Research Paper

Development and validation of a risk prediction model for visual impairment in older adults

Yue Zhao, Aiping Wang*

The First Afliated Hospital of China Medical University, Shenyang, Liaoning Province, China

ABSTRACT

Objectives: This study aimed to determine the risk factors that affect visual impairment in older adults for developing and evaluating a visual impairment risk prediction model.

Methods: In this hospital-based unmatched case-control design study, we enrolled 586 participants (411 in the training set and 175 in the internal test set) from the ophthalmology clinic and physical examination center of a teaching hospital in Liaoning Province, China, from June to December 2020. Visual impairment was defined as best-corrected visual acuity <6/18 (The WHO definition). Possible influencing factors of visual impairment were assessed, including demographic factors, socioeconomic factors, disease and medication factors, and lifestyle. A visual impairment risk prediction model was developed using binary logistic regression analysis. The area under the ROC curve (AUC) was used to evaluate the effectiveness of the proposed prediction model.

Results: Six independent influencing factors of visual impairment in older adults were identified: age, systolic blood pressure, physical activity scores, diabetes, self-reported ocular disease history, and education level. A visual impairment risk prediction model for older adults was developed, showing powerful predictive ability in the training set and internal test set with AUCs of 0.87 (95%CI 0.83−0.90) and 0.81 (95%CI 0.74−0.88), respectively.

Conclusions: The risk prediction model for visual impairment in older adults had high predictive power. Identifying older adults at risk for developing visual impairment can help healthcare workers to adopt appropriate targeted programs for early education and intervention to prevent or delay visual impairment and prevent injuries due to visual impairment in older adults.

© 2023 The authors. Published by Elsevier B.V. on behalf of the Chinese Nursing Association. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

What is known?

- Visual impairment is the result of a combination of factors, and it seriously affects the quality of life of older adults.
- Early assessment of risk factors can prevent or delay the onset of visual impairment in older adults.

What is new?

- This study developed a model for predicting the risk of visual impairment in older adults with powerful predictive ability.

- The prediction model developed in this study is helpful to screen out the high-risk visual impairment group and provide the basis for healthcare workers to make intervention programs.

1. Introduction

Globally, visual impairment is an important public health concern. It leads to physical and cognitive function decline in older adults [1], which results in increased incidences of falls [2], fractures [3], and even death [4]. Of note, worldwide, the number of people with visual impairment was approximately 253 million, about 65% of whom were aged 50 years or older [5]. It was estimated that 80% of visual impairment could be prevented or cured [5]. However, access to health care services for older adults has been greatly reduced because of the lack of continuous social support and ophthalmic medical resources [6]. Thus, it has become an essential concern to prevent and delay the development of visual impairment in older adults today.

* Corresponding author.
E-mail address: jianghaoran88@hotmail.com (A. Wang).
Peer review under responsibility of Chinese Nursing Association.

Early assessment of risk factors is key to effectively preventing visual impairment in older adults. Some studies have identified age, gender, educational attainment, marital status, residence style, food security, access to care, ability to perform daily activities, poorer memory, sleep, social participation and comorbidities such as diabetes as important factors in the development of visual impairment [7−12]. Diabetes, in particular, is a direct cause of diabetic retinopathy and an established risk factor for many other ophthalmic diseases, including cataract, macular degeneration, and macular edema. Diabetes-induced ocular manifestations lead to a risk of visual impairment, which is three times higher in the person with diabetes compared to the general population [13].

The aim of this retrospective study was to develop a prediction model that incorporates multiple risk factors and can provide an individualized prediction of the risk of visual impairment in older adults. This individualized risk assessment can identify those at high risk of visual impairment in older adults and help healthcare providers decide on individualized intervention programs to reduce and delay the onset of visual impairment in older adults.

2. Methods

2.1. Study design and setting

An unmatched hospital-based case-control study was conducted at a teaching hospital in Liaoning Province, China, from June 2020 to December 2020. The hospital is a large comprehensive Level A tertiary hospital in Liaoning Province, one of the most severely aging provinces in China [14].

2.2. Study population

Study participants were selected by the convenience sampling method in the ophthalmology outpatient, during which older patients with visual impairment were sequentially enrolled until the required sample was filled. For each older adult with visual impairment, a subsequent non-visually impaired older adult was selected as a control. If a control had a history of visual impairment, the next control without a history of visual impairment was selected. If a case or control declined to consent to participate in the study, the next eligible older adult was selected as a replacement. We also recruited the control group at the physical examination center with the same sample size as the control group at the ophthalmology outpatient. The ratio of the case to the control group was 1/2.

