Associations between visual impairment, incident falls and fall frequency among older asians: longitudinal findings from the Singapore Epidemiology of Eye Diseases study

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ABSTRACT

Background Association between baseline visual impairment (VI) bilaterality and severity, and associated causes; and incident and frequent falls at 6 years in a multiethnic Asian population aged ≥60 years.

Methods It is a population-based prospective cohort study. Visual acuity was clinically measured at both visits. Self-reported incidence and frequency of falls were defined as having no fall at baseline but having one fall and ≥2 incident falls in the 12 months prior to the follow-up visit, respectively.

Results Of the 1972 older participants (mean age (SD): 67.37 (5.4) years), 253 (12.8%) and 69 (3.5%) reported at least one fall and ≥2 falls, respectively, at a 6-year follow-up. After multivariable adjustments, baseline bilateral VI, but not unilateral, was associated with higher odds of any incident falls (mild bilateral VI: OR=1.79, 95% CI 1.07 to 2.98; moderate-severe VI in one eye and mild VI in the other eye: OR=1.58, 95% CI 1.01 to 2.47). However, having any form of bilateral VI (OR ranging between 2.46 and 4.32; all p<0.05) and even unilateral mild VI (OR=2.34, 95% CI 1.09 to 5.03) significantly increased the odds of incident frequent falls, compared with bilateral normal vision. VI caused by correctable (OR=2.02, 95% CI 1.19 to 3.44) and uncorrectable (OR=3.09, 95% CI 1.08 to 8.80) eye conditions were both associated with greater odds of incident frequent falls, compared with no VI.

Conclusions Baseline bilateral but not unilateral VI conferred nearly two-fold higher odds of incident fall. Importantly, even mild unilateral VI conferred a substantially greater likelihood of frequent falls from correctable and uncorrectable conditions.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Visual impairment (VI) increases the risk of falling in the older adults, but the relationship between VI bilaterality (unilateral versus bilateral), severity, and associated causes and prospective falls in elderly Asians is not known.

WHAT THIS STUDY ADDS

⇒ In this multi-ethnic population-based longitudinal study of older Asians, baseline bilateral but not unilateral VI conferred a greater likelihood of incident fall. Importantly, even mild unilateral VI conferred substantially higher odds of recurring falls.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings suggest that aside from community-based vision screening to detect and treat bilateral VI in the elderly to prevent falls, more aggressive vision screening and intervention strategies are needed to complement falls rehabilitation programs to better mitigate the risk of repeated falls in those at risk.

⇒ Moreover, given that the majority of VI in our sample is correctable (unoperated cataract and under corrected refractive error), subsidizing the cost of refractive corrections and cataract surgery for elderly individuals, particularly those who are fallers, should form a holistic approach to reducing the onset of any and recurring falls.

INTRODUCTION

Approximately, a third of community-living older people aged ≥65 years; and half of those aged >80 years will experience at least one fall in a year, with around 1 in 10 resulting in injury or fracture.[1–4] Falls are associated with longer term adverse mental and physical health outcomes, including fear of falling, reduced mobility and activity, depression, lack of independent living and diminished quality of life (QoL), leading to frailty, early admission to long-term care, functional decline and mortality.[5 6] As such, falling imposes a significant health and economic burden both on patients and society,[6–8] particularly as its frequency and severity increases.[7] Therefore, understanding the risk factors contributing to falls is imperative for appropriate intervention strategies to be implemented, in turn improving functional health and independence in ageing seniors.

One potentially modifiable risk factor is visual impairment (VI), which more than doubles the risk of falling in the older adults.[9–17] However,

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longitudinal data pertinent to the relationship between VI and falls are limited and have been confined to Caucasian populations,[18 19] which may have limited relevance in Asia due to the different prevalence and progression rates, and risk factors of VI and falls as well as differences in lifestyle, culture, environment and nutritional habits. Such data are important as Asia makes up to 60% of the world's population and accounts for more than half of VI and blindness cases globally.[20] Furthermore, our knowledge of the impact of the bilaterality (unilateral vs bilateral VI), severity and causes of VI on prospective falls is even more limited, with incident data in Asians currently unavailable.

