

Original Article

Community-Based Ocular Screening Integrated into Primary Healthcare for Older Adults: Design and 2-Year Follow-Up Results

Gu Zheng^{1,2}, Shiqi Hu^{1,2}, Yiming Zhao^{1,2}, Yanyan Lin^{1,2}, Hairui Jiao^{1,2}, Wanwan He^{1,2}, Tianhao Huang^{1,2}, Shilei Wang^{1,2}, Cong Ye^{1,2}, Meixiao Shen^{1,2}, Ming Li^{1,2}, Jie Chen^{1,2}, Xinting Liu^{1,2*}, Fan Lu^{1,2,3*}

¹Eye Hospital and School of Ophthalmology and Optometry, Wenzhou Medical University, Wenzhou, Zhejiang, China; ²National Clinical Research Center for Ocular Disease, Wenzhou, Zhejiang, China; ³Oujiang Laboratory (Zhejiang Lab for Regenerative Medicine, Vision and Brain Health), Eye Hospital, Wenzhou Medical University, Wenzhou, Zhejiang, China.

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ABSTRACT: This research aims to describe the design, objective and feasibility of a pioneering community-based eye screening program intended to facilitate the provision of ocular services to the elderly. As a prospective investigation, this project innovatively integrates comprehensive eye examinations into routine annual physical assessments by leveraging cutting-edge automation, digital documentation, and real-time data transmission technologies. Eligible participants included community-dwelling adults aged ≥ 60 years undergoing health check-ups. Four foundational ophthalmic assessments, namely presenting distance visual acuity, autorefractometry, intraocular pressure and non-mydriatic fundus photography, were measured to detect prevalent age-related eye diseases. Further, a dual-validation system combining artificial intelligence-driven analysis with on-site expert confirmation was implemented for high-risk case identification. Additionally, a tiered management strategy featuring rapid referral pathways was established to ensure timely tertiary care access. Among 3785 eligible residents, 3459 (91.4% response rate) completed initial screening, with an average examination duration of 4-8 minutes. Following expert validation, 1679 participants (48.5%) required advanced evaluation. Substantial unmet ophthalmic needs were uncovered, with prevalence rates of cataract (43.5%), age-related macular degeneration (37.5%), uncorrected refractive errors (14.6%), glaucoma suspicion (12.4%) and diabetic retinopathy (4.8%). A two-year follow-up analysis demonstrated observed visual improvements, particularly in younger cohorts (60-69 years). In contrast, the relatively older subgroup (70-74 years) exhibited progressive decline. This investigation establishes a model for geriatric vision care that demonstrated feasibility through its synergistic integration of technological innovation and existing primary community health infrastructure, although scalability to other populations and low referral completion require further evaluation.

Keywords: ocular screening, community-based, visual impairment, elderly

INTRODUCTION

Visual impairment and blindness are prominent public health concerns and have garnered considerable research and public attention in recent decades due to the rapid ageing of the global population. Demographic projections

reveal a disturbing trajectory that the population with moderate to severe visual impairment will surge from 237 million in 2020 to 588 million in 2050, whereas blindness cases will concurrently rise to 115 million worldwide [1]. The predominant aetiologies, such as uncorrected refractive errors (URE), cataracts, age-related macular

*Correspondence should be addressed to: Dr. Fan Lu (Email: lufan@eye.ac.cn) and Dr. Xinting Liu (liuxt@eye.ac.cn), School of Ophthalmology and Optometry, Wenzhou Medical University, Wenzhou, Zhejiang, China.

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degeneration (AMD), glaucoma and diabetic retinopathy (DR), display markedly higher prevalence in older adults, especially those aged over 60 years [2, 3]. China accounts for one-fifth of the global population; notably, the number of elderly people aged over 60 years is expected to grow to 35% by 2050, which will substantially exacerbate the global burden of vision-related disorders [4]. Due to the inconspicuous symptoms and slow progression of common ocular diseases in the elderly, early detection and treatment are considered crucial to preventing visual impairment. However, most elderly patients did not receive timely eye care, with principal barriers encompassing restricted health literacy regarding ocular diseases and deficiencies in eye care accessibility [5, 6]. Compounding these challenges, visual impairment is also reported to be associated with several adverse systemic outcomes such as low social connection, decreased functional status, reduced mobility, depression, cognitive impairment, dementia and even an elevated risk of death in older people [7, 8]. These compelling associations underscore the imperative for enhanced primary ocular healthcare delivery systems targeting geriatric populations.

The World Health Organization (WHO) recommends that primary eye care be integrated into current primary healthcare systems, which are widely accessible to the majority of the population living in urban and rural areas, to fully utilise the available medical resources (www.who.int/publications/i/item/9789241516570). At present, China has an established community-based healthcare centre system for annual general physical examinations. There are more than 37000 community-based healthcare centres across China, with an average yearly growth of 4.2% (www.stats.gov.cn/sj/ndsj/2025/indexch.htm). The target population of general physical examinations in the community healthcare centres is elderly people aged above 60 years, with a coverage rate of above 75% [9]. A previous study on glaucoma screening and the related cost-utility work found that patients with glaucoma in the screening group were diagnosed 5.1–8.6 years earlier than those diagnosed in the clinic, implying that community-based population screening for glaucoma is likely to be cost-effective in China [10]. Other investigations have also reported that screening for ocular diseases among the elderly is essential for detecting referable patients requiring comprehensive ocular examinations and for providing timely treatment to avoid further vision loss [11, 12]. The current community-based primary healthcare centre system has the potential to be an ideal platform for providing opportunistic ocular screening and covering the majority of the elderly in the community, while considering the well-established management system of community healthcare centres, accessibility of basic

medical services and the high adherence of the elderly [5, 10, 13]. Although there is presently a shortage of eye care providers in community healthcare centres in China, with the mature development of automated ophthalmic instruments, a feasible and reliable eye examination and healthcare solution that is suitable for ordinary technicians, easy to operate, highly accurate and can be integrated into existing healthcare systems is anticipated to be explored.

With support from the local community, we launched a community-based eye examination and healthcare project for the elderly, which aims to: (a) determine whether, from a cross-sectional study, the integration of opportunistic ocular screening into existing general physical examinations within the community is a feasible and applicable strategy for supporting ocular service delivery to the elderly; (b) evaluate how well the project detects early visual problems and hidden ocular diseases in the elderly; (c) estimate the long-term results of the project on older adults in terms of visual status. This report describes the study design, methodology and outlook of the community-based eye examination and healthcare project and summarises the baseline characteristics and two-year follow-up findings from a visual impairment perspective.

METHODS

Study design, participants and recruitment process

This is a longitudinal, observational cohort study conducted within community settings by the Affiliated Eye Hospital of Wenzhou Medical University. This examination was conducted according to the principles of the Helsinki Declaration and was approved by the ethics committee of the Eye Hospital of Wenzhou Medical University (identifier: 2021-086-K-73-01). After explaining the purpose of the study, the examination process, and the possible benefits and potential risks, written informed consent was obtained from all participants. For participants who were illiterate or unable to write, the researchers primarily communicated with them in the local dialect to ensure their full understanding of the ocular screening, following which they provided informed permission by fingerprinting. When family members were present, the authors also obtained their consent and support.