Inclusion Criteria: Older adults aged 60 years or older, conscious and without intellectual impairment. Exclusion Criteria: Those with severe hearing impairment or disease sequelae resulting in the inability to communicate or those with acute illness or acute onset of chronic disease. The WHO (1972) best-corrected visual acuity (BCVA) classification criteria [15] were used in this study: Visual impairment was classified as low vision and blindness based on the better eye. The low vision was defined as BCVA < 6/18 to ≥ 3/60. Blindness was defined as BCVA < 3/60. The subjects' vision levels were determined by the ophthalmologists in the hospital. Subjects were assigned to the case and control groups based on their diagnosis: Subjects diagnosed with visual impairment were recruited to the case group; Subjects without visual impairment were recruited into the control group.

2.3. Potential predictive variables

In this study, "blindness," "vision disorders," "low vision," "visual impairment," "vision loss," "risk factors," and "cause" were used as search terms in English databases, PubMed and Web of Science, for extracting the literature on risk factors of visual impairment in older adults. The literature search formula in PubMed was shown in Appendix A. We screened out variables that were difficult to measure, such as memory, food security, access to care and social participation, based on clinical experience after consultation with two experts (one eye care specialist and one ophthalmology clinical specialist). A questionnaire on the status of visual acuity and related factors in older adults was developed in this study. Personal information and potential predictive variables included 1) demographic factors: age and gender; 2) socioeconomic factors: education level, family monthly incomes, medical payment method, marital status and habitual residence; 3) disease and medication factors: self-reported family history of ocular diseases, history of chronic kidney disease, history of coronary heart disease, history of stroke, history of ocular disease, history of eye trauma, use of corticosteroids, use of antidepressants and use of anti-tuberculosis drugs, diabetes; 4) lifestyle: smoking history, drinking days in the past 30 days, history of electric welding, previous exposure to radiation for more than 1 month, physical activity score, and self-reported sleep duration. Diabetes was defined as any of the following conditions: 1) self-reported history of diabetes, excluding gestational diabetes; 2) oral hypoglycemic drugs or insulin injections; 3) fasting blood glucose level ≥7.0 mmol/L or random blood glucose level ≥11.1 mmol/L [16]. Physical activity score was calculated as (hours spent with intensive activity per week) × 5 + (hours spent with moderate activity per week) × 2 + (hours spent walking per week) − (hours spent sitting per week) with a range of −133 to 142, which assessed general physical activity including daily professional activities, rather than focusing only on sports activities, and better reflected the amount of physical activity performed by study participants [17].

2.4. Measurement and data collection

Visual acuity testing was performed using the Tumbling E Chart. Both eyes of the participants were examined separately at 5 m from the Tumbling E Chart. If the participant normally wore glasses, the corrected visual acuity with glasses was measured. The subject's visual acuity results were recorded as the smallest line where all letters were read correctly or only one was wrong. If the participant could not distinguish the biggest letter from 5 m, they would be moved to 4 m, 3 m, 2 m, or 1 m away from the chart consecutively. If the biggest "E" on the Tumbling E Chart could still not be distinguished, the vision was assessed by counting fingers, hand movements, and the presence or absence of light perception. Eyes with atrophy or without eyeballs were recorded as having no light perception. Visual acuity was measured by pinhole for participating subjects with visual acuity below 6/18 to rule out visual impairment due to refractive error.

The investigator self-introduced to the study participants and explained the purpose of the study. After obtaining written informed consent from the participants, the investigator collected data by interviewing them to complete the visual impairment risk factor questionnaire. Participants' fingertip glucose values were measured by the investigator with the help of a Contour TS Blood Glucose Meter produced by Ascensia Diabetes Care US Inc. They were recorded as fasting glucose values if the participant had fasted for 8 h or more. Otherwise, the value was considered random glucose if the participant had fasted for less than 8 h. Every participant's blood pressure was measured twice by the investigator using an automatic electronic sphygmomanometer HBP-1300 produced by Omron 5 min apart while the subject was at rest or 10 min after sitting. If the difference between the two systolic values was more than 10 mmHg (1 mmHg = 0.133 kPa) or the difference between the diastolic values was more than 5 mmHg, a

third measurement was taken 5 min later. Then the average between the two closest blood pressure values was recorded.

2.5. Sample size

This study summarized 25 potential risk factors through literature review and ophthalmologist consultation. The sample size was calculated as 250 to 500, as the ideal sample size was at least 10–20 times the number of independent variables to test logistic regression analysis.

2.6. Statistics analysis

The SPSS version 23 software from IBM(International Business Machines Corporation) was used for data analysis. The samples were divided randomly into a training set and an internal test set by a ratio of 7 to 3. Baseline characteristics of the subjects between the case and control groups in the training set were compared in the study. P value <0.05 was considered statistically significant. The chi-square test was used for intergroup comparisons of categorical data. In addition, the t-test was used to compare continuous type data conforming to the normal distribution. In contrast, the rank sum test was used for continuous type data not conforming to normal distribution.

Binary logistic regression was used for multivariate analysis. The weights of each risk factor were determined according to the B coefficients corresponding to the independent variables. The final formula of the model was obtained. The risk score of visual impairment for each subject was the sum of the scores of all its risk factors. Finally, the area under the receiver operating characteristic curve (ROC AUC) in the internal test set was used to evaluate the predictive validity of the risk prediction model for the occurrence of visual impairment.