We investigated the longitudinal associations between baseline VI bilaterality and severity, and associated causes of VI; and the 6-year incidence and frequency of falls in a multiethnic older Asian population ≥60 years of age in Singapore. We hypothesised that older individuals with bilateral VI would have a higher risk of incident and frequent falls compared with individuals with no or unilateral VI. Furthermore, given that major causes of vision loss, including diabetic retinopathy (DR) and diabetic macular oedema, cataracts, age-related macular degeneration (AMD) and glaucoma, are all age-related,[21] we speculated that both correctable (unoperated cataract and refractive error) and uncorrectable (glaucoma, DR, AMD) causes of VI would be associated with a higher incidence and frequency of falls.

METHODS

Study population and design

The Singapore Epidemiology of Eye Diseases (SEED) study is a longitudinal population-based study in Singapore that comprises adults from three major ethnicities: Chinese (The Singapore Chinese Eye study), Malay (The Singapore Malay Eye study) and Indian (The Singapore Indian Eye study). Participants from SEED were examined between 2004 and 2011 and 2011 and 2017 at baseline and follow-up, respectively. Details of the SEED study design and methodology have been described in detail previously.[22–25] Briefly, participants aged 40–80+ years residing in the Southwestern part of Singapore were recruited and underwent standardised ocular and systemic examinations. At baseline, 4407 individuals (1532 Chinese, 1509 Malay and 1366 Indian adults) aged 60 years and above participated in the study. Of these, 17 and 816 participants had missing falls data or had reported at least one fall at baseline, respectively, leaving 3574 participants to be included in this study. Of these, 2131 (response rate 59.6%) attended the 6-year follow-up assessment. After excluding 159 participants with missing data (baseline characteristics (n=150) or follow-up falls information (n=9)), we included 1972 participants in the final analysis (figure 1).

The study was conducted at the research clinic of the Singapore Eye Research Institute. All protocols followed the principles of the Declaration of Helsinki and received approval by the SingHealth Institutional Review Board. Written informed consent from participants was obtained before participation in the study.

Assessment of falls and frequent falls

Information on falls over a 12-month period before the study examination was based on participants' self-reported history, ascertained using an in-house questionnaire administered by trained interviewers fluent in English, Mandarin, Malay or Tamil (dependent on participant's choice). At the clinic visit, the participant was asked: 'In the past 12 months, have you fallen and landed on the floor or ground?' If the response was yes, the subject was further asked about the number of falls in the past

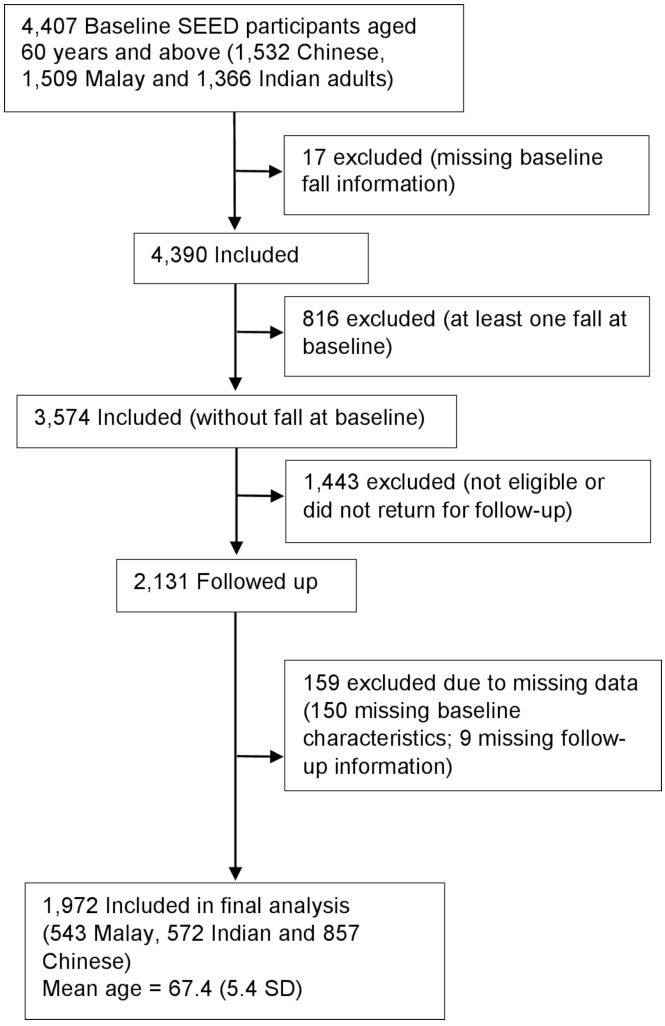

Figure 1 Study inclusion and exclusion criteria. SEED, Singapore Epidemiology of Eye Diseases.

