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Classification of Visual Field Abnormalities in Highly Myopic Eyes without Pathologic Change

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No animal subjects were included in this study.

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Abstract

Purpose: To develop a classification system of visual field (VF) abnormalities in highly myopic eyes with and without glaucoma.

Design: Secondary analysis of VF data from a longitudinal cohort study.

Participants: One thousand eight hundred ninety-three VF tests from 1302 eyes (825 individuals).

Methods: All participants underwent VF testing (Humphrey 24–2 Swedish interactive threshold algorithm standard program; Carl Zeiss Meditec) and detailed ophthalmic examination. A comprehensive set of VF defect patterns was defined via observation of the 1893 VF reports, literature review, and consensus meetings. The classification system comprised 4 major types of VF patterns, including normal type, glaucoma-like defects (paracentral defect, nasal step, partial arcuate defect, arcuate defect), high myopia-related defects (enlarged blind spot, vertical step, partial peripheral rim, nonspecific defect), and combined defects (nasal step with enlarged blind spot). A subset (n = 1000) of the VFs was used to evaluate the interobserver and intraobserver agreement and weighted κ values of the classification system by 2 trained readers. The prevalence of various VF patterns and their associated factors were determined.

Main Outcome Measures: The classification of VF in highly myopic eyes and its associated risk factors.

Results: We found that normal type, glaucoma-like defects, high myopia-related defects, and combined defects accounted for 74.1%, 10.8%, 15.0%, and 0.1% of all unique VF tests, respectively. The interobserver and intraobserver agreements were > 89%, and the corresponding κ values were 0.86 or more between readers. Both glaucoma-like and high myopia-related VF defects were associated with older age (odds ratios [ORs], 1.07 [95% confidence interval (CI), 1.04–1.10; $P < 0.001$] and 1.06 [95% CI, 1.04–1.10; $P < 0.001$]) and longer axial length (ORs,

1.65 [95% CI, 1.32–2.07; $P < 0.001$] and 1.37 [95% CI, 1.11–1.68; $P = 0.003$]). Longer axial length showed a stronger effect on the prevalence of glaucoma-like VF defects than on the prevalence of high myopia-related VF defects ($P = 0.036$).

Conclusions: We propose a new and reproducible classification system of VF abnormalities for nonpathologic high myopia. Applying a comprehensive classification system will facilitate communication and comparison of findings among studies.

Keywords

Classification system; High myopia; Visual field abnormalities

The prevalence of high myopia has increased markedly worldwide over the last 3 decades, in particular in East Asia.[1–4] Projections estimate that the global prevalence of high myopia will increase from 2.7% in 2000 to 9.8% in 2050.1 A recent meta-analysis revealed that, in Chinese adolescents 16 to 18 years of age, the prevalence of high myopia increased from 10.5%, as assessed from 2010 through 2013, to 19.4%, as examined from 2014 through 2016.2 Patients with high myopia have an increased risk of visual impairment and legal blindness worldwide.[5–8] It has been estimated that the odds ratio (OR) for eyes with high myopia to demonstrate primary open-angle glaucoma (POAG) is approximately 5.9, as compared with eyes without high myopia,[6,9–11] and that the prevalence of glaucomatous optic neuropathy can be as high as 27.2% in highly myopic eyes.[12]

Perimetry is an important tool for the diagnosis and monitoring of glaucoma.[13,14] Major glaucoma trials such as the Early Manifest Glaucoma Trial, the Ocular Hypertension Treatment Study (OHTS), and the United Kingdom Glaucoma Treatment Study have used perimetry as the primary end point method.[15–17] However, ophthalmologists frequently face the challenge of distinguishing glaucomatous visual field (VF) loss from nonglaucomatous VF defects in highly myopic eyes because of concurring myopic maculopathy and high myopia-associated optic neuropathy, both of which can mimic glaucomatous perimetric defects18; however, it is clinically important to differentiate between glaucomatous optic nerve damage and nonglaucomatous optic neuropathy because glaucoma can be addressed therapeutically. In particular, no commonly accepted classification of VF abnormalities in high myopia exists. Although a grading scheme was proposed previously, the study to assess the classification system had not excluded patients with significant myopic macular degeneration and had not examined the repeatability of the VF testing results.[19]

Because of the lack of a common VF classification system to identify VF damage in those with high myopia, our ability to differentiate between functional damage resulting from glaucoma and damage resulting from high myopia is limited. Therefore, we aimed to develop a classification system to describe VF loss patterns in highly myopic eyes without myopic maculopathy. We assessed the intraobserver and interobserver agreement by trained readers. In addition, the frequency and the risk factors that were associated with various patterns of VF defects were assessed.

Methods

Study Participants

Participants were recruited from a longitudinal, observational high-myopia registry cohort study that was designed to explore the natural course of myopic optic neuropathy and was initiated in Guangzhou, China, in June 2019 (ClinicalTrials.gov identifier, NCT04302220).[20] The ethics committee of the Zhongshan Ophthalmic Center, Sun Yat-sen University, approved the protocol, and the methodology adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment.