2.7. Ethics approval

This study adhered to all Declaration of Helsinki Guidelines and was approved by the Ethics Review Committee of the First Hospital of China Medical University (NO:AF-SOP-07-1.1-01). Prior to data collection, the investigators explained the study procedures to the subjects and then obtained written informed consent from each participant or their family members.

3. Results

3.1. General information

A total of 586 participants were included in this study. Two hundred and seventy (46.1%) were male, and 316 (53.9%) were female, aged 60–92 years, with a mean age of 69.1 years ($SD = 7.0$). One hundred and eighty-four participants were enrolled to the case group from the ophthalmology clinic. In addition, 402 participants were enrolled in the control group. In the control group, 184 were from the ophthalmology outpatient and 218 from the physical examination center. The training set contained 411 participants, 129 of whom were visually impaired. The internal test set contained 175 participants, which included 55 with visual impairment.

3.2. The causes of visual impairment

The primary cause of visual impairment in older adults was cataract (45.7%, 84/184), followed by diabetic retinopathy (20.7%, 38/184), glaucoma (12.0%, 22/184), and macular degeneration (10.9%, 20/184). The primary causes are listed in Table 1.

3.3. Univariate analysis

In the univariate analysis, age was analyzed as a categorical variable based on 75 years which is because a study showed that older adults over the age of 75 had 10 times the risk of developing visual impairment than those aged 55–65 years [18]. Univariate analysis of risk factors for visual impairment showed that older age, higher systolic blood pressure, lower education level, physical activity scores, diabetes, history of ocular disease, and long-term radiation exposure were associated with visual impairment. Conversely, a lower frequency of drinking (1–10 drinking days past 30 days) was associated with non-visual impairment. The univariate analysis of risk factors for visual impairment is shown in Table 2.

3.4. Multivariate analysis

The variable of radiation exposure was excluded because there were few events in the present study. So, 7 statistically significant variables were included in the binary logistic regression analysis. The variable selection was performed using the binary logistic-forward-conditional method. Table 3 shows age, systolic blood pressure, physical activity score, diabetes, history of eye diseases, and education level were associated with visual impairment in older adults ($P < 0.05$). The analysis result indicated that these 6 factors were independent risk factors for visual impairment.

The formula for calculating the risk score for visual impairment is as follows:

$$Y = 1.30 \times X_1 + 1.19 \times X_2 + 2.60 \times X_3 - 1.30 \times X_4 + 0.98 \times X_5 + 1.85 \times X_6 + 2.69 \times X_7 - 1.38 \times X_8$$

X_1 to X_8 refer to variables age 75 or older, diabetes, history of ocular disease, high-intensity physical activity, mild hypertension, moderate hypertension, severe hypertension, and college or higher education, respectively (yes = 1, no = 0).

Table 1
Primary causes of visual impairment ($n = 184$).

Primary cause of visual impairment	Low vision ($n = 145$)	Blindness ($n = 39$)	Visual impairment ($n = 184$)
Cataract	71 (49.0)	13 (33.3)	84 (45.7)
Diabetic retinopathy	27 (18.6)	11 (28.2)	38 (20.7)
Macular degeneration	18 (12.4)	2 (5.1)	20 (10.9)
Glaucoma	14 (9.7)	8 (20.5)	22 (12.0)
Retinal detachment	5 (3.4)	2 (5.1)	7 (3.8)
Retinal vein obstruction	6 (4.1)	2 (5.1)	8 (4.3)
Ocular malignancy	1 (0.7)	0 (0)	1 (0.5)
Ocular trauma	2 (1.4)	1 (2.6)	3 (1.6)
Myopic retinopathy	1 (0.7)	0 (0)	1 (0.5)

Note: Data are n (%).

Table 2
Univariate analysis of risk factors for visual impairment ($n = 411$).