12 months. Incidence of falls was defined as having no falls in the 12 months prior to the baseline visit but having one fall in the 12 months prior to the follow-up visit. Incidence of frequent falls was defined as having no falls in the 12 months prior to the baseline visit but having ≥2 falls in the 12 months prior to the follow-up visit.

Ocular examination and vision assessment

All participants underwent a comprehensive ophthalmic examination, which included visual acuity (VA) testing, colour fundus photography and a detailed clinical slit-lamp examination.

Vision assessment

Distance VA was measured uniocularly using a logarithm of the minimum angle of resolution (LogMAR; Lighthouse International, Distance VA Number Chart CAT No. C102, New York) number chart at 4 m. Both presenting VA (PVA), ascertained with participants wearing habitual optical correction (if any) and best-corrected VA, in which refraction was corrected by trained and certified study optometrists, were obtained. If the participants were unable to read the largest line of numbers on the VA chart, the chart was moved to 3, 2 and 1 m, respectively. However, if he/she was still unable to make out any numbers at 1 m, finger counting, hand movement and the ability of the eye to perceive light with a pen torch were assessed. In this study, we report

only PVA data because PVA provides a more accurate picture of the role of VI in the performance of daily living activities than best-corrected VA.[15]

Definition of VI

VI was based on the 2019 WHO definition, International Classification of Diseases 11th Revision.[26] Any VI at baseline was defined as a LogMAR score of >0.3 (<6/12), further broken down into mild (0.3<PVA≤0.48) and moderate or worse (PVA >0.48) VI. Participants with no VI were categorised as normal (PVA ≤0.3 logMAR). For analysis of bilaterality (unilateral vs bilateral VI), we defined the following exclusive six groups with increasing severity: (1) normal vision in both eyes (reference), (2) mild VI in one eye and normal vision in the other eye, (3) moderate or worse VI in one eye and normal vision in the other eye, (4) mild VI in both eyes, (5) moderate or worse VI in one eye and mild VI in the other eye and (6) moderate or worse VI in both eyes.

Primary causes of VI were assessed by the study ophthalmologist on the basis of information obtained from the participant's clinical ocular history (eg, previous eye surgery including cataract, refractive error and glaucoma, laser photocoagulation or anti-vascular endothelial growth factor (VEGF) injections for DR and AMD and use of eye drops) and examination, and if necessary, from ocular imaging data (lens and retina). If there was more than one cause, the primary contributing cause, as determined by the study ophthalmologist, was selected as the principal cause for the person. For example, if there was DR in one eye and epiretinal membrane in the fellow eye, the principal cause was DR for that person.

The presence of eye diseases (DR, AMD, cataract and glaucoma) was assessed using standardised protocols detailed elsewhere.[27–30] Undercorrected refractive error (UCRE) was defined as the difference of at least 0.2 logMAR between presenting and best-corrected VA in either eye. Because of the small number of participants in each eye disease group, the main cause of vision loss was grouped into uncorrectable and correctable. Uncorrectable causes included DR, AMD, glaucoma or any other anterior or posterior segment pathology, while correctable causes included the presence of cataract, UCRE or posterior capsule opacification. Better-eye data were used as the better eye best represents the role of VI on an individual's likelihood of falling.

Assessment of other covariates

Trained interviewers fluent in English, Malay, Tamil and Mandarin administered questionnaires to collect sociodemographic characteristics (eg, age, gender, income, education), lifestyle factors (eg, smoking, alcohol use), medical history (eg, previous diagnosis of myocardial infarction, angina, stroke) and current medication. Information on self-reported mobility was obtained via The European Quality of Life-5 Dimensions (EQ-5D) mobility domain score.[31] Cognitive impairment was assessed using the validated abbreviated mental test, defined as scores of ≤6 and ≤8 for those with 0–6 and >6 years of formal education, respectively. Low socioeconomic status (SES) was defined as primary or lower education, individual monthly income <Singapore dollar 2 000, and living in a 1–2 room apartment or smaller.

