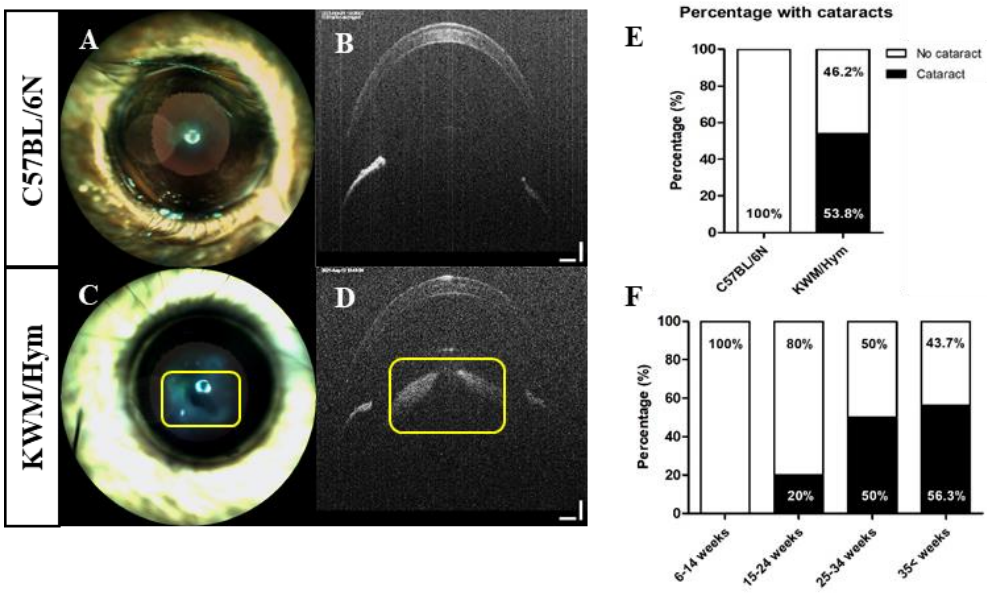

Figure 5. The percentage of lens cataract development in KWM/Hym mice.
Representative anterior segment images of 25 weeks aged C57BL/6N (A, B) and KWM/Hym mouse (C, D). The lens opacity in KWM/Hym observed with high reflection (in yellow box). The bar graphs shows the cataract developing percentage in 25 weeks aged laboratory mouse and wild mouse (E) and cataract screening result among the different aged KWM/Hym groups (F). The cataract developing percentage is calculated by each eye of individual mouse.
Control group, n=6; KWM/Hym, n=13 (E); n=4-8 per group (F) Scale bar - 100μm

different aged Korean wild mice. Twenty-two mice were included in this screening test and as result, the presence of the cataract started at 15-24 weeks age with 20%. And it reached 50% in 25-34 weeks, and 56.2% in the over-35-aged group respectively. In addition, lens cataract was found in 63% of all male mice, and 33% of all female mice that included in this study.

As for the changes in fundus examination, we could not find any abnormality from OCT scans that corresponded with those changes (Fig 6C). Therefore, we proceeded with a retinal histopathological and transmission electron microscopic (TEM) test to reveal their retinal structure more clearly. Mice were sacrificed by asphyxiation with carbon dioxide, and their eyes were dissected immediately. Tissue preparation and experimental procedures were carried out by experts. In consequence, the retinal histology image of the KWM/Hym mice showed well-ordered retinal layers (Fig 6D) and characterized by their slightly hypopigmented RPE. Also, through an electron micrograph, this characterization is presented and confirmed in their ultrastructure (Fig 6E, F) with reduced light-absorbing melanosomes (black arrowheads) compared to the control C57BL6/N background mouse, which is shown numerous melanosomes (white arrowheads). Also, by an electron microscopic examination, there were no abnormalities or damages observed in their Bruch's membrane (BM) and choroid because those changes of the following structures can show a similar fundus appearance as KWM/Hym mice views.