The study was conducted in Yaoxi Community, located in eastern Wenzhou City, Zhejiang Province, China. Covering an area of 33.46 km², this community administers 19 villages and is situated in an urban-rural fringe area. Nearly 4000 residents aged over 60 years participated in the general physical examinations every year. All community residents presenting to the Yaoxi

Community Healthcare Centre from 12 September to 15 November 2021 for their annual general physical examinations and blood collection were invited to engage in the eye examination and healthcare project. The standardised examination flow of the project is illustrated in Figure 1. The ocular screening comprised three steps: basic ocular examinations, outpatient service provision and further referral. First, four basic ocular examinations based on automatic ocular equipment were performed for screening common ocular diseases in the elderly. Subsequently, the findings of these four examinations

were analysed using artificial intelligence (AI) diagnostic technology combined with manual confirmation at an on-site ophthalmology expert consultation; moreover, further slit-lamp examination and explanations were provided. Finally, those with a high risk of ocular disorders were advised to be referred to the eye hospital via a rapid referral channel. The eye examination and healthcare project was opened to all participants, and this paper summarised the impact of this novel ocular screening model applied to the elderly aged ≥ 60 years.

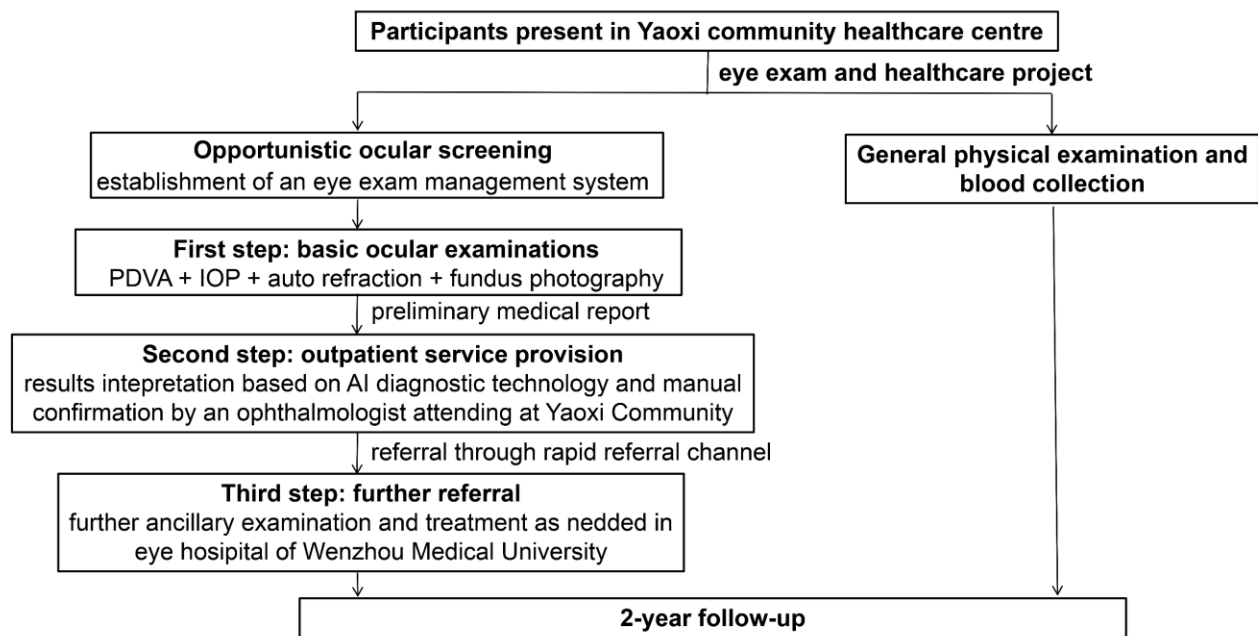


Figure 1. The standardised examination flow of the eye examination and healthcare project. PDVA: presenting distance visual acuity; IOP: intraocular pressure; AI: artificial intelligence.

General physical examination and blood collection

Residents who participated in the general physical examination underwent several examinations, such as height, weight, waist circumference, blood pressure, abdominal ultrasound scan, electrocardiogram measurements and chest X-ray. They were asked about their hearing, exercise methods, cigarette use and alcohol consumption. A urine sample and fasting venous blood sample were collected for routine urine and blood examinations, including fasting blood glucose, blood urea nitrogen, serum uric acid, serum creatinine, aspartate aminotransferase, alanine transaminase, total bilirubin, total cholesterol, total triglycerides, high-density lipoprotein-cholesterol and low-density lipoprotein-cholesterol, among others. In addition, serum and plasma extracted from the blood samples after processing were stored in the laboratory. All examinations were performed

by experienced local clinicians and in accordance with standardised methods. The general physical examinations and blood collection at community healthcare centres have been running for several years, and both community clinicians and the elderly are very familiar with the process of physical examinations and ensure good compliance. The proposed eye examination and healthcare project is followed up with routine general physical examinations.

Establishment of an eye exam management system

An eye examination management system, including automatic ocular screening equipment for fundamental ocular examinations, real-time data transmission, electronic data recording and automatic fundus photography pre-judgement technology, was established to make the screening procedure more convenient. The

management system of the eye examination and healthcare project leverages hardware technology innovation and software improvement, which include automatic ocular equipment combined with a calibration and tracking system, as well as accelerated detection, error correction and automatic online output. The initial baseline data for the project were collected electronically via a custom-made application on a mobile device, developed by Clear Vision Company.

According to the eye examination management system, the basic information of the participants, such as their name, gender, date of birth and address, was automatically procured from their identity cards by the card reader for registration. Upon successful registration, the eye exam system generated a unique QR code for each participant. After scanning the QR code with a mobile phone, examiners can quickly access the recording interface for each fundamental ocular examination item. Four basic ocular examination items that include presenting distance visual acuity (PDVA), autorefractometry, intraocular pressure (IOP) and fundus photography were conducted by trained staff between 8:00 a.m. and 11:30 a.m. Tests were performed on both eyes, starting with the right eye.

Assessment of the basic ocular examinations and quality control

1. PDVA: PDVA was measured monocularly according to the Chinese Standard Logarithmic Visual Acuity E Scale (GB 11533-2011) using an electronic eye chart (WSVC-100; Clear Vision; Hangzhou, China), with the participants wearing a habitual optical prescription (spectacles, if any) at a distance of 5 m. Those who could not read the largest optotype were asked to move closer, and if any optotype was not identified at a distance of 1 m, PDVA was recorded as counting finger, hand motion, light perception or no light perception. For those with a PDVA worse than 20/40 in either eye, pinhole visual acuity was further assessed using a pinhole occluder to test whether it could improve the results by one or two lines [14]. By using an electronic eye chart, the examiner stood beside the participants to conduct a remote PDVA examination while simultaneously monitoring the entire process and correcting improper occluder use among the elderly. When the examination was completed, the findings were recorded digitally and transmitted in real time.

2. Refraction and keratometry: A full auto refractor-keratometer (WSRMK-8000; Vision; Shanghai, China) was used to measure noncycloplegic autorefractometry (including sphere, cylinder and cylinder axis) and conduct keratometry readings. After placing the head into the right position, the average result of three rapid measurements

was obtained automatically and transmitted simultaneously.