Clinical covariates were obtained via a standardised clinical examination. Two measurements of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken using a digital automatic BP monitor (Dinamap Pro Series DP110X-RW; GE Medical Systems Information Technologies), and a third measurement was obtained if the two previous SBP or DBP readings differed by more than 10 mm Hg or 5 mm Hg, respectively. The mean of the two closest measurements was used in analyses. Height was measured using a wall-mounted, adjustable measuring scale, and weight was measured with a calibrated scientific weight scale. Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared. Blood samples were collected for haemoglobin A1c (HbA1c), random glucose and total, high-density lipoprotein, low-density lipoprotein cholesterol and triglycerides measurements.

Hypertension was defined as SBP ≥140 mm Hg, DBP ≥90 mm Hg, self-reported use of antihypertensive medications or self-reported history of physician-diagnosed hypertension. Diabetes was defined as random glucose ≥11.1 mmol/L, HbA1c ≥6.5%, self-reported use of diabetic medication or reported history of physician-diagnosed diabetes. Hyperlipidaemia was defined as total cholesterol ≥6.2 mmol/L or self-reported use of lipid-lowering medications. Chronic kidney disease was defined as an estimated glomerular filtration rate <60 mL/min/1.73 m^2 using the Chronic Kidney Disease Epidemiology Collaboration equation.[32] Cardiovascular disease (CVD) was defined as self-reported history of stroke, myocardial infarction or angina, similar to previous epidemiologic studies conducted by our group.[33]

Statistical analyses

All analyses were conducted with Stata V.16.0 (StataCorp LLC). Characteristics between non-fallers and any incident fallers were compared using t test for continuous variables and Pearson χ^2 test for categorical variables. Vision-specific characteristics of participants were summarised using mean (SD) for continuous variables and N (%) for categorical variables. Multivariable logistic regression models were used to determine the independent relationships between the various VI categories with the incidence of any and frequent falls, and the main cause of VI in the better eye, while adjusting for participant characteristics found substantively different by fall status and hitherto known risk factors of falls, including baseline age, gender, race, BMI, low SES, EQ-5D mobility score, diabetes, hypertension, hyperlipidaemia, CVD and medication use. We reported effect estimates as OR with associated 95% CI and considered a p value ≤0.05 as statistically significant.

RESULTS

Of the 1972 participants (543 Malay, 572 Indian and 857 Chinese) included in the final analyses (mean (SD) age: 67.37 (5.4) years; 1078 (54.7% men), 253 (12.8%) participants had fallen once and 69 (3.5%) were frequent fallers. Among those who fell, 202 (79.8%) sustained a broken or fractured bone.

Comparison of baseline sociodemographic, lifestyle and systemic characteristics of non-fallers and any incident fallers are shown in table 1. Compared with non-fallers, any incident fallers were more likely to be older, men, of Indian ethnicity, have higher BMI, diabetes, hypertension, hyperlipidaemia, low SES and lower EQ-5D mobility score at baseline.

Of the 324 (16.43%) participants with unilateral mild and 257 (13.03%) with unilateral moderate or worse VI, 42 (12.9%) and 30 (11.6%) participants, respectively, had incident fall; while of the 121 (6.14%) with bilateral mild VI, 241 (12.22%) with bilateral moderate or worse, and 185 (9.38%) with moderate or worse in one eye and mild in the other eye, 23 (19.0%), 32 (13.2%) and 31 (16.7%), respectively, had incidence of falls (table 2).

Table 1 Characteristics of non-fallers and any incident fallers

Characteristics	Non-fallers (N=1719)	Any incident fallers (N=253)	P value
Age	67.21 (5.38)	68.43 (5.73)	**<0.001**
Female gender	761 (44.27)	133 (52.57)	**<0.001**
Ethnicity			
Malay	478 (88.03)	65 (11.97)	**<0.046**
Indian	482 (84.27)	90 (15.73)	
Chinese	759 (88.56)	98 (11.44)	
BMI	24.83 (4.14)	25.58 (4.76)	**0.008**
Diabetes	561 (32.64)	108 (42.69)	**0.002**
Hyperlipidaemia	962 (55.96)	160 (63.24)	**0.029**
Hypertension	1385 (80.57)	188 (74.31)	**0.021**
Chronic kidney disease	311 (18.09)	39 (15.42)	0.298
Cardiovascular disease	213 (12.39)	35 (13.83)	0.518
Alcohol consumption	151 (8.78)	19 (7.51)	0.500
Current smoker	205 (11.93)	32 (12.65)	0.741
Living alone	88 (5.12)	15 (5.93)	0.589
Low socioeconomic status	1165 (67.77)	189 (4.70)	**0.026**
EQ-5D mobility score	2.86 (0.34)	2.78 (0.41)	**0.001**
Cognitive impairment	160 (9.46)	29 (11.79)	0.249
Medications	1054 (61.35)	163 (64.43)	0.347