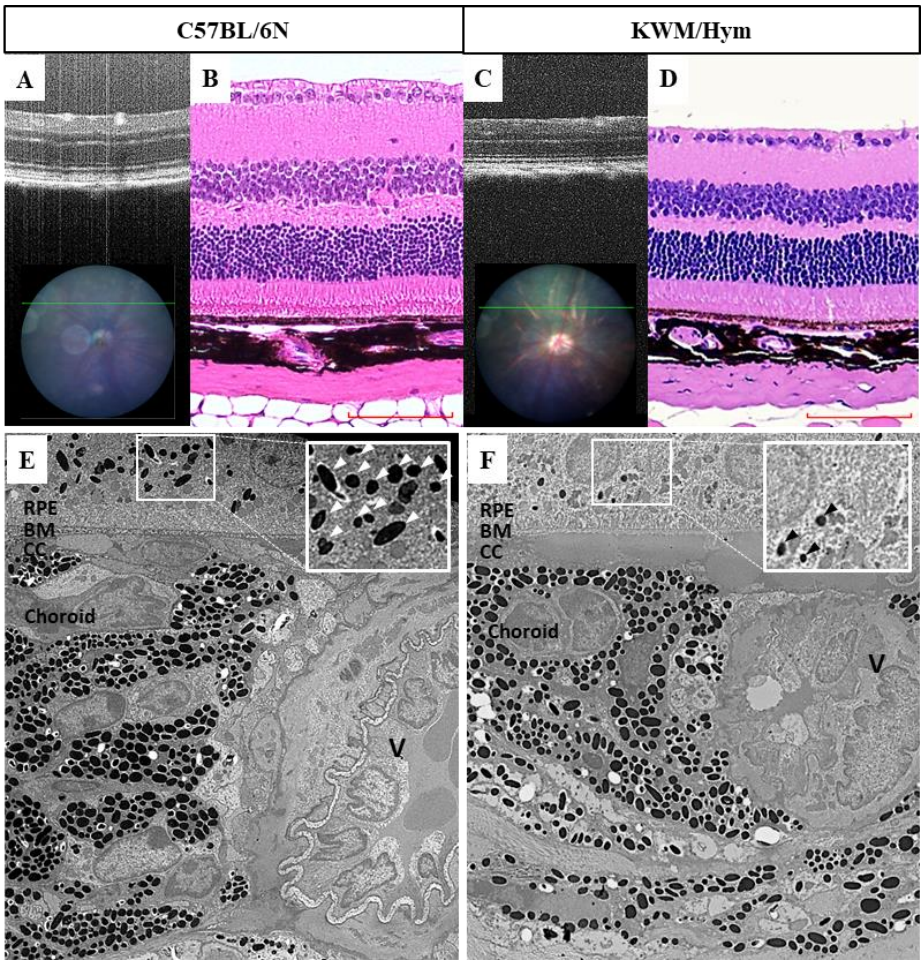

Figure 6. Retinal structure confirmation with histology and transmission electron micrographs. OCT scans shown part of the retina section corresponded with the green line on the fundus image (A, C). Retinal histologic images of 25 weeks-aged laboratory strain C57BL/6N (B) and KWM/Hym mouse (D) shown their retinal well-organization. Transmission electron micrograph shows an ultrastructure of retina-choroidal section. Melanosomes (arrowheads) appeared with great reduction in RPE layer of KWM/Hym (F) compared to control strain (E).

RPE, Retinal pigmented epithelium; BM, Bruch's membrane; CC, choriocapillaries; V, large vessel in choroid. Scale bar in B and D – 80um, 15x magnification

Since there were no abnormal changes confirmed in the retinal structure of KWM/Hym mice by the above experiments, I compared their fundus image with other wild-type laboratory strains (Fig 7). So, I observed that KWM/Hym mice showed a lighter fundus and more apparent choroidal vasculature (Fig 7D) as similar to other bright-colored strains such as 129S (Fig 7B) which has a light-brown fur coat, and albino Balb/c mice (Fig 7C) compared to black-coated C57BL6 mouse fundus (Fig 7A).