Details of the study protocol and participant eligibility have been described previously.[20] In brief, inclusion criteria were an age of 18 years or older, best-corrected visual acuity of 6/12 or more, the diagnosis of high myopia (defined as spherical equivalent of ≤ −6 diopters [D] or axial length [AL] of ≥ 26.5 mm), and individuals with and without POAG. Exclusion criteria were a history of ocular surgery, secondary glaucoma, other ocular diseases such as severe cataracts, myopic maculopathy constituting diffuse choroidal atrophy, patchy choroidal atrophy, macular atrophy, lacquer cracks, acitve choroidal neovascularizaion, or Fuchs spot (based on the International Meta-Analysis for Pathological Myopia classification system), the presence of a distinct posterior staphyloma as assessed on fundus photographs, or a combination thereof.[21,22] Primary open-angle glaucoma was diagnosed by glaucoma specialists (F.Li, X.G., and X.Z.) based on the presence of glaucomatous optic disc changes (i.e., vertical cup-to-disc ratio of > 0.7, neuroretinal rim notching, wedge-shaped retinal nerve fiber layer defects, or disc hemorrhage) on optic disc photographs, with corresponding glaucomatous VF defects and intraocular pressure of 21 mmHg or more.

All participants completed a comprehensive ocular examination, including slit-lamp–based biomicroscopy, automatic refractometry (autorefractor KR-800; Topcon Co), assessment of best-corrected visual acuity, tonometry using Goldmann applanation tonometry, ocular biometry including measurement of central corneal thickness and AL (IOL Master 700; Carl Zeiss Meditec), fundus photography (fundus camera Nonmyd WX3D; Kowa), swept-source OCT (Triton, DRI-OCT 2; Topcon Co), and standard automated perimetry (Humphrey Field Analyzer 3; Carl Zeiss Meditec). We additionally evaluated the medical history, asked the level of education, obtained anthropometric measurements, and assessed blood pressure. The level of education was graded between low (primary school or less) and high (secondary school or more).

VF Testing and Fundus Assessment

The VF examinations were performed using the Swedish interactive threshold algorithm standard 24–2 program in a dark room (ambient light, < 5 lux). A trained technician explained the procedures to each participant before the test. The built-in liquid lens of the Humphrey Field Analyzer 3 was used to correct for myopia to avoid refractive artifacts after participants were evaluated using an autorefractor. Participants showing abnormal VFs had to have a minimum of 2 and a maximum of 3 reliable tests at baseline before they were eligible for inclusion into the study. For those with normal VF findings at the first test, consecutive repeatable tests were not required. The reproducibility of the first and

second VF tests determined the times of testing results. If the first 2 testing results differed, a third test was required to confirm. For reliable VF findings, the rate of false-positive answers and false-negative answers had to be < 15%, and the rate of fixation losses had to be < 20%. Visual field tests not fulfilling these criteria were repeated no more than 5 times, either on the same day after a break of at least 30 minutes or at the following visit within 1 month.[23,24] From June 2019 through December 2020, a total of 1302 eyes with 1893 VF test results was available. The VF test with the least serious defect (based on the mean deviation of the VF) was chosen for the final analysis if participants had undergone repeated perimetric testing tests. The study eventually included a total of 1302 eyes with 1302 unique VF tests for the final analysis (Fig 1). Two retinal fellows (W.W. and S.C.) evaluated the fundus grading based on the International Meta-Analysis for Pathological Myopia classification system to exclude eyes with *plus* lesions and C2, C3, and C4 myopic maculopathy.[21]

Formulating and Assessment of the VF Classification System

The detailed procedure of formulating and assessing the classification system is summarized in Figure S1 (available at www.aaojournal.org). First, all of the VF tests were used to develop an initial draft of a classification system, based on the OHTS classification, which divided the VF defects into nerve fiber bundle abnormalities and non–nerve fiber bundle abnormalities.[25] Then, those VF defects that did not meet any of the definitions of the OHTS classification were labeled as novel defect patterns. Discussions about the novel defect patterns were held among experts in the Glaucoma Suspects with High Myopia study group (consisting of 12 international members, including glaucoma and retinal specialists and clinician scientists) in consensus meetings,[20,23] with additional information obtained from a literature review.[19,26,27] Finally, a new classification system for highly myopic eyes was formulated. The classification system comprised 4 major types: normal type, glaucoma-like defects (paracentral defect, nasal step, partial arcuate defect, arcuate defect), high myopia-related defects (enlarged blind spot, vertical step, partial peripheral rim, nonspecific defect), and combined defects (nasal step with enlarged blind spot). A VF defect was defined as a reproducible reduction in sensitivity at a cluster of 2 or more contiguous test points with a P value of < 1% loss or more or a cluster of 3 or more contiguous test points with a P value of < 5% loss or more in the pattern deviation plot, located in the superior or inferior arcuate areas, or a 10-dB difference across the nasal horizontal midline at a cluster of 2 or more adjacent test points in the total deviation plot in at least 2 consecutive reliable perimetric examinations.[23,24] Definitions and examples of the VF abnormality classification (with the corresponding fundus photograph) are presented in Table 1 and Figure 2.