Data presented as number (%) for continuous variables and mean (SD) for categorical variables.
P values were obtained with t-test for continuous variables and Pearson χ^2 test for categorical variables. Bolded values indicate significant difference.
BMI, body mass index; EQ-5D, European Quality of Life-5 Dimensions; N, number of participants.

Table 3 shows the association between baseline VI bilaterality and severity with any incident falls at 6-year follow-up. After multivariable adjustments, compared with those with normal bilateral vision, those with bilateral mild VI and moderate or worse VI in one eye and mild VI in the other had significantly increased likelihood of any incident falls (OR=1.79, 95% CI 1.07 to 2.98; and OR=1.58, 95% CI 1.01 to 2.47, respectively).

Table 4 shows the association between baseline VI bilaterality and severity with incident fall frequency at the 6-year follow-up. After multivariable adjustments, having any form of VI bilaterally (mild VI in both eyes: OR=4.22, 95% CI 1.77 to 10.03; moderate or worse VI in one eye and mild VI in the other eye: OR=4.32, 95% CI 2.01 to 9.28; moderate or worse VI in both eyes: OR=2.46, 95% CI 1.09 to 5.57) and even unilateral mild VI (OR=2.34, 95% CI 1.09 to 5.03) substantially increased the risk of incident frequent falls, compared with those with normal vision in both eyes.

Table 3 Association between baseline visual impairment bilaterality and severity with any incident falls

Characteristics	Any incident fall	
	OR (95% CI)	P value
Presenting bilateral/unilateral categories of VI		
Normal vision in both eyes	Reference	
Mild VI in one eye, normal vision in the other	1.21 (0.82 to 1.80)	0.320
Moderate-worse VI in one eye, normal vision in the other	1.04 (0.67 to 1.62)	0.833
Mild VI in both eyes	**1.79 (1.07 to 2.98)**	**0.024**
Moderate-worse VI in one eye, mild VI in the other	**1.58 (1.01 to 2.47)**	**0.043**
Moderate-worse VI in both eyes	1.22 (0.79 to 1.88)	0.365

Model adjusted for age, gender, race, body mass index, low socioeconomic status, EQ-5D mobility score, diabetes, hypertension, hyperlipidaemia, CVD and medication use. Bolded values indicate significance.
CVD, cardio vascular disease; EQ-5D, European Quality of Life-5 Dimensions; VI, visual impairment.

In the better-seeing eye, 533 (27.03%) and 50 (2.54%) had correctable and uncorrectable VI, respectively. Correctable causes of VI included cataract (n=264 (45.28%)) and refractive error (n=269 (46.14%)), while uncorrectable causes of VI involved glaucoma (n=9 (1.37%)), AMD (n=15 (2.57%)), DR (n=9 (1.54%)) and others (n=18 (3.09%)). Because of the small number of participants in each eye disease group, particularly uncorrectable eye conditions, the association between the main causes of VI and incident/frequent falls was analysed by grouping them into correctable and uncorrectable causes rather than separate eye diseases. Table 5 shows the associations between the main causes of VI at baseline and incident fall and frequent falls. In the older people, VI caused by both correctable and uncorrectable eye conditions was associated with greater odds of incident frequent falls (OR=2.02, 95% CI 1.19 to 3.44 for correctable and OR=3.09, 95% CI 1.08 to 8.80 for uncorrectable) compared with those with no VI.