Variables	Case group ($n = 129$)	Control group ($n = 282$)	χ^2 or Z	P
Age (years)			15.171	< 0.001
60—74	89 (69.0)	241 (85.5)		
≥75	40 (31.0)	41 (14.5)		
Systolic blood pressure (mmHg)	138 (128—153)	130 (123—140)	−4.89	< 0.001
Diastolic blood pressure (mmHg)	80 (74—85)	80 (74—87)	−0.97	0.334
Sex			< 0.01	0.948
Male	59 (45.7)	128 (45.4)		
Female	70 (54.3)	154 (54.6)		
Education level			13.12	0.004
Primary school/No formal education	33 (25.6)	51 (18.1)		
Junior high school	52 (40.3)	84 (29.8)		
High school	24 (18.6)	63 (22.3)		
College/Higher education	20 (15.5)	84 (29.8)		
Family monthly income (CNY)			5.76	0.217
≤1,000	5 (3.9)	28 (9.9)		
> 1,000—3,000	34 (26.3)	62 (22.0)		
> 3,000—5,000	44 (34.1)	82 (29.1)		
> 5,000—10,000	40 (31.0)	95 (33.7)		
> 10,000	6 (4.7)	15 (5.3)		
Marital status			0.93	0.335
Married	110 (85.3)	250 (88.7)		
Single	19 (14.7)	32 (11.3)		
Habitual residence			0.50	0.479
City	98 (76.0)	223 (79.1)		
Rural area	31 (24.0)	59 (20.9)		
Medical payment method			1.81	0.179
Medical insurance	120 (93.0)	271 (96.1)		
Self-paying	9 (7.0)	11 (3.9)		
History of electric welding			< 0.01*	1.000
No	125 (96.9)	274 (97.2)		
Yes	4 (3.1)	8 (2.8)		
Exposed to radiation			5.91*	0.015
No	125 (96.9)	282 (100)		
Yes	4 (3.1)	0 (0)		
Diabetes			37.18	< 0.001
No	75 (58.1)	241 (85.5)		
Yes	54 (41.9)	41 (14.5)		
History of coronary heart disease			0.19	0.665
No	111 (86.0)	238 (84.4)		
Yes	18 (14.0)	44 (15.6)		
History of stroke			0.27	0.604
No	114 (88.4)	244 (86.5)		
Yes	15 (11.6)	38 (13.5)		
History of chronic kidney disease			2.71	0.100
No	119 (92.2)	271 (96.1)		
Yes	10 (7.8)	11 (3.9)		
Family history of ocular diseases			1.09	0.296
No	104 (80.6)	239 (84.8)		
Yes	25 (19.4)	43 (15.2)		
History of ocular diseases			92.25	< 0.001
No	23 (17.8)	194 (68.8)		
Yes	106 (82.2)	88 (31.2)		
History of eye trauma			0.28	0.600
No	122 (94.6)	270 (95.7)		
Yes	7 (5.4)	12 (4.3)		
Use of corticosteroids			2.02	0.155
No	121 (93.8)	273 (96.8)		
Yes	8 (6.2)	9 (3.2)		
Use of antidepressants			0.038*	0.845
No	129 (100)	280 (99.3)		
Yes	0 (0)	2 (0.7)		
Use of anti-tuberculosis drugs			< 0.001*	1.000
No	128 (99.2)	279 (98.9)		
Yes	1 (0.8)	3 (1.1)		
Smoking history			0.39	0.535
No	89 (69.0)	203 (72.0)		
Yes	40 (31.0)	79 (28.0)		
Frequency of drinking (total drinking days in the past 30 days)			19.03	< 0.001
0	120 (93.0)	214 (75.9)		
1—10	4 (3.1)	51 (18.1)		
11—20	2 (1.6)	9 (3.2)		
21—30	3 (2.3)	8 (2.8)		
Self-reported sleep duration (h/night)			1.13	0.569
≤5.0	21 (17.9)	35 (14.9)		

Table 2 (*continued*)

Variables	Case group (*n* = 129)	Control group (*n* = 282)	χ^2 or Z	*P*
> 5.0—8.5	100 (75.5)	229 (79.4)		
> 8.5	8 (6.5)	18 (5.7)		
Physical activity score	0 (−21.0 to 24.5)	14.0 (−7.0 to 49.0)	−4.51	0.001

Note: Data are *n* (%), or *Median* (*IQR*). * Continuity corrected chi-square test.

Table 3
Multivariate logistic regression analysis of risk factors for visual impairment.

Variables	B	OR (95%CI)	P
Age (years)			< 0.001
≥60—74		1	
≥75	1.30	3.66 (1.87—7.17)	
Diabetes			< 0.001
No		1	
Yes	1.19	3.29 (1.81—5.98)	
History of ocular diseases			< 0.001
No		1	
Yes	2.60	13.40 (7.02—25.57)	
Physical activity score			0.002
Low intensity (< −7)		1	
Medium intensity (−7 to 28)	−0.30	0.74 (0.38—1.46)	0.390
High intensity (> 28)	−1.30	0.27 (0.13—0.60)	< 0.001
Systolic blood pressure (mmHg)			0.001
Normal (< 140)		1	
Mild hypertension (140—159)	0.98	2.66 (1.47—4.84)	0.001
Moderate hypertension (160—179)	1.85	6.37 (1.47—27.61)	0.013
Severe hypertension (> 179)	2.69	14.75 (1.15—189.05)	0.039
Education level			0.012
Primary school/No formal education		1	
Junior high school	−0.34	0.71 (0.34—1.48)	0.359
High school	−0.58	0.56 (0.25—1.27)	0.165
College/Higher education	−1.38	0.25 (0.11—0.59)	0.002
Constant	−2.34	0.10	0.000

3.5. Evaluation of the predictive validity of the model

To test the validity of the initially constructed model for predicting the risk of visual impairment in older adults, the ROC curve was drawn in this study with the occurrences of visual impairment as the state variables and the risk of visual impairment scores as the test variables. The model developed in this study had powerful predictive ability in both the training set and the internal test set participants with AUCs of 0.87 (95%CI 0.83—0.90) and 0.81 (95%CI 0.74—0.88), *P* < 0.001 (see Fig. 1).