Two readers (B.Y. and G.N., both ophthalmologists with > 10 years of experience) were trained to use the new classification system and then were asked to apply the classifications to the same set of 1000 VF test results, which included all the patterns in the system. The 2 readers graded the tests twice with an interval of 1 month without other clinical information. The disagreement of the VF assessments between the readers was adjudicated by group consensus (F.Lin, S.C., Y.S., F.Li, W.W., and X.Z.). The intraobserver and interobserver agreement (agreed between 2 assessments by the same reader and agreed between the second reading by a different reader) and the weighted κ statistic were calculated by SPSS

software version 27.0 (IBM Corporation). A κ value of 0.4 or more generally is considered to be moderate, a κ value of 0.6 or more is considered good, and a κ value of 0.8 or more is considered excellent.[21]

Statistical Analysis

The normality of the distribution of all variables was examined using the Shapiro–Wilk test. Data are presented as mean ± standard deviation (range) for normally distributed continuous variables and frequency (percentage) for categorical variables. Logistic regression models with the generalized estimating equation were used to investigate the association between VF defects and ocular and systemic parameters accounting for the correlation between eyes. All variables that the associations of which had a *P* value of < 0.05 in the univariate regression analysis were included in the binary multivariate regression analysis. We used a generalized linear mixed model, which is a single model that allows for 2 dichotomous outcomes (glaucoma-like VF defects and high myopia-related VF defects) and allows testing of both the effect of covariates on outcomes (in terms of OR) and whether the OR for a given covariate differs across the 2 outcomes. The generalized estimating equation and generalized linear mixed model were performed using SAS software version 9.4 (SAS Institute). A *P* value of < 0.05 was considered statistically significant.

Results

Demographics

A total of 1302 highly myopic eyes from 825 participants was included in the study (Table 2). The mean age was 30.94 ± 9.75 years (range, 18–64 years), the mean AL was 26.87 ± 1.13 mm (range, 23.58–33.54 mm), the mean spherical equivalent was −8.61 2.10 D (range, −20.13 to −3.50 D), and the average best-corrected visual acuity was 0.01 ± 0.05 logarithm of the minimum angle of resolution units (range, 0.3 to −0.1 logarithm of the minimum angle of resolution units).

Distribution of VF Defects Using the Classification System

Figure 3 demonstrates the number and frequency of the final VF classification in highly myopic eyes. Among the 1302 VF tests, the most frequent result was normal type, found for 965 eyes (74.1%). The next most common types of findings were high myopia-related defects, grouped together with an enlarged blind spot (123 eyes [9.5%]), nonspecific defect (67 eyes [5.1%]), and vertical step and partial peripheral rim (5 eyes [0.4%]) in a total of 195 eyes (15.0%). The glaucoma-like defects, including paracentral defect (29 eyes [2.2%]), nasal step (49 eyes [3.8%]), partial arcuate defect (48 eyes [3.7%]), and arcuate defect (14 eyes [1.1%]), contributed up to 10.8% (140 eyes). The combined defects (nasal step with enlarged blind spot) accounted for 0.1% (2 eyes). Among the 142 eyes with glaucoma-like defects and combined defects, 38 eyes (26.8%) finally were given a diagnosis of POAG.

Intraobserver and Interobserver Agreement of the Classification System

The intraobserver and interobserver agreement (percentage) and the κ value of the selected VFs graded by 2 independent readers are shown in Table 3. The intraobserver agreements of the 2 graders assessing the same 1000 VFs twice were 92.5% and 91.5%, and the

corresponding κ values were 0.90 and 0.89, respectively. The interobserver agreement and the κ value between the second assessment of the 2 graders were 89.1% and 0.86, respectively. Because the agreement may be higher as a result of a high proportion of normal VFs, we removed the VFs read as normal by both graders, resulting in an intraobserver agreement of 87.8% and 86.2% and a κ value of 0.85 and 0.83, respectively. The interobserver agreement and the κ value with the normal VFs removed were 82.2% and 0.79, respectively.

Factors Associated with Abnormal VF Defects in Nonpathologic Highly Myopic Eyes

Based on the collective data for abnormal VF defects (335 eyes, including 140 eyes with glaucoma-like defects and 195 eyes with high myopia-related defects), a binary multivariate logistic regression analysis showed that the prevalence of the glaucoma-like VF defects and the prevalence of high myopia-related VF defects were associated positively with older age (OR, 1.07 [95% confidence interval (CI), 1.04–1.10; $P < 0.001$] and 1.06 [95% CI, 1.04–1.10; $P < 0.001$]) and longer AL (OR, 1.65 [95% CI, 1.32–2.07; $P < 0.001$] and 1.37 [95% CI, 1.11–1.68; $P = 0.003$]), respectively (Table 4). The differential effect test suggested significantly different effects of AL on glaucoma-like VF defects and high myopia-related VF defects, with a higher effect on the prevalence of glaucoma-like VF defects than on the prevalence of high myopia-related VF defects ($P = 0.036$). In contrast, the effect of age did not differ on both parameters ($P = 0.575$; Table 4).