3. IOP: The IOP examination was performed using a full auto non-contact tonometer (HNT-7000; Huvitz; Gyeonggi-do, Korea); the average of three IOP measurements in each eye was digitally recorded as the result and uploaded into the system simultaneously. Palpation estimation was performed if the IOP could not be measured due to corneal abnormalities.

4. Fundus photography: Using a non-mydratric fully automatic fundus camera (RetiCam 3100; SYSEYE; Chongqing, China), which has a voice guidance function that instructs the operator and participants to finish the shooting process, 45-degree retinal images were obtained after the camera focussed on the pupil and uploaded automatically. For participants who were unable to cooperate during imaging, repeated attempts were made after providing an explanation. For those with poor image quality, the reason was documented accordingly.

All the examiners were trained by qualified personnel and acquired the competence before conducting the basic eye examinations. The screening examination prioritized feasibility and ease of administration, and these methods showed high agreement both among different operators and with standard hospital equipment [15]. Although these methods may have lower specificity compared to gold-standard dilated eye examinations, the screening model was considered suitable in the population-based screening setting [16]. Calibrations for automated devices were performed daily prior to ocular screening. To ensure the accuracy and integrity of data collection and storage, quality control procedures were performed throughout the basic ocular examinations. The data for the four ocular examinations were uploaded and stored automatically onto a secure central server in a password-protected file after each examination. During the examination process, examiners were able to quickly enter the data editing interface to confirm the ocular results. Supervisors oversaw the data collection through regular visits to ensure adherence to the standardised data collection procedures. Incorrectly input data were verified and corrected by the screening staff.

Double-checking of AI diagnostic technology and expert confirmation

Upon the completion of the four baseline ocular examinations, all the findings were analysed using an AI-assisted diagnostic system, followed by on-site expert verification. An experienced ophthalmologist was assigned to the Yaoxi Community Healthcare Centre, who confirmed the outcomes of ocular examinations based on an AI-assisted system, and further examined the anterior segment of the eye with a slit-lamp biomicroscope

(IEC601-1, SL-1E, Topcon, Japan). Under the slit-lamp examination, anterior segment ocular diseases affecting visual acuity, such as cataract, pterygium, nebula and abnormal eyelid, were diagnosed and recorded in the custom-made application. AI-assisted fundus photography reading and pre-judgement system combined with expert double-checking makes the early warning for suspect high-risk patients.

Diagnosis and definitions

Visual impairment was defined according to the WHO 2003 criteria and based on the PDVA results in the better eye, such as no visual impairment ($PDVA \geq 20/40$), mild visual impairment ($20/60 \leq PDVA < 20/40$), moderate visual impairment ($20/200 \leq PDVA < 20/60$), severe visual impairment ($20/400 \leq PDVA < 20/200$) and blindness ($PDVA < 20/400$) (<https://icd.who.int/browse11/l-m/en>). URE was defined as spherical equivalent ≤ -0.75 D or $\geq +1.0$ D, with $PDVA < 20/40$ in the better-seeing eye [17]. A participant was classified as a glaucoma suspect if any of the following characteristics were observed in either eye: IOP > 21 mmHg, vertical cup-to-disc ratio (CDR) ≥ 0.6 , CDR asymmetry between the two eyes ≥ 0.2 , neural rim tissue ratio ≤ 0.1 , optic disc margin haemorrhage, diffused or localised defect of the retinal nerve fibre layer [18]. AMD screen-positive status was defined according to the Clinical Classification of Age-Related Macular Degeneration developed by the Beckman Initiative for Macular Research Classification Committee, and those with geographic atrophy involving the center of fovea/any of features associated with neovascular AMD were recommended for referral [19]. DR screen-positive status was defined based on the International Classification of Diabetic Retinopathy and Diabetic Macular Edema, and those with moderate/severe non-proliferative or proliferative DR, DME was suggested to be referred [20]. Cataract diagnosis and severity grading were initially assessed using fundus photographs, which were classified into five grades as follows: grade 0, fundus structures clearly visible; grade 1, retinal small vessels vaguely visible; grade 2, retinal large vessels vaguely visible; grade 3, optic disc vaguely visible; and grade 4, fundus structures completely invisible [21]. For participants with grade 2 or higher, slit-lamp examination using the Lens Opacities Classification System II (LOCS II) was performed for further verification. Participants with moderate to severe cataracts (cortical grades were more than or equal to 3, nuclear grade for colour or opalescence, or posterior subcapsular cataract is more than or equal to 2) with $PDVA < 20/40$ were suggested to be referred.

AI model specification and validation

The development of the AI model consists of two main steps: quality control and model training. To ensure diagnostic reliability, a dedicated quality control module was developed to identify and exclude images of insufficient quality caused by blurriness, improper lighting, or shadowing. Our team previously collaborated with Evison Technology to successfully develop an artificial intelligence algorithm software, EVISION-GLA, for identifying common fundus diseases based on over 100000 color fundus photographs. This software has obtained a Medical Device Registration Certificate in China (identifier: Zhejiang Medical Device Registration 20222210022) and has been applied in clinical practice [22, 23]. For each disease category, internal validation was performed using a large dataset of color fundus photographs. The datasets were randomly split into training, validation, and test sets in an 8:1:1 ratio. Specifically, there are more than 30000 images for DR, more than 30000 images for AMD and more than 20000 images for glaucoma. All images were obtained from patients attending routine eye examinations, and the validation population reflected the target screening population. No external validation using an independent dataset from a different population or setting was performed, which is acknowledged as a limitation.

For each disease, specific deep learning networks were employed, and diagnostic performance metrics were calculated against expert ophthalmologist consensus as the reference standard. For suspected glaucoma, a segmentation pipeline based on TransUnet and DETR was employed to identify the optic disc, optic cup, and retinal nerve fiber layer defects, followed by cup-to-disc ratio calculation. This approach was combined with a classification network to assess glaucoma likelihood, achieving an accuracy of 95.81%, a sensitivity of 99.36%, a specificity of 97.95%, and a false-negative rate of 0.64%. For DR detection, the system primarily utilized a TransUnet-based network to identify lesions, including microaneurysms, hemorrhages, hard exudates, and cotton-wool spots. DR and its grading were then determined based on lesion detection metrics such as lesion count and total area, yielding an AI-expert agreement rate of 96.6%, a sensitivity of 96.79%, a specificity of 96.33%, and a false-negative rate of 3.21%. For AMD detection, the system uses an SSD object detection network to locate the macula, followed by a classification network to identify AMD. The AI achieved an accuracy of 95.81%, a sensitivity of 99.36%, a specificity of 97.95%, and a false-negative rate of 0.64%. In cases of disagreement between the AI output and the initial expert review, a third senior ophthalmologist was consulted to adjudicate the final diagnosis.