Furthermore, of the 1128 individuals with any baseline VI 43.79% (n=494) improved to normal vision at the 6-year follow-up; the main cause for the improved vision in these individuals was the uptake of cataract surgery (~40%). We additionally looked into the association between change in vision status over 6 years and incident/frequent falls. After multivariable adjustment, individuals whose better eye vision improved to no VI had significantly lower odds of incident falls (better eye: OR=0.59, 95% CI 0.36 to 0.97), compared with people who remained visually impaired. Similarly, the likelihood of frequent falls was lower, although, the association was not significant (better eye: OR=0.73, 95% CI 0.35 to 1.53). However, the development of VI in any eye at the 6-year follow-up in

Table 2 Vision-specific characteristics and incident falls of the study participants

Characteristics	Total (N=1972)	Incident falls	
	n (%)	n (%)	95% CI
Presenting bilateral/unilateral categories of VI			
Normal vision in both eyes	844 (42.80)	95 (11.2)	0.09 to 0.13
Mild VI in one eye, normal vision in the other	324 (16.43)	42 (12.9)	0.09 to 0.17
Moderate-worse VI in one eye, normal vision in the other	257 (13.03)	30 (11.6)	0.08 to 0.16
Mild VI in both eyes	121 (6.14)	23 (19)	0.12 to 0.27
Moderate-worse VI in one eye, mild VI in the other	185 (9.38)	31 (16.7)	0.12 to 0.22
Moderate-worse VI in both eyes	241 (12.22)	32 (13.2)	0.09 to 0 0.18

VI, visual impairment.

Table 4 Association between baseline visual impairment bilaterality and severity with incident falls frequency

Characteristics	≥2 falls	
	OR (95% CI)	P value
Presenting bilateral/unilateral categories of VI		
Normal vision in both eyes	Reference	
Mild VI in one eye, normal vision in the other	2.34 (1.09 to 5.03)	**0.028**
Moderate-worse VI in one eye, normal vision in the other	1.47 (0.59 to 3.69)	0.403
Mild VI in both eyes	4.22 (1.77 to 10.03)	**0.001**
Moderate-worse VI in one eye, mild VI in the other	4.32 (2.01 to 9.28)	**<0.001**
Moderate-worse VI in both eyes	2.46 (1.09 to 5.57)	**0.030**

Model adjusted for age, gender, race, body mass index, low socioeconomic status, EQ-5D mobility score, diabetes, hypertension, hyperlipidemia, CVD, and medication use. Bolded values indicate significance.
CVD, cardiovascular disease; EQ-5D, European Quality of Life-5 Dimensions; VI, visual impairment.

individuals with no VI in both eyes at baseline was not associated with higher odds of incident falls (OR=1.52, 95% CI 0.93 to 2.4), compared with those who had any VI at baseline.

To discount a potential confounding effect of participants receiving vision interventions during the 6-year period, we looked into the association between the bilaterality and severity of VI and incident falls/frequent falls at the 6-year follow-up visit in those with any VI at baseline and the 6-year follow-up visits (n=634 (56.21%) of the 1128 who had any VI at baseline). Due to the small number of individuals in this category with falls/multiple falls, we collapsed the VI categories into unilateral and bilateral categories only. After multivariable adjustments, compared with those with no VI, those with baseline bilateral VI (OR=1.64, 95% CI 1.13 to 2.39) but not unilateral VI (OR=1.35, 95% CI 0.89 to 2.04) had more than 1.5 times higher odds of any incident fall at the 6-year follow-up visit. Interestingly, both unilateral and bilateral vision loss in those who had fallen at least once conferred a substantially greater likelihood of falling again (OR=2.53, 95% CI 1.14 to 5.63 and OR=3.03, 95% CI 1.42 to 6.42, respectively).

DISCUSSION

In our multiethnic Asian population-based cohort study, we found that adults aged ≥60 years with baseline bilateral VI, but not unilateral VI of any severity, had nearly two times higher odds of any incident fall at 6-year follow-up, compared with those without baseline VI. Interestingly, having even mild unilateral vision loss in those who had fallen at least once conferred a substantially greater likelihood of falling again. Not unexpectedly, VI due to both correctable and uncorrectable eye diseases was associated with an increased risk of incident frequent falls in older people. Community screening to detect and treat bilateral VI in the ageing seniors is warranted as well as more aggressive screening and intervention strategies for VI to complement falls rehabilitation programmes in fallers aged ≥60 years to mitigate their risk of repeated falls. Moreover, given that the majority of VI in our sample is correctable (unoperated cataract and UCRE), subsidising the cost of refractive corrections and cataract surgery for older individuals, particularly those who are fallers, should form a holistic approach to reducing the onset of any and recurring falls.