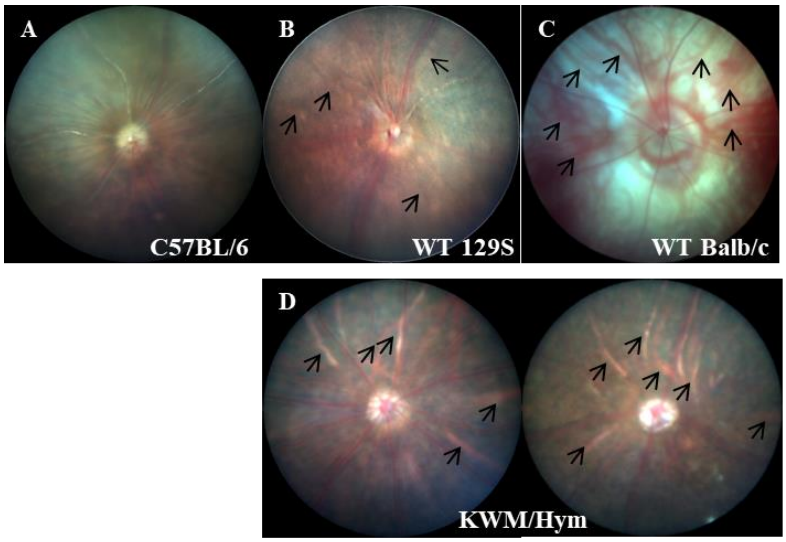

Figure 7. The fundus images of the wild-type mice strains.
Choroidal posterior medium and large vessels (black arrows) shown in hypopigmented mice (B-D) compared to C57BL/6N mouse fundus (A). WT, Wild-type mouse.

IV. DISCUSSION

In the present study, I aimed to analyze the visual phenotype of Korean new inbred strain KWM/Hym mice which originated from a wild population in Chuncheon, Korea to see whether they are suitable for visual experiments. And this is the first report of the visual phenotyping of the Korean wild mouse KWM/Hym.

Wild and wild-derived mice are physically smaller than age-matched laboratory strains[9]. And the KWM/Hym mice used in this study were also smaller obviously. The thinness of the cornea and retina of KWM/Hym mice can be explained by their light body weight characteristics. In previous studies, they have shown a positive correlation between body weight and measured corneal thickness[10] and eye mass[11]. Also, I considered that according to their thin cornea, intraocular pressure was measured dramatically lower than in laboratory strain. Numerous studies have reported that corneal thickness is directly correlated with intraocular pressure, which means pressure alterations are likely to depend on the corneal thickness or other conditions[12,13,14]. Similarly, in our study, a significant positive correlation confirmed this relation. Moreover, wild mice have good vision. Their well-developed a- and b-waves in electroretinogram indicated their normal visual function and confirmed they would be useful in the visual experiment.

In the mammal retina, the choroid and the retinal pigmented epithelium cell layers contain numerous melanosomes and pigment granules that absorb excess light entering the eye. Pigment density differs in various parts of the retina, which can give the fundus a mottled appearance when viewed with the ophthalmoscope[15]. Typically the wild-type C57BL/6N controls have a uniformly black fur coat and carry numerous darkly pigmented melanocytes in their retinal pigmented epithelium and choroid. Through this study, the retinal ultra-structural analysis confirmed these agouti-colored KWM/Hym mice had comparatively fewer melanocytes in their retina. Therefore I considered that due to their hypopigmented retinal phenotype, they showed a lighter fundus and more apparent

choroidal vasculature as similar to other bright-colored strains such as 129S which has a light-brown fur coat and albino Balb/c mice compared to wild-type C57BL6 mouse fundus.