4. Discussion

The results of this study showed that cataract remained the leading cause of visual impairment in older adults today. Nonetheless, the visual impairment due to retinal diseases such as diabetic retinopathy and macular degeneration is progressively increasing. A similar trend was also found in the nine-province surveys of visual impairment in rural China [19]. Survey conducted in the nine areas (including Heilongjiang, Beijing, Hebei, Xinjiang, Jiangsu, Jiangxi, Guangdong, Chongqing, and Yunnan) showed that the causes of visual impairment in 2006 in rural China were cataract, retinal diseases, corneal clouding, and glaucoma [19]. Though in 2014, the causes of visual impairment were approximately the same as in 2006, the retinal disease percentage was significantly higher than in 2006. This may be because people's living standards and lifestyles have significantly changed with the development of the economy. As a result, the incidence of chronic diseases such as hypertension and diabetes has increased significantly among older adults, leading to increased incidences of related eye diseases.

To our knowledge, no effective predictive models for visual impairment in older adults have been developed or validated. In this study, we developed a risk prediction model for visual impairment in older adults based on a literature analysis approach and clinical experience, which presented the effort to incorporate comprehensive risk factors such as demographics, socioeconomics, disease, and lifestyle that affect visual impairment. The proposed model was based on data from a hospital population to predict the risk of visual impairment in older adults, using internal validation with an AUC of 0.81, showing higher predictive power. In this single-center study, we used a case-control study design to identify independent risk factors associated with visual impairment in older adults. Our results showed that age, systolic blood pressure, physical activity score, diabetes, history of eye diseases, and education level were independent risk factors for visual impairment in older adults.

Age is a well-known and strong risk factor for visual impairment. A study from Taiwan showed that the prevalence of visual impairment was strongly correlated with age [18]. In our research, age remained a significant predictor after controlling for self-reported history of ocular disease. This finding suggested that other age-related factors might contribute to vision loss, such as the lack of ongoing social support for older adults, declined physical function, and reduced access to the lack of ophthalmic medical resources [6]. In addition, most older adults considered vision deterioration a natural aging process and usually did not seek appropriate medical care [20].

In concurrence with a study in Singapore [8], our study also found higher systolic blood pressure as a major risk factor for developing visual impairment. Hypertension is a risk factor for many vision-threatening ocular diseases, and it not only plays a key
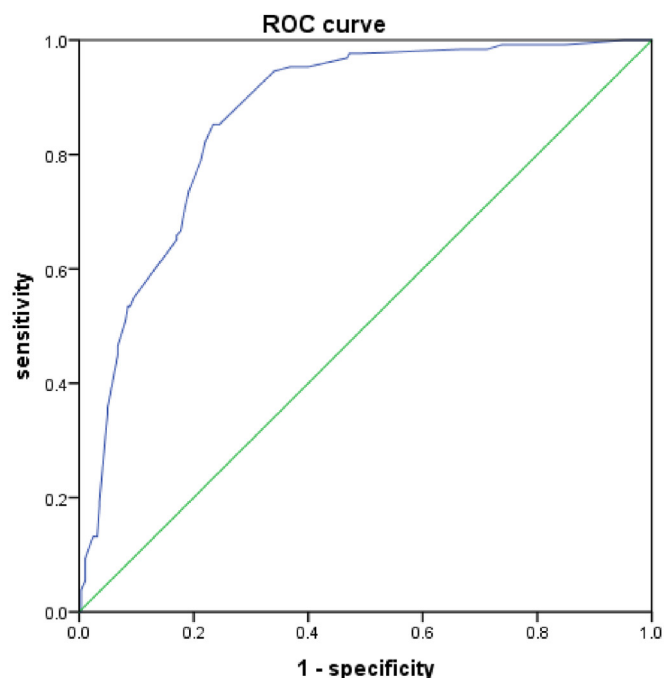
a. ROC curve in the training
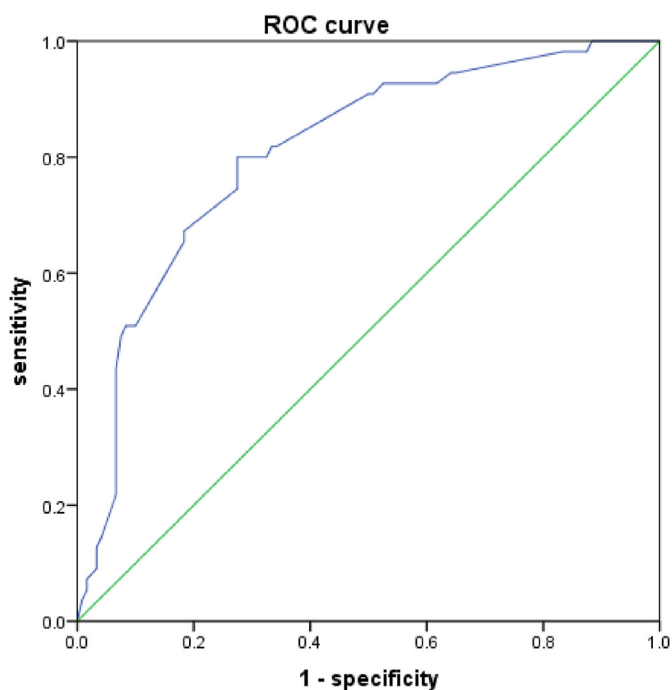
b. ROC curve in the internal test