Discussion

We propose a new and broader VF classification system for high myopia without myopic maculopathy, which includes normal type, glaucoma-like defects, high myopia-related defects, and combined defects and has a relatively high intraobserver and interobserver agreement. Additionally, we found that 10.8% of highly myopic eyes without myopic maculopathy showed glaucoma-like VF defects, the prevalence of which was associated with longer AL. The system may provide a common framework for clinical and epidemiologic studies of high myopia and glaucoma.

Standardized classifications have played an important role in promoting clinical and epidemiologic studies. The Early Treatment Diabetic Retinopathy Study severity scale for diabetic retinopathy and the International Meta-Analysis for Pathological Myopia classification for myopic maculopathy have been used widely by researchers and clinicians[21,28]; however, a commonly accepted VF classification system for high myopia, which has become an important sight-threatening disease, has been missing so far.[3,5,6] Based on the OHTS classification and a high number VF tests in participants with high myopia,[25] we developed this new classification of VF defects in highly myopic eyes.

This classification system differentiates among 4 major VF types: normal type, glaucoma-like defects, high myopia-related defects, and combined defects. Some of the identified VF defects were similar to those in the OHTS classification,25 such as paracentral defect, arcuate defect, vertical step, and partial peripheral rim; however, we also modified some of them to make them more applicable to high myopia (Table S1, available at www.aaojournal.org). For example, we revised “cannot include more than 1 significant point

(on either plot) in the nerve fiber region on the temporal side" in the nasal step of OHTS to "can include more than 1 abnormal test point in the nerve fiber bundle region on the temporal side, but the abnormal test points on the temporal side cannot be contiguously clustered." As another example, we also revised "the defect is generally contiguous with either the blind spot or the nasal meridian" in the partial arcuate defect of OHTS to "the defect might not be contiguous with either the blind spot or the nasal meridian." Moreover, we added some novel myopia-specific defect patterns, such as enlarged blind spot, nonspecific defect, and nasal step with enlarged blind spot.

The validation of our proposed classification system for VF defects showed relatively good agreement. After being trained to use the new classification, the 2 VF graders obtained an average intraobserver agreement of 87% ($\kappa = 0.84$) and interobserver agreement of 82.2% ($\kappa = 0.79$) for all abnormal VF results. This was better than the VF classification of high myopia reported by Ding et al,[19] with a κ value between 2 readers of 0.56, but slightly lower than the values of 88% for superior hemifield interobserver agreement and 89% for inferior hemifield interobserver agreement found in the OHTS.[25] A possible reason for the lower interobserver agreement as compared with the OHTS may be that the OHTS reported the agreement among readers as the percentage of hemifield classification, whereas we presented the percentage of classification of all categories.[25]

The most common defect in our classification was an enlarged blind spot, which is in line with the findings of Ding et al.19 Previous studies indicated that peripapillary atrophy and an optic disc tilt lead to an enlargement of the blind spot and were the most common causes for an enlarged blind spot in static perimetry.29 In support of this hypothesis, our current results indicate that, among the 123 eyes with an enlarged blind spot, 120 (97.6%) showed peripapillary atrophy, and 91 (74.0%) showed an optic disc tilt. Nonspecific defect, added as a novel pattern in our study, is the next most common VF defect. The irregular stretching and bending during axial elongation resulting from high myopia may be a cause of atypical damage to the retinal nerve fiber layer, potentially leading to this type of VF defect (Fig S2 [available at www.aaojournal.org], for example, shows the repeatability of a nonspecific defect).30 Further studies may evaluate the mechanism that caused the VF defects in eyes with high myopia.

Classically, paracentral defect, nasal step, partial arcuate defect, and arcuate defect are associated strongly with glaucoma.[25] In the present study, we found that 10.8% of highly myopic eyes without myopic maculopathy showed these glaucoma-like VF defects. These eyes also tended to have longer AL, consistent with previous studies that longer AL is a risk factor for glaucoma.[6,10,12,31,32] The figure of 10.8% in our study was lower than the figure reported by Ding et al,[19] who showed that 16.1% fields demonstrated the glaucomatous defect. We suggest 2 possible reasons for the difference. First, they had only 1 VF to identify an abnormality. In contrast, we repeated those tests and then chose the VF with a less serious defect (based on the mean deviation of the VF) for final analysis. Second, the eyes with significant myopic maculopathy that might mimic glaucomatous VF defects were excluded from our study but were included in the study of Ding et al.