Further referral

Any participants with ocular diseases or visual impairment who met the prespecified referral criteria (Fig. 2) were advised to attend the Eye Hospital of Wenzhou Medical University for final diagnosis and further treatment. An on-site brief explanation of their ocular condition was provided by the experienced expert, and referral to the rapid channel of the hospital was made to

enhance management. A prompt reminder message was sent to the patient's mobile phone after a successful appointment. The referred patients underwent further ancillary examinations based on the ophthalmologist's professional judgement at the eye hospital to confirm the diagnosis and decide on treatment. Given the heterogeneity and complexity among these patients, the treatment plans were individualised according to the ophthalmologist's professional determination.

Eye examination	Referral criteria
Visual acuity	PDVA < 20/40 with pinhole correction in any eye
Refraction	Uncorrected refractive error SE ≤ -0.75D or SE ≥ +1D with PDVA < 20/40 in the better-seeing eye
IOP	Suspect glaucoma > 21mmHg
Fundus photography	Suspect glaucoma optic disc margin hemorrhage; CDR ≥ 0.6, CDR asymmetry between two eyes ≥ 0.2 or neural rim tissue ratio ≤ 0.1; diffused or localized defect of retinal nerve fibre layer
	Referral-recommended DR and DME Anyone of the following stage without treated: non-proliferative or proliferative DR, DME;
	Referral-recommended AMD Advanced AMD: geographic atrophy involving the center of fovea/any of features associated with neovascular AMD
	Other fundus diseases Other referable retinal pathology
Slit lamp	Referral-recommended Cataract moderate to severe cataracts (cortical grades were more than or equal to 3, nuclear grade for color or opalescence or posterior subcapsular cataract is more than or equal to 2) with PDVA < 20/40,
	Other anterior segment diseases Other referable ocular surface disorder: pterygium, nebula, abnormal eyelid

Figure 2. Referral criteria of the eye examination and healthcare project for high-risk individuals. PDVA: presenting distance visual acuity; SE: spherical equivalent; IOP: intraocular pressure; CDR: cup-disc ratio; DR: diabetic retinopathy; DME: diabetic macular oedema; AMD: age-related macular degeneration.

Statistical analysis

The statistical analysis was performed with SPSS statistical software (SPSS version 25.0; IBM Corp., Armonk, NY, USA). The prevalence rates of ocular disorders and referrals were calculated based on the entire sample of participants. The Kolmogorov-Smirnov test was applied to evaluate the normality of the data

distribution. Independent *t*-tests were employed to analyse the differences in normally distributed data between the two groups, whereas Wilcoxon Mann-Whitney tests were used for non-normally distributed data. The χ^2 test was used to evaluate differences in the age and gender groups, and paired *t*-tests were applied to analyse the visual changes during the two-year follow-up. The Stuart-Maxwell test was employed to assess the

symmetry in the distribution shifts of ordinal categories of visual impairment status (e.g. none/mild/moderate/severe) between baseline and follow-up. Linear mixed models were used to examine changes in visual acuity over the 2-year follow-up period. Fixed effects included visit time (baseline vs. 2 years), age, gender, body mass index (BMI), hypertension, diabetes, exercise, smoking, drinking, and the visit time $\times$ age interaction term. Multiple imputation with 20 datasets was performed using predictive mean matching to address potential attrition bias due to older age in participants lost to follow-up. Linear mixed models were fitted to each imputed dataset and pooled using Rubin's rules. A two-tailed $P < 0.05$ was considered statistically significant.

RESULTS

Feasibility evaluation and baseline characteristics of the project

In total, 3459 of the 3785 residents (91.4% response rate) of over 60 years who registered in the annual general physical examinations participated in the eye examination and healthcare project. All participants were Han Chinese,

and most were females (53.7%), aged between 60 and 79 years old (91.9%). The median age of the sample was 68 years (range from 60 to 99 years), and the interquartile range was 65-73 years old.

For each elementary ocular examination item in the first step, the response rates of the participants were high, such as 93.7% for PDVA, 95.6% for autorefraction, 95.1% for IOP and 96.7% for fundus photography examinations. The majority of participants (86.9%) completed the full ocular examinations, with an average time of only about 4-8 minutes to complete the four basic eye examination items using automatic examination technology. Based on the double-checking of AI technology and on-site expert confirmation, 1679 subjects met the referral criteria and were suggested for further examination and treatment in a tertiary hospital, including 1557 participants with abnormal ocular findings on the basic four eye examinations and 122 participants with relative normal performance on basic examinations but had abnormal ocular surface manifestation based on slit lamp (Fig. 3). It previously took an average of 3-7 days for manual image interpretation and report finalization; AI assistance has shortened the turnaround time to within 3 days.

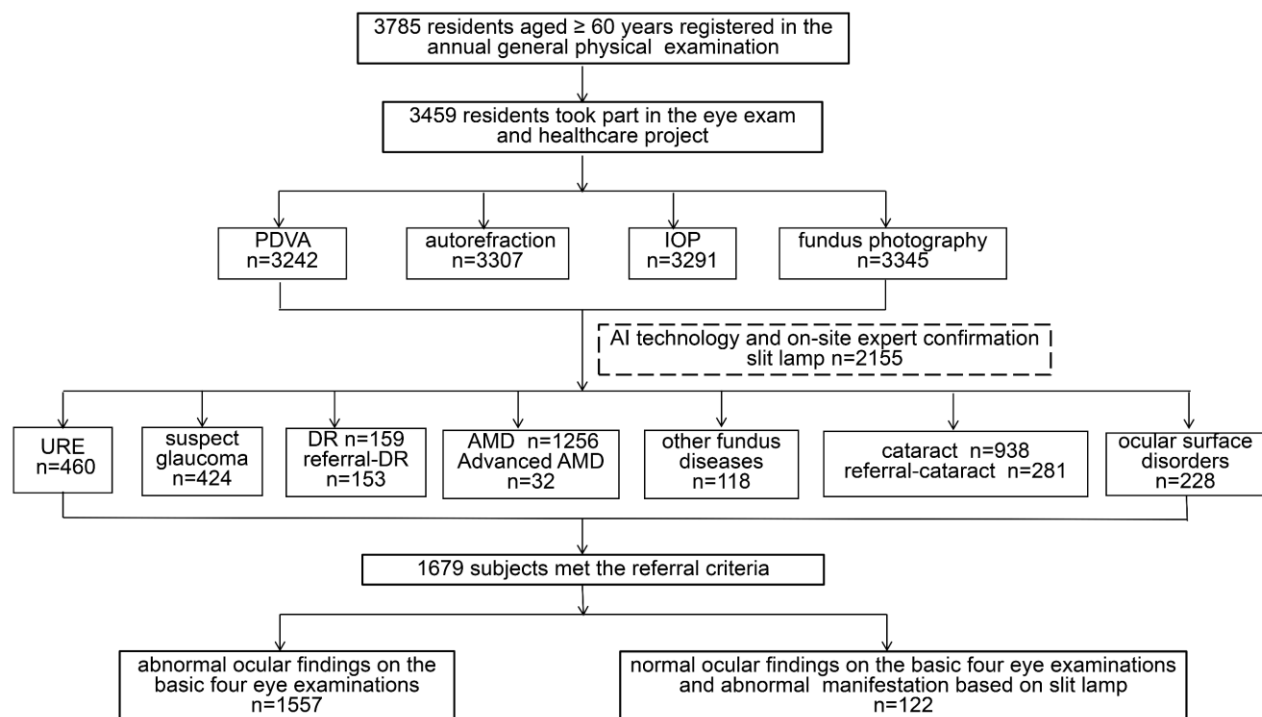


Figure 3. Number of people in each stage of the eye examination and healthcare project. PDVA: presenting distance visual acuity; IOP: intraocular pressure; AI: artificial intelligence; URE: uncorrected refractive error; DR: diabetic retinopathy; AMD: age-related macular degeneration.