Table 5 Association between cause of vision loss in the better-seeing eye at baseline and incident/frequent falls

Cause of VI in the better-seeing eye	Any incident falls		≥2 falls	
	OR (95% CI)	P value	OR (95% CI)	P value
None	Reference		Reference	
Correctable cause	1.13 (0.83 to 1.54)	0.407	2.02 (1.19 to 3.44)	**0.009**
Uncorrectable cause	1.42 (0.68 to 2.99)	0.346	3.09 (1.08 to 8.80)	**0.034**

Model adjusted for age, gender, race, body mass index, low socioeconomic status, current smoker, EQ-5D mobility score, diabetes, hypertension, hyperlipidaemia, CVD and medication use.
CVD, cardio vascular disease; EQ-5D, European Quality of Life-5 Dimensions; VI, visual impairment.

Our findings of the longitudinal association between baseline VI and incident falls complement previous cross-sectional findings from the baseline examination of the same population, which also reported an increased likelihood of falls and recurrent falls during the 12 months before the study baseline visit among persons with VI[9 10] as well as other studies in older Asians (The Shihpai Eye study)[11] and Western populations.[15 16 34–36] In addition, our longitudinal association found between VI and incident falls aligns with limited prospective data in community-dwelling older Caucasian adults with VI having a 1.5-fold to 2-fold greater likelihood of incident falls.[18 19]

There are several plausible explanations for the VI incident/frequent falls relationship. For example, older individuals with VI, particularly bilateral, may have difficulty navigating their surroundings and, resulting in a fear of falling, leading to activity limitation and functional disability.[37–39] This, in turn, may lead to musculoskeletal disabilities, and deterioration in gait and balance,[40 41] eventually leading to an increased risk of falling. Conversely, older individuals with severe bilateral VI may experience an increased fear of falling due to high difficulties with visual navigation,[42] which can lead to a reduced ability to moving around and/or enhanced care while mobile, resulting in a reduction in fall risk. Furthermore, those with VI who have fallen may be more likely to fall again, due to the cumulative contribution of VI and impairments in strength, balance and gait components in these individuals, contributing to the common pathway of functional deterioration, including frailty and recurrent falling.

We hypothesise that older individuals may have a decreased capacity to cope with worsening vision, particularly if the loss occurred in later years, perhaps due to a documented decrease in adaptive abilities with age.[43] In addition, decrements in other aspects of the visual function system, including contrast sensitivity and visual fields, are known to affect falls.[17 44] In older people, the use of eyewear such as bifocal or multifocal corrective lenses may impair distance contrast sensitivity and depth perception.[45] For example, if the wearer views through the wrong part of a bifocal lens, this can lead to a depth misjudgement and potentially lead to an increased falls risk.[16] Unfortunately, we did not collect data on adaptation to vision loss or other visual function aspects aside from VA in our subjects and, as such, we are unable to gauge if any of these factors underlie our VI falls findings. Further studies to evaluate the effect of these factors on age-specific VI falls are warranted.

Interestingly, we observed that even unilateral mild VI was associated with a greater risk of incident frequent falls in these individuals aged ≥60 years, compared with their normal-sighted counterparts of the same age. This may be due to the deficiency in stereoacuity among unilateral cases that affects depth perception needed for navigation.[17] Because no other study to date has undertaken this comparison, we are unable to compare our

results directly. However, our stratified analyses of the association between the bilaterality and severity of VI and incident falls/frequent falls at the 6-year follow-up visit in those with any VI at baseline and the 6-year follow-up visits are similar to those presented in our full sample. These results suggest that our associations between baseline VI and incident fall/frequent falls are valid and are not confounded by uptake of visual interventions between the baseline and follow-up period. Nevertheless, studies on the impact of the bilaterality (unilateral vs bilateral VI) and severity of VI on prospective falls are needed to confirm our findings and determine the applicability of our results to falls prevention and intervention programmes.

Although, we found that the development of VI in any eye at the 6-year follow-up in individuals with no VI in both eyes at baseline was not significantly associated with higher odds of incident falls, this could likely be due to low number of our incident VI cases (n=209) and also because of our longer 6-year follow-up time. In our study, the development of VI could have occurred at any time during the 6-year period, so we may not necessarily be looking at those with acute VI development, but our incident VI group could be similar to our prevalent group in terms of how long they have had VI. Hence, further studies to evaluate the association of incident VI and incident falls are needed.