Fig. 1. ROC curve of the model predicting the risk of visual impairment in older adults.

role in the pathogenesis of diabetic retinopathy, but may also exacerbate the effects of diabetic retinopathy on visual impairment. In a prospective diabetes study in the United Kingdom, participants with tightly controlled blood pressure had a 34% lower rate of progression of retinopathy and a 47% lower rate of vision loss [21].

Physical activity was a protective factor for visual impairment in older adults in our study. Physical activity has been identified as a crucial factor in holistic health. One study showed that higher daily physical activity was associated with a lower prevalence of diabetic retinopathy [17]. Exercise lowers intraocular pressure and prevents irreversible damage to the retinal ganglion cells and their axons [22]. In addition, a longitudinal study in the United States showed that higher level physical activity reduced the risk of progression to advanced age-related macular degeneration (AMD) in patients with early or mid-stage AMD [23].

Diabetes was a significant risk factor, consistent with other studies [19,24—27]. Individuals with diabetes are more susceptible to a variety of ocular diseases, including diabetic retinopathy [24], cataracts [25], open-angle glaucoma [26], and central retinal vein occlusion [27]. In our study, cataract and diabetic retinopathy were the main causes of visual impairment. Therefore, strict glucose control is needed for older diabetic patients to reduce the occurrence and progression of visual impairment.

As previously reported, a strong association was found between a history of ocular disease and visual impairment [28]. Older adults with a history of ocular disease may be more susceptible to visual impairment due to eye disease affecting the ocular integrity. Early diagnosis and treatment of ocular diseases and reducing the risk of exposure to such diseases are important for preventing visual impairment.

Our study showed that people with less education in school were more likely to suffer from visual impairment. In the Singapore Malay Eye Study, those with less education than elementary school were more likely to have unilateral and bilateral visual impairment than those who completed high school or college [8]. One possible explanation was that those with less education might lack knowledge and awareness of their health status. Thus, those older adults are less likely to go for routine vision examinations and less compliant regarding further treatment [29].

Regarding the application of the model in clinical practice, its strengths or barriers require further investigation; however, since the six risk factors it incorporated were readily available and the calculation process was simple, it was an extremely convenient assessment tool for hospitals, nearby community workers, and older adults. In fact, many older adults tend to neglect eye examinations. Our model is expected to identify high-risk populations of visual impairment, appropriately allocate medical and nursing resources for early intervention, and positively affect patient outcomes and reduce the burden of visual impairment.

A 17-year diabetic retinal screening program in the United Kingdom has demonstrated that timely and early screening is an important management tool for preventing and delaying the development of visual impairment [30], and nurses played a vital role in the early monitoring and management of diabetic retinopathy [31]. The Age-Related Eye Disease Project in Australia focuses on access to care and vision for patients with age-related eye disease and improves visual function and quality of life through follow-up [32]. Our model is expected to help medical practitioners identify people at high risk of visual impairment. After identifying people at high risk of visual impairment, community health workers or nurses can provide comprehensive management, such as establishing a management and control platform for visual impairment in older adults, improving their knowledge through health education and follow-up visits, controlling their blood pressure and blood sugar levels, and taking different preventive measures for individuals with different risks, so as to reduce the occurrence of visual impairment and improve their quality of life.

This study had several limitations. First, as it is a case-control study, with data collected during the same period, this study

could not determine the sequential timing of exposure to certain risk factors of the disease. However, identifying social demography, disease, and lifestyle characteristics specific to visual impairment in older adults, regardless of cause or outcome, is important for the targeted implementation of eye health interventions. Second, this was an observational study. As visual impairment can originate from a combination of factors, confounding effects from unmeasured and unknown factors could not be excluded. Third, the study was a single-center study, internally validated only, and the population studied was skewed toward older adults seeking eye care services. Therefore, the findings cannot be generalized to the community, province, or national population. Further studies with larger populations are needed to identify other potential risk factors for visual impairment.