In addition to its use with clinical trials and epidemiologic studies, the classification system provides a tool for clinicians to distinguish glaucoma-like defects from high myopia-related defects at the time of patient encounter. The diagnosis of glaucoma in highly myopic eyes has remained challenging, especially when intraocular pressure is within the normal range. Therefore, in the current study, we defined POAG by glaucomatous optic disc changes with corresponding glaucomatous VF defects and an intraocular pressure of 21 mmHg or more. We found that 38 eyes were given a diagnosis of POAG among the 142 eyes with glaucoma-like defects and combined defects. This indicates that even individuals categorized as having glaucoma-like defects or combined defects also might be overdiagnosed. Because progression is a defining feature of glaucoma, follow-up perimetric examinations to confirm progression may offer a clue to determine whether the remaining eyes with glaucoma-like defects and combined defects have POAG.[31,33]

The strengths of the proposed classification system include a large number of highly myopic study participants, good repeatability and reproducibility agreement, having repeated sets of testing for VF abnormalities, and the exclusion of eyes with myopic maculopathy. The limitations of this study should be noted as well. First, the study participants mostly were recruited at a tertiary hospital and not from a population-based study. Also, the participants were relatively younger, suggesting the possibility of a referral bias. The ability of this classification system to be generalizable directly to other high myopia groups in the general population has yet to be determined. Second, limited by the prevalence of VF defect in the general population (approximately 4.8%–6.5%) and the prevalence of glaucomatous optic neuropathy of 27.2% in highly myopic eyes,[12,25,34] a relatively small number of abnormal VF findings (25.9%) was identified in the current study. Third, because of the effects of perimetric learning, the reproducibility of the defect classification of the first and second VF tests was 31.2% among the 337 abnormal VF eyes; however, we performed a third VF test to confirm the patterns for these eyes, and the VF test with the least serious defect was chosen for the final analysis, which could minimize the effects. Fourth, a previous study already addressed the topic of a classification of perimetric defects in highly myopic eyes.19 This study and the current investigation refer to the OHTS classification, explaining some overlap between the classification schemes of both studies.16 The current study differs from the previous investigation (1) in a relatively large clinical sample of 1893 VF reports as the basis of the current study; (2) in discussions of the current classification scheme in consensus meetings comprising 12 international members, including glaucoma and retinal specialists and clinician scientists; (3) by including perimetric findings obtained from the Glaucoma Suspects with High Myopia study group; (4) by including descriptions of novel patterns of perimetric defects and modification of previous definitions; (5) by excluding highly myopic eyes with myopic maculopathy, which by itself could have caused VF defects; (6) by the necessity of having a minimum of 2 and a maximum of 3 reliable test results in the case of abnormal VF findings; and (7) by a significantly higher intraobserver and interobserver agreement in the current study. Fifth, we defined the partial peripheral rim defect as a general continuous field loss outside of 15°, showing some curved shape, but not in all quadrants; however, myopic peripheral rim defects are sometimes located outside the 20° to 30° region.35 The 24–2 VF testing performed in this study thus might have missed some peripheral rim defects. Finally, because the testing points of program 24–2, as compared

with programs 10–2, 24–2C, and the G pattern, are less densely arranged in the macular region, identifying central VF defects might have been difficult in the current study.[36–38]

In summary, we propose a new, comprehensive VF classification system for high myopia without myopic maculopathy that is based on results of previously published studies and also on observations made in a prospective, longitudinal high-myopia study. This system comprised 4 major types: normal type, glaucoma-like defects, high myopia-related defects, and combined defects. A relatively high intraobserver and interobserver agreement was found using this classification system. In addition, we showed that glaucoma-like VF defects were present in 10.8% of highly myopic eyes, with their prevalence increasing with longer AL. This system provides a tool for clinicians to distinguish glaucomatous VF loss from nonglaucomatous VF defects in highly myopic eyes in clinical practice and also may facilitate a comparison of findings among clinical trials and epidemiologic studies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Abbreviations and Acronyms:

AL	axial length
CI	confidence interval
D	diopter
OHTS	Ocular Hypertension Treatment Study
OR	odds ratio
POAG	primary open-angle glaucoma
VF	visual field

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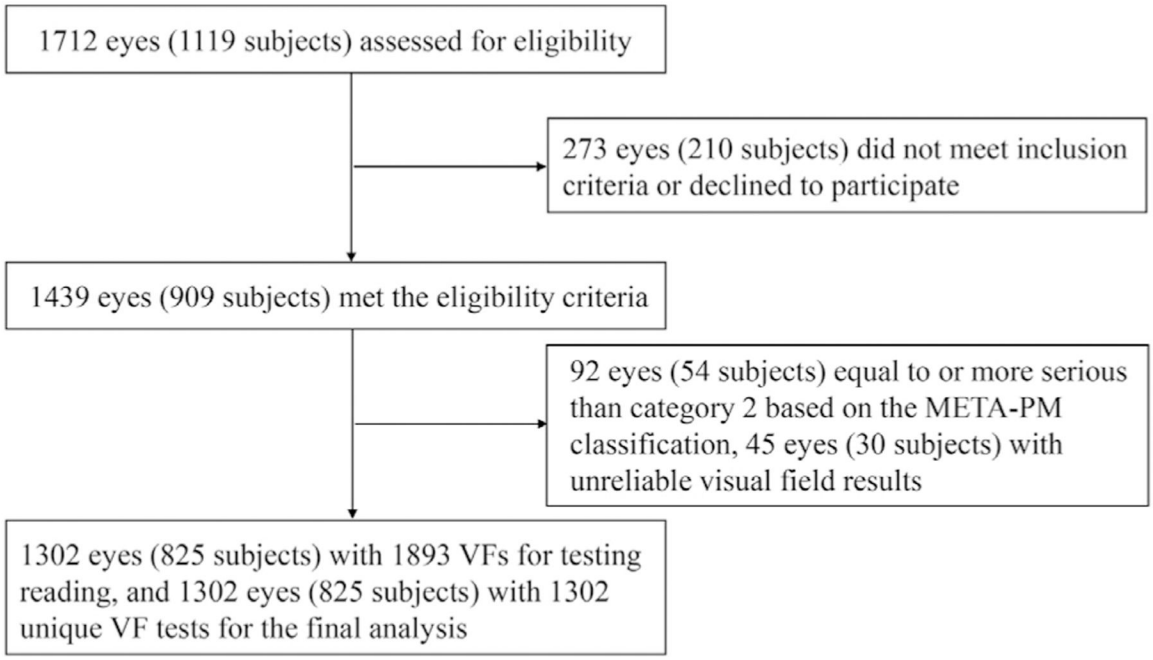