Hidden visual problems among the elderly

According to a review of four fundamental ocular examinations and the on-site expert confirmation, hidden ocular disorders among the elderly population were found, including URE in 460 participants (14.6%, 460/3148), suspect glaucoma in 424 participants (12.4%, 424/3422), DR in 159 participants (4.8%, 159/3345), AMD in 1256 participants (37.5%, 1256/3345), and cataract in 938 participants (43.5%, 938/2155). The number of other fundus ocular diseases and common ocular surface disorders was 118 (118/3345=3.5%) and 228 (228/2155=10.6%), respectively (Fig. 3). Disease prevalence denominators varied because each diagnosis relied on a specific examination with its own data quality standards. Specifically, cataract severity was preliminarily graded using fundus photographs on a five-grade scale [21]. Participants with grades 2 or higher underwent further slit-lamp examinations using LOCS II, and a total of 2155 participants completed this evaluation. Valid fundus photography for AMD, DR and other fundus diseases were obtained from 3345 participants (96.7%). Valid and reliable autorefraction readings and visual

acuity measurements for uncorrected refractive errors were obtained from 3148 participants (95.6%), and unreliable readings were excluded. For glaucoma suspicion, gradable optic disc images or IOP measurements were available in 3422 participants. Thus, each denominator reflects the number of participants meeting the examination-specific quality criteria for that diagnosis. Moreover, over 80% of the elderly had never undergone any ophthalmic examination or corresponding treatment before this study. Figure 4 depicts the distribution and tendency of PDVA among different ages in the elderly tested in the eye examination and healthcare project at baseline. The ratio of people with no visual impairment declines gradually, starting at 88.9% for ages 60-64 and reaching 57.0% among those over 85. Among individuals with mild visual impairment, the ratio gradually increases from 6.8% in the 60-64 age group to 26.6% in those aged over 85 years. Moderate visual impairment affects 3.5% of people aged 60-64 years, with the percentage steadily growing to 13.9% in individuals aged over 85 years. For those experiencing severe visual impairment, the ratio progressively increases with age, rising from 0.8% to 4.3%.

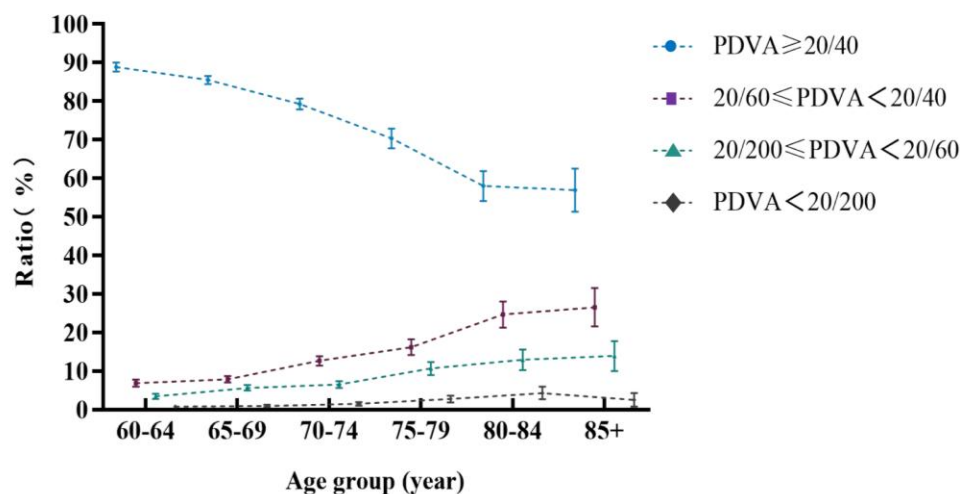


Figure 4. Proportion of participants across different age groups by visual levels in the better-seeing eye at baseline. Data are presented as the percentage of participants within each visual category for every age group: 60-64 years (total n=749): 88.9% (PDVA $\geq 20/40$), 6.8% ($20/60 \leq \text{PDVA} < 20/40$), 3.5% ($20/200 \leq \text{PDVA} < 20/60$), 0.8% (PDVA $< 20/200$); 65-69 years (n=1131): 85.5%, 7.9%, 5.6%, 1.0%; 70-74 years (n=797): 79.3%, 12.7%, 6.5%, 1.5%; 75-79 years (n=327): 70.3%, 16.2%, 10.7%, 2.8%; 80-84 years (n=162): 58.0%, 24.7%, 13.0%, 4.3%; and 85+ years (n=79): 57.0%, 26.6%, 13.9%, 2.5%. Connecting lines across age groups are provided to visualize trends and do not imply a continuous fitted model. PDVA: presenting distance visual acuity.

Referral completion for various ocular diseases

Among the 1679 subjects who met the referral criteria, 151 individuals finally attended the hospital for evaluation. There were no significant differences in baseline characteristics between patients who completed

the referral and those who did not, such as gender, age, BMI, diabetes, hypertension, physical activity, smoking, and alcohol consumption (Supplementary Table 1, all P value > 0.05). Among the 1528 individuals who didn't complete the referral, the proportion for each suggested referral disease category was as follows: 93.8% (30/32)

for AMD, 93.5% (143/153) for DR, 93.5% (430/460) for URE, 90.8% (385/424) for suspected glaucoma, 89.0% (105/118) for other fundus diseases, 87.2% (245/281) for cataract, and 84.2% (192/228) for anterior surface diseases. Specifically, among those who did not complete the visit, 93.0% (133/143) were moderate DR and 67.2% (96/143) had no visual impairment in the better-seeing

eyes. In other disease categories, the prevalence of no visual impairment in the better-seeing eye was 74.5% (287/385) for suspected glaucoma, 72.4% (139/192) for anterior segment diseases, 54.3% (57/105) for other fundus diseases, 46.7% (14/30) for severe AMD, and 40.8% (100/245) for cataract.

Table 1. Comparison of baseline characteristics between participants retained in and lost to follow-up

Characteristic	Total (n=3459)	Follow-up (n=2663)	Lost-to-follow-up (n=796)	Standardized differences	P Value
Age at baseline, y	69.5±6.2	69.0±5.6	71.1±7.8	0.31	<0.001
Gender,				0.05	0.253*
Male	1603 (46.3%)	1220 (45.8%)	383 (48.1%)		
Female	1856 (53.7%)	1443 (54.2%)	413 (51.9%)		
BMI	24.4±3.2	24.5±3.2	24.2±3.4	0.07	0.101
Diabetes	1092 (31.6%)	846 (31.8%)	246 (30.9%)	0.02	0.645*
Hypertension	2393 (69.2%)	1841 (69.1%)	552 (69.3%)	0.01	0.909*
Exercise	1896 (54.8%)	1479 (55.5%)	417 (52.4%)	0.06	0.117*
Current smoking	452 (13.1%)	335 (12.6%)	117 (14.7%)	0.06	0.120*
History of alcohol	1354 (39.1%)	1062 (39.9%)	292 (36.7%)	0.07	0.105*

Data are presented as mean ± standard deviation and number (%). Boldface values indicate statistical significance. P values were obtained from independent *t*-tests, except those marked * (χ^2 tests). BMI: body mass index.