Unexpectedly, the cataracts were observed with high frequency among the 25 weeks aged KWM/Hym mice and confirmed by additional cataract screening in different age groups of Korean wild mice, whereas wild-type laboratory strains develop the lens cataracts naturally when aged out to 12-30 months[16,17]. At present, there are several mouse models of cataracts, but most of them are genetic mouse cataract models provided rather to the study of lens development or early onset lens defects than the aging process[18]. Furthermore, other cataract models, are induced with ultraviolet radiation[19] or chemical such as sodium selenite that induces acute oxidative stress, triggering cataract formation within only 4-6 days after injection[20]. Although these models are suitable for studying severe cataracts, they do not capture the gradual and variable onset that occurs with aging. On the other hand, even various strains of wild-type mice develop age-related cataracts naturally up to 30 months of age and show various opacities[16], but it is over-priced and difficult to keep mice out to such old age.

V. CONCLUSION

Although the usage of a wild-derived mouse in biomedical research is under-researched, the current studies showed the great potential of wild mice as mentioned in the introduction, and they suggested that wild mice would add a valuable component to existing experimental mouse resources. As part of the efforts to develop a better mouse model, Hallym University research team is developing a new inbred strain of KWM/Hym derived from a wild population in Korea. In the present study, I determined the visual phenotype of these unique mice.

In conclusion, Korean wild mouse KWM/Hym shows normal physiology in ophthalmic phenotypes. Currently, the mouse is available as a request to the Department of Medical Genetics at Hallym University College of Medicine, and it is useful for vision research by providing visual experiments. Retina, intraocular pressure and external eye morphology present stable ranges of phenotypes. Through sufficient numbers of lens cataracts with aging, we suggest that KWM/Hym mice could be an animal model for lens cataract disease.

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ABSTRACT (IN KOREAN)

한국형 야생 마우스의 시각 표현형 분석

<지도교수 서 경 률>

연세대학교 대학원 의학과

Jamiyansharav Munkhdelger

현재 실험용으로 사용하고 있는 마우스는 유전자가 인간과 상당부분이 일치하기 때문에 인간 질환 연구 모델로 일반적으로 사용하는 동물이다. 그러나 1900 년때부터 실험용으로 사용하게 된 마우스는 수년 동안 자연 환경 조건에서 멀리 떨어져 있고, 가축화의 선택적 압력에 의해 영향을 받은 것으로 인해서 인간 질병을 흉내내기에 부족하다고 볼 수 있다. 따라서 많은 연구자 분들 이러한 한계를 극복하여 더 적합한 동물 모델을 만들려고 노력하고 있다. 그 중 하나로 한국 한림 대학교 연구팀에서 자연 야생 마우스를 포획하여 유전적 조성이 동일한 근교계를 육성하고 있으며 본 연구에서 이 마우스가 시각기 연구 및 실험에 적합한지 보기 위해 시각 표현형 분석을 진행하였다.

시각표현형 분석을 하기 위해 KWM/Hym 마우스의 기능 및 형태학적 검사를 진행하고 가장 일반적인 실험용 C57BL/6N 마우스와 결과를 비교했다. 그 결과 KWM/Hym 은 실험용 마우스 보다 더 얇은 각막과 망막을 가졌다. 안저 촬영에서는 균열과 같은 이상이 나타났으나 OCT 및 조직병리검사와 같은 구조 검사에서 이상 소견은 관찰되지 않았다. 또한 예기치 않게 대부분 25 주령 KWM/Hym 마우스의 수정체에서 백내장이 관찰됐다. 그러나 시세포 기능

분석인 ERG 결과에 따르면 망막 세포 기능은 실험실 마우스와 차이 없으므로 한국 야생형 마우스에서 유래한 이 계통이 시각기 실험에 적합하며 인간 수정체 백내장 질환의 동물 모델로 활용할 수 있음을 제안한다.

핵심되는 말: 한국형 야생 마우스, KWM/Hym, 시각표현형분석