Figure 1.
Flowchart showing inclusion and exclusion of eyes in this study. META-PM = Meta-Analysis for Pathological Myopia; VF = visual field.

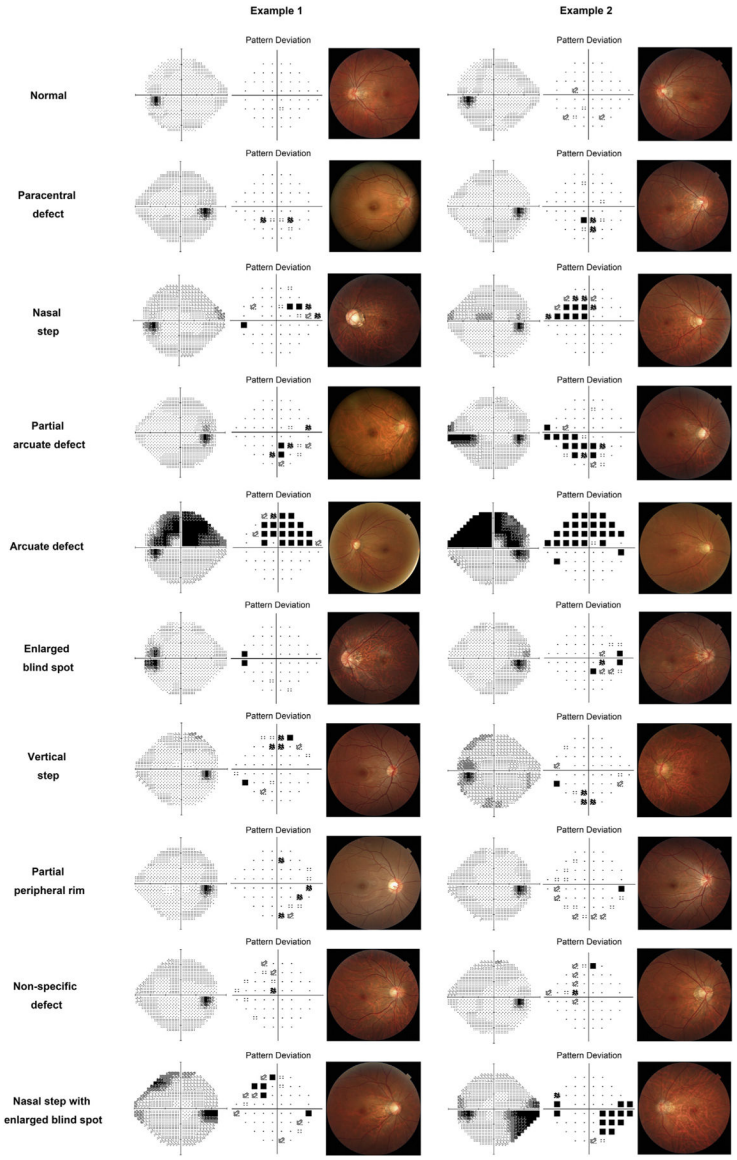

Figure 2.
Examples of the visual field abnormality classification with the corresponding fundus photographs.