Two-year follow-up of visual changes in the eye exam and healthcare project

After two years, 4970 residents aged over 60 years registered in the annual general physical examination, and 4472 residents participated in ocular examinations. Over half of the participants (53.9%) were female, and the predominant age group was 60-79 years (91.7%). The sample had a median age of 69 (range from 60-95 years) and an interquartile range of 65-73 years (Fig. 5). Among the cohort, 2663 individuals both completed the ocular examinations integrated in the annual general physical examination in 2021 and 2023, with a mean age of 69.0 ± 5.6 years, and 1443 (54.2%) were female. Of the individuals lost to follow-up, 622 discontinued due to scheduling conflicts or relocation with their children, 24 could not be contacted, 13 were attributed to ischaemic stroke, 13 discontinued due to heart disease, 4 cases were lost due to severe mental disorders, and an additional 120 were lost to follow-up for other unknown reasons. The differences in age distribution and health status between retained and lost-to-follow-up participants are shown in Table 1, which indicated a significant difference in age distribution but not in health status. Because participants lost to follow-up ($n = 796$, 23.0%) were older than follow-ups ($P < 0.05$), multiple imputation was performed to assess the impact of potential attrition bias. Pooled results from 20 imputed datasets showed that the visit time $\times$ age interaction remained significant ($\beta = 0.0025$, 95% CI: 0.0007 to 0.0043, $P = 0.008$), consistent with the primary

analysis. The relative efficiency of the imputation was 92.7%, indicating good imputation quality.

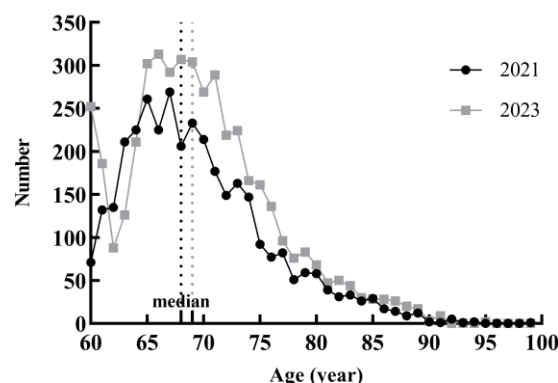


Figure 5. Age distribution trends of participants in the eye exam and healthcare project in 2021 ($n=3459$) and 2023 ($n=4472$). The black and grey dashed lines represent the median age distribution of the population in 2021 (68 years) and 2023 (70 years), respectively.

The number of patients with no vision impairment, mild vision impairment, moderate vision impairment, severe vision impairment or blindness in the better eyes was 2190 (82.3%), 275 (10.3%), 166 (6.2%) and 32 (1.2%) in 2021. However, in 2023, the numbers of individuals in these different levels of visual impairment within the same population were 2196 (82.5%), 267 (10.0%), 171 (6.4%) and 29 (1.1%), respectively (Stuart–Maxwell test, $\chi^2=2.33$, $P = 0.887$). The linear mixed model revealed an observed improvement in visual acuity

from baseline to 2-year follow-up (main effect of visit time: $\beta = -0.186$, 95% CI: -0.293 to -0.080, $P = 0.001$). However, the visit time $\times$ age interaction was also significant ($\beta = 0.0026$, 95% CI: 0.0011 to 0.0041, $P =$

0.001), indicating that the magnitude of improvement decreased with increasing age. Specifically, younger participants showed greater improvement, while older participants showed little to no improvement.

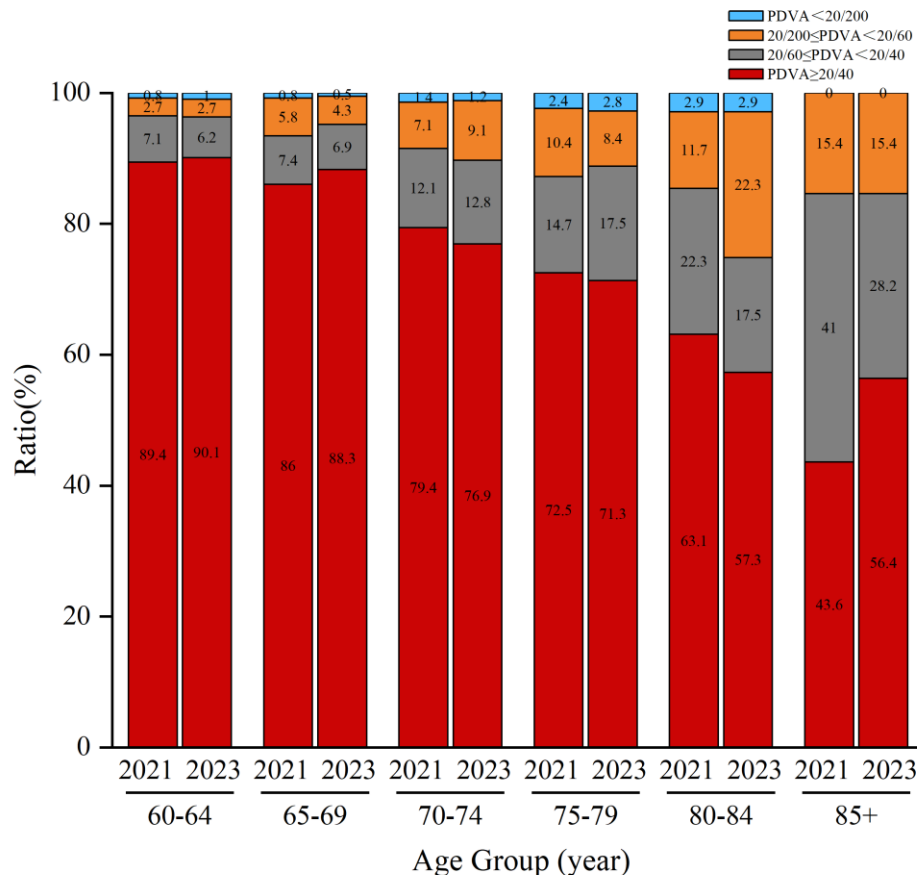


Figure 6. The proportion and trends of visual status across age groups in the two-year follow-up study. 60-64 years: n=595; 65-69 years: n=982; 70-74 years: n=693; 75-79 years: n=251; 80-84 years: n=103; 85+ years: n=39.