Importantly, the main causes of VI in our aged population were cataract (44.2%) and UCRE (46.1%)—the two most easily correctable forms of vision loss, and these were associated with a higher risk of frequent falls. Although uncorrectable eye diseases made up a much smaller proportion of those with VI in our sample, they also contributed to a greater likelihood of frequent falls. Interestingly, among individuals with baseline VI, whose vision improved to normal (mostly due to cataract surgery) at the 6-year follow-up, had lower risk of falling, compared with people who remained visually impaired. These findings further advocate for prevention and treatment of both correctable and uncorrectable eye conditions via early vision screening, referral of at-risk adults to eye care providers and provision of refractive corrections, cataract surgery and tailored low vision rehabilitation for seniors with VI at home and in the community to minimise the occurrence and consequences of falling.

Strengths of this study include a large and well-characterised population-based older cohort, which means that our findings are likely to be generalisable to the older Singaporean community; and the availability of baseline and follow-up data, enabling us to make causal inferences. In addition, the objective assessment of VA allowed VI to be categorised according to international standards. The main limitation of our study is that falls were self-reported and obtained retrospectively in the 12-month period prior to the 6-year follow-up visit; as a result, our outcome may be subjected to recall bias,[46] and we may have included people who have had fall from baseline to first 4 years. Future research using objective measure of falls, such as fall diaries, are required. Information on use of assistive devices such as walking stick/cane was not ascertained in the questionnaire, which may have led to overrepresentation of falls in our population. Importantly, we did not collect information on frailty, strength, balance and gait components of mobility that have been linked to increased risk of falls.[47 48] Although we did account for self-reported mobility obtained via the EQ-5D mobility score, it may not reflect the individual's actual mobility status. Additional longitudinal studies with information on these physical functions assessed objectively are needed to provide a more robust assessment of the association between presence of VI and falls risk and confirm our findings. Low number of fallers in the moderate–severe VI category (n=7 (2.9%) of 234 frequent fallers) limited our ability to properly assess the VI-falls association in older individual with moderate–severe VI. Unfortunately, due to the small number of individuals aged >75 years (n=213), we could not perform the age-stratified analyses in those 60–75 years and >75 years in our sample. Further studies to evaluate the age-specific VI-incident/frequent falls relationship are warranted. In addition, we did not account for the contribution of other aspects of the visual function system to falls, for example, colour discrimination, contrast sensitivity, depth perception and visual fields, which are shown to be associated with falling.[17 49] Given these limitations, our group has recently set up a population-based cohort study of older Asian adults (≥60 years; The PopulatION HEalth and Eye Disease PRofile in Elderly Singaporeans study following standardised protocol for the assessment of both clinical and patient-reported ocular and systemic outcome measures,[50] which will allow us to address these limitations in detail.

In conclusion, in our multiethnic, population-based longitudinal study of older Asians, we showed that bilaterally visually impaired individuals have a considerably greater likelihood of incident falls than normally sighted individuals or those suffering from unilateral vision loss. Importantly, even mild unilateral vision loss conferred a substantially higher odds of recurring falls in the older individuals. Our findings suggest that aside from community-based vision screening to detect and treat bilateral VI in the seniors to prevent falls, more aggressive vision screening and intervention strategies are needed to complement falls rehabilitation programmes to better mitigate the risk of repeated falls in those at risk.

Contributors PG and ELL had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. ELL is the gurantor. Study concept and design: PG, CS, C-YC, TYW, ELL. Acquisition, analysis, or interpretation of data: PG, REKM, EKF, C-YC, TYW, ELL. Drafting of manuscript: PG, REKM, EKF and ELL. Critical revision of the manuscript for important intellectual content: PG, REKM, EKF, CQ, RS, SM, YCT, CS, TYW, C-YC, ELL. Obtained funding: TYW, C-YC and CS. Statistical analysis: PG. Administrative, technical or material support: TW, C-YC and CS. Study supervision: PG, TYW, CS, C-YC, ELL.

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Ethics approval SEED was conducted in accordance with the Declaration of Helsinki and was approved by the Singhealth Centralised Institutional Review Board (2018/2717, 2018/2921, 2012/487/A, 2015/2279, 2018/2006, 2018/2594, 2018/2570). Informed consent was obtained from all participants. Participants gave informed consent to participate in the study before taking part.

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