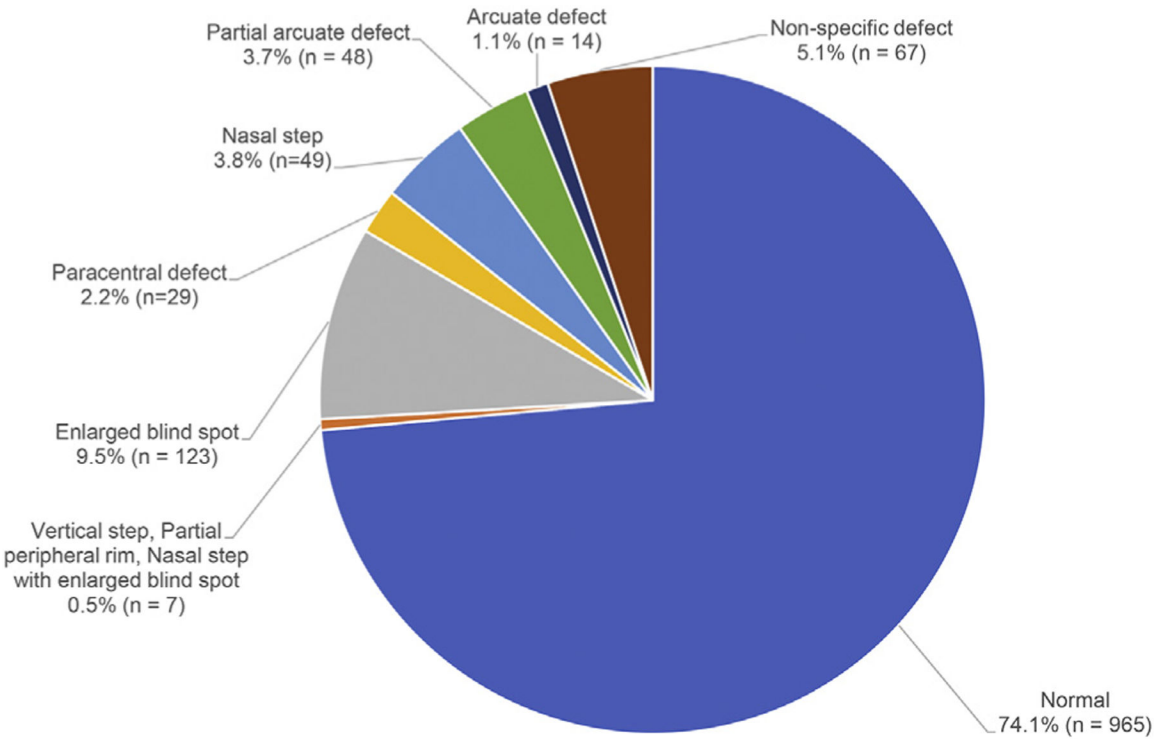

Figure 3.
Pie chart showing the frequency distribution of each visual field type in highly myopic eyes.

Table 1.

Visual Field Abnormality Classification in Nonpathologic Highly Myopic Eyes

Type	Pattern	Definition
Normal		Pattern standard deviation within normal limits and no VF defects. *
Glaucoma-like defects	Paracentral defect	A relatively small VF defect in the nerve fiber bundle region. The defect generally is not contiguous with the blind spot or the nasal meridian. Does not involve points located outside of 15° that are adjacent to the nasal meridian.
	Nasal step	Limited field loss adjacent to the nasal horizontal meridian. Includes at least 1 abnormal test point † located at or outside of 15° on the nasal horizontal meridian. Can include >1 abnormal test point in the nerve fiber bundle region on the temporal side, but the abnormal test points on the temporal side cannot be clustered contiguously.
	Partial arcuate defect	Visual field loss in the nerve fiber bundle region that extends from the temporal side to the nasal side. Must include at least 1 abnormal test point in the temporal half of field. The defect might not be contiguous with either the blind spot or the nasal meridian.
	Arcuate defect	Significant VF loss in the nerve fiber bundle region extending across contiguously abnormal test points from the blind spot to at least 1 point outside of 15° adjacent to the nasal meridian.
High myopia-related defects	Enlarged blind spot	At least 2 abnormal test points with $P < 0.05$ contiguous with the blind spot and at least 1 worse than $P < 0.01$ in the pattern deviation plot.
	Vertical step	Limited VF loss that respects the vertical meridian. Includes at least 2 abnormal test points located at or outside of 15° along the vertical meridian.
	Partial peripheral rim	General continuous field loss located outside of 15° showing some curved shape but not in all quadrants.
	Nonspecific defect	A VF defect that does not belong to another defect type or classification.
Combined defects	Nasal step with enlarged blind spot	Nasal step paired with enlarged blind spot in the field.

VF = visual field.

* A reproducible (in at least 2 consecutive reliable tests) reduction in sensitivity at a cluster of 2 or more contiguous test points with $P < 0.01$ loss or more or a cluster of 3 or more contiguous test points with $P < 0.05$ loss or more in the pattern deviation plot in the superior or inferior arcuate areas, or a 10-dB difference across the nasal horizontal midline at a cluster of 2 or more adjacent test points in the total deviation plot.

† Point with $P < 0.05$ loss or more in the pattern deviation plot.

Table 2.