In detail, the proportion and tendency of visual status in different age groups are presented in Figure 6. Significant improvements in visual acuity were observed in the 60-64 and 65-69 age groups (Wilcoxon signed-rank test, $z = -2.837$, $P = 0.005$, $z = -3.552$, $P < 0.001$, respectively, Fig. 7). In contrast, the 70-74 age group exhibited a significant decline (Wilcoxon signed-rank test, $z = -2.707$, $P = 0.007$, Fig. 7); however, no notable changes were observed in the remaining age groups. During the two-year follow-up period, the number of participants with uncorrected refractive error decreased from 369 to 368, among whom 159 had their refractive error corrected and maintained good adherence to spectacle wear, whereas 158 new cases of uncorrected refractive error were identified. In total, 76 individuals (128 eyes) underwent cataract surgery during this period, with the age distribution predominantly concentrated in the 60-79 age group. To explore the potential role of

regression to the mean, we re-analysed the baseline data by categorising participants based on whether they had received subsequent interventions (such as prescription glasses or cataract surgery) into an intervention group and a non-intervention group. Within the 60-64 and 65-69 age groups, the magnitude of observed visual change was significantly greater in the intervention group than in the non-intervention group (Wilcoxon signed-rank test, $z=3.048$, $P < 0.001$, $z=-9.916$, $P < 0.001$, respectively), suggesting that the observed changes in these younger cohorts were not fully explained by regression to the mean alone.

DISCUSSION

The community-based eye examination and healthcare project is an elderly-centric initiative that integrates comprehensive ocular assessments into routine annual

physical examinations within China's established primary healthcare system. These findings illustrate a feasible, uncontrolled observational model for delivering eye care services to an elderly population. In this descriptive study, we observed a high response rate for participant

recruitment, efficient resource utilization in practice, and practical accessibility to services. These descriptive observations may offer illustrative information for policy and decision-makers when considering the accessibility, application, and distribution of eye care resources.

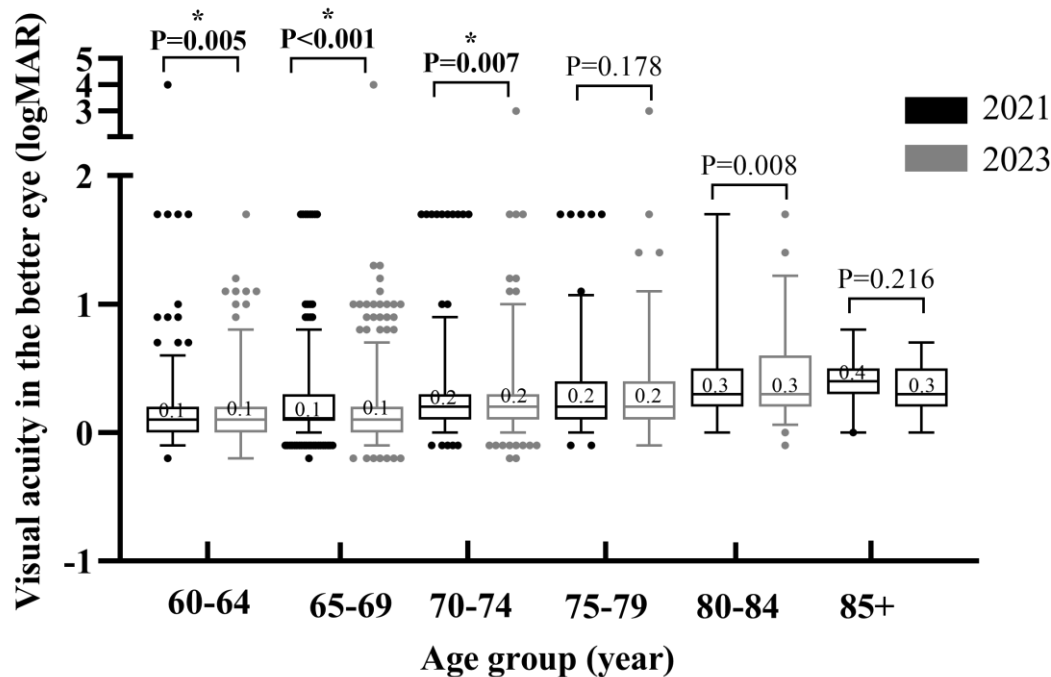


Figure 7. Longitudinal visual acuity changes in the better-seeing eye across different age groups during the two-year follow-up study. Wilcoxon signed-rank test was used for comparisons within-group. Error bars represent 95% confidence intervals. Statistical significance is indicated as *represent $P < 0.008$ (0.05/6). 60-64 years: $n=595$; 65-69 years: $n=982$; 70-74 years: $n=693$; 75-79 years: $n=251$; 80-84 years: $n=103$; 85+ years: $n=39$.

The three-step screening model developed in this project's eye examination and healthcare project demonstrated feasibility in both design and technological implementation. First, the selection of appropriate screening technology represented a critical consideration, as the programme needed to evaluate 150-200 participants within a three-hour morning window during annual physical examinations. This requirement necessitated an integrated ocular screening approach that carefully balanced feasibility, safety, operability and sensitivity. Targeting the five leading causes of visual impairment in elderly populations (URE, cataracts, glaucoma, DR and AMD), the project implemented four essential ocular examinations as first-step screening measures: PDVA, autorefractometry, IOP measurement and fundus photography. These examinations employed fully automated technologies that could be quickly administered by trained non-medical personnel. Although PDVA has been recommended for primary eye care, recent cohort studies have demonstrated that visual acuity screening alone does not substantially boost vision

outcomes in elderly populations [24-26]. This enhanced screening model, therefore, incorporated three additional examinations to enhance the detection of common ocular diseases. For example, URE were identified using combined non-cycloplegic autorefractometry and PDVA testing, whereas suspected glaucoma cases were assessed using IOP measurements and fundus photography. For DR and AMD screening, fundus photography served as the primary diagnostic tool, which is recognised by current guidelines as a practical, reliable and sensitive method for community-based screening [19, 20, 27]. This strategy offered the additional advantage of detecting other fundus abnormalities and potentially identifying early indicators of systemic disorders. The model achieved excellent participant engagement, with a 91.4% response rate (3459/3785) in the first step, indicating strong acceptance among elderly participants in the annual health examination programme.

Second, the proper management of screen-positive cases represents a crucial component of any screening programme, as guidelines emphasise that without access

to subsequent ophthalmologic care, screened patients derive limited benefit [20]. This model incorporated a detailed double-checking process involving AI technology and expert confirmation, along with standardized referral protocols for high-risk cases. The referral criteria aligned with international standards [18-20, 28], enhancing both the comparability of this project's findings with other screening approaches and the evidence-based nature of this design, to some extent. Third, the present ocular screening model leveraged the well-developed community healthcare centre management system, which provides a centralized space and relatively fixed screening time for the elderly in the community. The well-developed community management system and prominent attention paid to public health, such as offering a free pickup service and breakfast, promoted the participation of elderly community members in the annual general physical examination, which, in turn, offered a pivotal opportunity to integrate the ocular screening into the existing healthcare system.

In this study, 3459 participants completed initial ocular examinations within 45 days, with each first-stage screening requiring only 4-8 minutes per participant. The systematic digitisation, which enabled real-time data acquisition, centralised storage and seamless interoperability with existing health records was observed in high-volume community settings. Furthermore, the integration of AI-assisted diagnostics with on-site expert confirmation enhances screening efficacy through automated abnormality detection while alleviating the diagnostic challenges faced by primary healthcare providers simultaneously. Notably, the average examination time is within 8 minutes, and high participant compliance (91.8%) reflects the viability of such integrated models in resource-conscious environments. This constructive collaboration of scalable digital infrastructure and intelligent triaging provides a descriptive reference for considering conventional barriers to equitable eye care access.