5. Conclusion

Age, systolic blood pressure, physical activity level, diabetes, self-reported history of ocular disease, and education level are associated with visual impairment in older adults. Preliminary predictive models of visual impairment could distinguish between those with and without visual impairment. Identifying those at high risk of visual impairment can help healthcare workers to develop appropriate targeted programs for early education and intervention to prevent and/or delay the onset and progression of visual impairment in older adults and prevent injuries due to visual impairment.

Funding

Data availability statement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Zhao Yue: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Project administration. **Aiping Wang**: Conceptualization, Methodology, Validation, Formal analysis, Funding acquisition, Writing - review & editing, Supervision, Project administration.

Declaration of competing interest

We have no conflicts of interest to disclose.

Acknowledgments

Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2023.06.010.

References

[1] Hajek A, Brettschneider C, Lühmann D, Eisele M, Mamone S, Wiese B, et al. Effect of visual impairment on physical and cognitive function in old age: findings of a population-based prospective cohort study in Germany. J Am Geriatr Soc 2016;64(11):2311–6. https://doi.org/10.1111/jgs.14458.

[2] Niihata K, Fukuma S, Hiratsuka Y, Ono K, Yamada M, Sekiguchi M, et al. Association between vision-specific quality of life and falls in community-dwelling older adults: LOHAS. PLoS One 2018;13(4):e0195806. https://doi.org/10.1371/journal.pone.0195806.

[3] Hamedani AG, VanderBeek BL, Willis AW. Blindness and visual impairment in the medicare population: disparities and association with hip fracture and neuropsychiatric outcomes. Ophthalmic Epidemiol 2019;26(4):279–85. https://doi.org/10.1080/09286586.2019.1611879.

[4] Wang LH, Zhu ZT, Scheetz J, He MG. Visual impairment and ten-year mortality: the liwan eye study. Eye 2021;35(8):2173–9. https://doi.org/10.1038/s41433-020-01226-x.

[5] Bourne RRA, Flaxman SR, Braithwaite T, Cicinelli MV, Das A, Jonas JB, et al. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. Lancet Global Health 2017;5(9):e888–97. https://doi.org/10.1016/S2214-109X(17)30293-0.

[6] Stagg BC, Choi H, Woodward MA, Ehrlich JR. Association of social support network size with receipt of cataract surgery in older adults. JAMA Ophthalmol 2018;136(4):423–7. https://doi.org/10.1001/jamaophthalmol.2018.0244.

[7] Hashemi H, Mehravaran S, Emamian MH, Fotouhi A. Five-year incidence of visual impairment in middle-aged iranians: the shahroud eye cohort study. Ophthalmic Epidemiol 2017;24(1):11–6. https://doi.org/10.1080/09286586.2016.1255342.

[8] Chong EW, Lamoureux EL, Jenkins MA, Aung T, Saw SM, Wong TY. Socio-demographic, lifestyle, and medical risk factors for visual impairment in an urban asian population: the Singapore Malay eye study. Arch Ophthalmol 2009;127(12):1640–7. https://doi.org/10.1001/archophthalmol.2009.298.

[9] Zhao JL, Xu X, Ellwein LB, Cai N, Guan HJ, He MG, et al. Prevalence of vision impairment in older adults in rural China in 2014 and comparisons with the 2006 China nine-province survey. Am J Ophthalmol 2018;185:81–93. https://doi.org/10.1016/j.ajo.2017.10.016.

[10] Ehrlich JR, Stagg BC, Andrews C, Kumagai A, Musch DC. Vision impairment and receipt of eye care among older adults in low- and middle-income countries. JAMA Ophthalmol 2019;137(2):146–58. https://doi.org/10.1001/jamaophthalmol.2018.5449.

[11] Zhu RR, Shi J, Yang M, Guan HJ. Prevalences and causes of vision impairment in elderly Chinese: a socioeconomic perspective of a comparative report nested in Jiangsu Eye Study. Int J Ophthalmol 2016;9(7):1051–6. https://doi.org/10.18240/ijo.2016.07.19.

[12] Pan CW, Qian DJ, Sun HP, Ma QH, Xu Y, Song E. Visual impairment among older adults in a rural community in eastern China. J Ophthalmol 2016;2016: 9620542. https://doi.org/10.1155/2016/9620542.

[13] Hayward LM, Burden ML, Burden AC, Blackledge H, Raymond NT, Botha JL, et al. What is the prevalence of visual impairment in the general and diabetic populations: are there ethnic and gender differences? Diabet Med 2002;19(1):27–34. https://doi.org/10.1046/j.0742-3071.2001.00603.x.

[14] National Bureau of Statistics. Bulletin of the seventh national population census (No. 5). http://172.18.71.24:81/2Q2W43D0A2321386FD3CBFC3DF3F9B75A9F12CDC4933_unknown_8B28D3874CAB469E4200F60BED445DB910391D55_8/www.stats.gov.cn/sj/pcsj/rkpc/d7c/202303/P020230301403217959330.pdf. [Accessed 11 May 2021].