Demographic and Ocular Characteristics of Study Participants

Characteristics	Description
By participant, no.	825
Age, yrs	30.94 ± 9.75 (18.00–64.00)
Sex, no. (%)	
Female	511 (61.94)
Male	314 (38.06)
Education level, no. (%)	
Low (primary/below education)	61 (7.39)
High (secondary/above education)	764 (92.61)
Self-reported history of diabetes, no. (%)	4 (0.48)
Self-reported history of hypertension, no. (%)	9 (1.09)
Blood pressure, mmHg	
Systolic	114.38 ± 13.99 (82.00–170.00)
Diastolic	66.59 ± 10.25 (40.00–119.00)
By eye, no.	1302
BCVA, logMAR	0.01 ± 0.05 (0.30 to −0.10)
Baseline IOP, mmHg	13.89 ± 2.47 (6.00–33.60)
Axial length, mm	26.87 ± 1.13 (23.58–33.54)
Spherical equivalent, diopter	−8.61 ± 2.10 (−20.13 to −3.50)
CCT, μm	541.57 ± 33.21 (417.00–655.00)
MD of VF, dB	−1.92 ± 2.14 (−28.91 to 2.07)
PSD of VF, dB	2.27 ± 1.68 (0.98–15.40)
VFI of VF, %	97.99 ± 4.64 (20.00–100.00)
Classification of myopic maculopathy, no. (%)	
0	402 (30.88)
1	900 (69.12)
Plus lesions	0 (0)
Posterior staphyloma	0 (0)

BCVA best-corrected visual acuity; CCT central corneal thickness; IOP intraocular pressure; logMAR logarithm of the minimum angle of resolution; MD mean deviation; PSD pattern standard deviation; VF visual field; VFI visual field index.

Data are presented as mean ± standard deviation (range), unless otherwise indicated.

Table 3.

Intraobserver and Interobserver Agreement of the Visual Field Classification System in Nonpathologic Highly Myopic Eyes

Parameter	No.	Agreement (%)	κ (95% Confidence Interval)	Standard Error
All VFs				
Intraobserver				
Reader 1	1000	92.5	0.90 (0.88–0.92)	0.010
Reader 2	1000	91.5	0.89 (0.87–0.91)	0.011
Interobserver *	1000	89.1	0.86 (0.84–0.88)	0.012
VFs with abnormality †				
Intraobserver				
Reader 1	608	87.8	0.85 (0.82–0.88)	0.015
Reader 2	616	86.2	0.83 (0.80–0.87)	0.017
Interobserver *	613	82.2	0.79 (0.75–0.82)	0.018

VF = visual field.

*Results of the second assessment of the 2 readers.

†The fields both graders read as normal were removed from the 1000 VFs.

Table 4.

Regression Analysis of Associations between Abnormal Visual Field Defects and Ocular and Systemic Parameters in Nonpathologic High Myopia Eyes

	Univariate Regression by Generalized Estimating Equation Model*				Bivariate Multivariate Logistic Regression by Generalized Linear Mixed Model†				
	Glaucoma-like VF Defect		*High Myopia-Related VF Defect*		*Glaucoma-like VF Defect*		*High Myopia-Related VF Defect*		
Parameter	***Odds Ratio (95% CI)***	**P *Value***	***Odds Ratio (95% CI)***	**P *Value***	***Odds Ratio (95% CI)***	**P *Value***	***Odds Ratio (95% CI)***	**P *Value***	**P *Value for Differential Effect***
Age, per 1 yr	1.04 (1.02–1.06)	**<0.001**	1.03 (1.01–1.05)	0.002	1.07 (1.04–1.10)	**<0.001**	1.06 (1.04–1.10)	**<0.001**	0.575
Sex, female vs. male	1.01 (0.67–1.51)	0.970	1.39 (0.96–2.02)	0.083					
Education level, high vs. low	0.94 (0.44–1.99)	0.871	0.74 (0.37–1.45)	0.375					
Blood pressure, per 1 mmHg									
Systolic	0.99 (0.98–1.01)	0.463	0.99 (0.98–1.00)	0.093					
Diastolic	1.01 (0.99–1.03)	0.420	0.99 (0.97–1.01)	0.258					
BCVA (logMAR < 0.1), per 0.1-logMAR unit	0.57 (0.21–1.58)	0.281	0.49 (0.20, 1.24)	0.134					
Baseline IOP, per 1 mmHg	1.01 (0.93–1.08)	0.885	0.95 (0.88–1.02)	0.132					
Axial length, per 1 mm	1.33 (1.11–1.61)	**0.002**	1.30 (1.11–1.54)	**0.002**	1.65 (1.32–2.07)	**<0.001**	1.37 (1.11–1.68)	**0.003**	**0.036**
CCT, per 1 μm	1.00 (0.99–1.00)	0.617	1.00 (0.99–1.00)	0.932					

BCVA = best-corrected visual acuity; CCT = central corneal thickness; CI = confidence interval; IOP = intraocular pressure; logMAR = logarithm of the minimum angle of resolution; VF = visual field. Boldface values indicate statistical significance.

*Adjusted for correlation between eyes.

†All variables with $P < 0.05$ in the univariate regression analysis were included in the bivariate multivariate regression analysis by the generalized linear mixed model, which is a single model that allows for 2 dichotomous outcomes (glaucoma-like visual field defect and high myopia-related visual field defect) and allows testing of both the effect of covariates on outcomes (in terms of odds ratios) and whether the odds ratios for a given covariate differ across the 2 outcomes.