The proposed eye examination screening model also demonstrated feasibility in detecting ocular conditions. Following the double-checking of AI diagnostic technology and expert confirmation, 48.5% (1679/3459) of participants met referral criteria. This rate is higher than those reported in some Western optometrist-based screening programs, including a British programme screening 1733 participants over three years and a U.S. initiative examining 13000 individuals across 5 years [29, 30], likely reflecting differences in population characteristics and referral thresholds. Several factors explain this high referral rate. First, our elderly population aged ≥ 60 years has a high burden of age-related eye diseases, with prevalence rates (cataract 43.5%, AMD 37.5%, URE 14.6%, glaucoma suspicion 12.4%, DR

4.8%) consistent with Chinese epidemiological studies [31-34]. Second, the referral criterion (PDVA $< 20/40$ with pinhole correction in any eye) was intentionally designed to be highly sensitive in order to minimize false negatives, thereby inevitably increasing the referral rate [35, 36]. The detected rate of visual impairment (18.9%) and low vision (7.9%) were comparable to the findings from Yueqing County, Wenzhou (22.6% and 8.1%, respectively) [31]. The estimated prevalence of URE in this study may not be directly comparable to population-based epidemiological reports [37], due to variations in diagnostic criteria and a more stringent case definition. Consistent with global ageing trends, we observed a progressive increase in visual impairment prevalence across all severity categories with advancing age. These findings underscore the critical need for systematic ocular screening programmes in ageing populations, particularly for detecting previously undiscovered conditions.

Among the elderly participants recommended for referral, the actual follow-up rate for fundus diseases remains relatively low, which are substantial for interpreting the screening model's utility. Specifically, the low referral completion rate (approximately 9%) and the absence of linked follow-up data mean that this study cannot determine whether, or to what extent, the screening model led to beneficial clinical actions. Moreover, patient-level barriers to referral completion were not systematically collected. Based on previous implementation research in community-based screening programs, potential barriers may include financial costs, transportation difficulties, limited health literacy, competing time demands, and relevant to the present findings of low perceived need for care [5, 6]. In our data, a substantial proportion of participants who did not complete the referral had no visual impairment in the better-seeing eye (e.g., 93.0% for moderate diabetic retinopathy, 74.5% for suspected glaucoma). This observation raises the possibility that asymptomatic or mild disease may be associated with lower motivation to seek confirmatory care, a pattern consistent with prior literature [6]. In contrast, conditions such as ocular surface disease and cataract are more likely to prompt this population to seek medical attention. This result shows that awareness and attention to fundus diseases are still insufficient among the elderly. Following community-based screening, improving their subsequent eye health management and enhancing their understanding of these diseases remains a long and challenging task. Future implementation research should explicitly track referral barriers using mixed methods (e.g., structured questionnaires, semi-structured interviews, or routine documentation of reasons for non-attendance) and, where feasible, establish data-sharing agreements with referral hospitals to capture complete diagnostic and treatment

pathways. Such efforts would be necessary to determine whether screening uptake translates into meaningful clinical benefit.

Two-year follow-up data from this descriptive observational study showed certain changes in visual acuity among elderly participants. The proportion of individuals without vision impairment increased from 82.3% in 2021 to 82.5% in 2023, whereas the prevalence of severe vision impairment or blindness decreased from 1.2% to 1.1%. Statistically significant changes in visual acuity were observed in the 60-64 and 65-69 age groups. These longitudinal observations coincided with a documented reduction in URE and the performance of cataract surgeries during the study period. Previous studies have highlighted that the prevalence of visual impairment increases with age, with individuals over 70 years representing a high-risk population for progressive vision loss [38, 39], which was consistent with the finding in the 70-74 age group. In contrast, participants aged over 75 years old exhibited a non-significant visual acuity decline during the follow-up period. However, given that 23.0% of baseline participants were lost to follow-up and those lost were significantly older, this finding may partly reflect selection bias rather than a true absence of deterioration, although the possibility that proactive engagement of high-risk individuals in subsequent ophthalmic treatments contributed to this finding cannot be ruled out with the available data. Nevertheless, the trend of observed visual deterioration in this population likely reflects both the natural progression of age-related ocular pathologies and systemic ageing among older adults. The significance of this screening model lies in its potential for early identification and management, which is a critical focus for future research that could potentially slow disease progression or enhance quality of life even in this rapidly progressing population. All these findings demonstrate the feasibility of implementing an ocular screening model for elderly vision services. Observed associations between screening and service delivery patterns are reported, but no causal or effectiveness claims can be made. The question of whether screening improves daily visual acuity in older populations cannot be answered by this uncontrolled observational design. Nevertheless, ongoing challenges in health education and service accessibility demand sustained attention.

A principal strength of this proposed ocular screening study is its well-characterised participant cohort, which leverages high-quality ocular and systemic data alongside a comprehensive biorepository. The programme's feasibility was enabled by China's extensive health insurance coverage (>95% of the population) and robust primary care infrastructure. Looking forward, the integration of routine ocular screening into primary care-based comprehensive physical examinations would be

both warranted and significant. Furthermore, the future integration of telemedicine with AI-assisted screening could substantially facilitate access to primary eye care and determine whether this integrated model can achieve higher compliance, greater efficiency and improved cost-effectiveness. And the collection of multimodal data on vision impairment in ageing populations may yield novel insights into the relationship between ocular and systemic health.

Several limitations of this study should be acknowledged. First, the absence of a control group in this longitudinal observational cohort may limit the ability to control for confounding factors. Recognizing this limitation, the two-year follow-up data can still inform the descriptive understanding of feasibility and observed patterns associated with integrating ocular screening into community-based health assessments. Second, this study was conducted in a single community health service center and enrolled a population consisting exclusively of Han Chinese individuals who participated in annual physical examinations, which may introduce selection bias and healthy survivor bias. Therefore, the findings may not generalize directly to populations with different demographic characteristics, socioeconomic backgrounds, or healthcare-access contexts, multicenter studies involving diverse community settings and ethnic populations are warranted to further validate the applicability and generalizability of this screening model. Third, follow-up data could not be systematically collected, as older adults in this population primarily received further ophthalmic care at various local eye hospitals, which limits the interpretation of the screening model's real-world utility. Strengthening collaboration and system integration between community health centers and regional ophthalmology departments may help capture more complete follow-up information and boost referral compliance in the future. Besides, the AI system was validated only using an internal test set. No external validation was conducted using an independent dataset from a different population. Therefore, the reported diagnostic performance may not generalize directly to other populations or settings. Future external validation studies are needed.

In summary, this community-based eye examination initiative demonstrated strong feasibility within the study context. The integrated screening system is presented as a descriptive model for community-based elderly eye care that utilizes existing primary healthcare systems to facilitate eye health screening for older adults. Further research is needed to assess its replicability in diverse settings and to overcome the persistent challenge of low referral completion.

Competing Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Supplementary Materials

The Supplementary data are available online at: www.aginganddisease.org/EN/10.14336/AD.2026.10331.

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