[15] World Health Organization. Visual impairment and blindness fact sheet. http://www.who.int/mediacentre/factsheets/fs282/en/. [Accessed 14 August 2014].

[16] Emancipator K. Laboratory diagnosis and monitoring of diabetes mellitus. Am J Clin Pathol 1999;112(5):665–74. https://doi.org/10.1093/ajcp/112.5.665.

[17] Wang YX, Wei WB, Xu L, Jonas JB. Physical activity and eye diseases. The beijing eye study. Acta Ophthalmol 2019;97(3):325–31. https://doi.org/10.1111/aos.13962.

[18] Wang WL, Chen N, Sheu MM, Wang JH, Hsu WL, Hu YJ. The prevalence and risk factors of visual impairment among the elderly in Eastern Taiwan. Kaohsiung J Med Sci 2016;32(9):475–81. https://doi.org/10.1016/j.kjms.2016.07.009.

[19] Zhao JL, Xu X, Ellwein LB, Guan HJ, He MG, Liu P, et al. Causes of visual impairment and blindness in the 2006 and 2014 nine-province surveys in rural China. Am J Ophthalmol 2019;197:80–7. https://doi.org/10.1016/j.ajo.2018.09.011.

[20] Evans BJW, Rowlands G. Correctable visual impairment in older people: a major unmet need. Ophthalmic Physiol Opt 2004;24(3):161–80. https://doi.org/10.1111/j.1475-1313.2004.00197.x.

[21] Matthews DR, Stratton IM, Aldington SJ, Holman RR, Kohner EM, Group UPDS. Risks of progression of retinopathy and vision loss related to tight blood pressure control in type 2 diabetes mellitus: UKPDS 69. Arch Ophthalmol 2004;122(11):1631–40. https://doi.org/10.1001/archopht.122.11.1631.

[22] Ong SR, Crowston JG, Loprinzi PD, Ramulu PY. Physical activity, visual impairment, and eye disease. Eye Lond Engl 2018;32(8):1296–303. https://

doi.org/10.1038/s41433-018-0081-8.

[23] Seddon JM, Cote J, Davis N, Rosner B. Progression of age-related macular degeneration: association with body mass index, waist circumference, and waist-hip ratio. Arch Ophthalmol 2003;121(6):785−92. https://doi.org/10.1001/archopht.121.6.785.

[24] Varma R, Choudhury F, Klein R, Chung J, Torres M, Azen SP. Four-year incidence and progression of diabetic retinopathy and macular edema: the los angeles Latino eye study. Am J Ophthalmol 2010;149(5). https://doi.org/10.1016/j.ajo.2009.11.014. 752-61.e3.

[25] Tan JSL, Wang JJ, Mitchell P. Influence of diabetes and cardiovascular disease on the long-term incidence of cataract: the blue mountains eye study. Ophthalmic Epidemiol 2008;15(5):317−27. https://doi.org/10.1080/09286580802105806.

[26] Chopra V, Varma R, Francis BA, Wu J, Torres M, Azen SP. Type 2 diabetes mellitus and the risk of open-angle glaucoma the los angeles latino eye study. Ophthalmology 2008;115(2). https://doi.org/10.1016/j.ophtha.2007.04.049. 227-32.e1.

[27] Klein R, Moss SE, Meuer SM, Klein BEK. The 15-year cumulative incidence of retinal vein occlusion: the Beaver Dam Eye Study. Arch Ophthalmol 2008;126(4):513−8. https://doi.org/10.1001/archopht.126.4.513.

[28] Burkemper B, Torres M, Jiang XJ, McKean-Cowdin R, Varma R. Factors associated with visual impairment in Chinese American adults: the Chinese American eye study. Ophthalmic Epidemiol 2019;26(5):329−35. https://doi.org/10.1080/09286586.2019.1622737.

[29] Newcomb PA, Klein R. Factors associated with compliance following diabetic eye screening. J Diabet Complicat 1990;4(1):8−14. https://doi.org/10.1016/0891-6632(90)90058-D.

[30] Jones CD, Greenwood RH, Misra A, Bachmann MO. Incidence and progression of diabetic retinopathy during 17 years of a population-based screening program in England. Diabetes Care 2012;35(3):592−6. https://doi.org/10.2337/dc11-0943.

[31] Gale R, Scanlon PH, Evans M, Ghanchi F, Yang Y, Silvestri G, et al. Action on diabetic macular oedema: achieving optimal patient management in treating visual impairment due to diabetic eye disease. Eye Lond Engl 2017;31(S1):S1−20. https://doi.org/10.1038/eye.2017.53.

[32] Guymer C, Casson R, Howell C, Stocks N. The AgED Study. Age-related eye disease (AgED) in South Australian general practice: are we blind to early detection and intervention? Aust J Prim Health 2017;23(1):75−9. https://doi.org/10.1071/PY15189.