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Longitudinal associations between self-reported vision impairment and all-cause mortality: a nationally representative cohort study among older Chinese adults

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ABSTRACT

Objective To compare the effects of pre-existing and new self-reported vision impairment (VI), and its correction, on all-cause mortality among Chinese adults aged 45 years and older.

Methods We used four waves of data from the China Health and Retirement Longitudinal Study. Our analytical cohort consists of 15 808 participants aged 45 years and older with an average follow-up of 6.4 years. Exposures included pre-existing self-reported VI and vision correction (time-independent exposures), new self-reported VI and vision correction (time-dependent exposures). Outcomes were measured as the risk of all-cause mortality and the risk stratification for pre-specified factors.

Results Compared with participants with normal vision, all-cause mortality was higher among those with pre-existing self-reported VI (crude HR (cHR)=1.29, 95% CI: 1.17 to 1.44; adjusted HR (aHR)=1.22, 95% CI: 1.09 to 1.37) and new self-reported VI (cHR=1.42, 95% CI: 1.28 to 1.58; aHR=1.36, 95% CI: 1.21 to 1.51). Mortality risk was lower among those with high school or higher education. Participants who were wearing eyeglasses/contact lenses or had cataract surgery at baseline did not have significantly higher all-cause mortality (eyeglasses: aHR=0.82, 95% CI: 0.65 to 1.02; cataract surgery: aHR=1.12, 95% CI: 0.74 to 1.69) compared with participants with normal vision. The same was true among participants with new correction of self-reported VI (glasses: aHR=1.01, 95% CI: 0.78 to 1.24; cataract surgery: aHR=0.95, 95% CI: 0.68 to 1.31).

Conclusions Both pre-existing and new self-reported VI increase all-cause mortality among Chinese adults aged 45 years and older, though visual correction reduces this risk.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Vision impairment (VI) is associated with mortality. However, little is known about how existing and new self-reported VI influence mortality risk among older adults.

WHAT THIS STUDY ADDS

⇒ In this cohort study of Chinese residents aged 45 and older, all-cause mortality was higher among participants with self-reported existing (aHR=1.22, 95% CI: 1.09 to 1.37) or new VI (aHR=1.36, 95% CI: 1.21 to 1.51). However, participants with corrected VI did not have a higher mortality risk compared with those with normal vision.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our finding that VI correction with glasses and cataract surgery can reduce mortality by at least 12% provides a strong impetus for further government investment in ophthalmology and optometry practices in China and other low-income and middle-income countries.

INTRODUCTION

The burden of vision impairment (VI) has become a global public health issue. More than half a billion people are blind or have VI around the world.[1] Due to the growth and ageing of the world's population, the prevalence of VI and blindness is projected to more than double in the next 30 years.[2] VI has become an important driver of avoidable healthcare utilisation, rising health expenditures, low quality of life and other adverse health outcomes.[3–7] Some recently published systematic reviews and meta-analyses have recognised VI as an independent risk factor for mortality.[8 9]

Although more than 80% of people with VI and blindness live in low-income and middle-income countries (LMICs),[1] limited evidence on the impacts of VI has been collected from these areas. As the most populous and rapidly ageing LMIC, China had 59.28 million people with moderate-to-severe VI or blindness in 2019, nearly equivalent to the entire population of the UK.[10] However, few studies have investigated longitudinal associations between VI and mortality in China and other LMICs.[11] Most of these studies were based on regional data and provided inconsistent results, and few have reported on nationally representative cohort data.

The leading causes of VI and blindness worldwide are cataract and uncorrected refractive error, both of which are easily treatable with inexpensive and cost-effective interventions.[12] Although previous population-based cohort studies in high-income countries have shown that older people with unoperated cataract[13] or cataract surgical patients with persistent visual impairment[14] increased their mortality and a gain in visual acuity was associated with a reduced risk of death,[15] little evidence exists

regarding the effect of vision correction on mortality in China and other LMICs. Additional data would inform interventions to alleviate the increasing burden of VI.

Existing studies within and outside China also suffer from methodological limitations. Due in part to limited data, available studies are inconsistent in their inclusion of potential confounders.[16–18] A framework-based empirical approach to adjusting for such confounders is needed to better characterise the impact of VI on mortality. Additionally, few studies examining the association between vision and mortality have distinguished between pre-existing and new VI. Time-varying statistical models are needed to account for temporal effects and estimate the impact of both fixed vision loss and declining vision function on mortality.

The current study aims to address these issues by analysing a nationally representative prospective cohort of older Chinese adults, following a framework-based empirical approach that captures time-varying changes in exposure and potential confounders. This will be accomplished by: (1) characterising the longitudinal relationships of pre-existing and new VI with mortality and (2) estimating the protective effect of vision correction (cataract surgery and refractive correction with glasses) on all-cause mortality. We hypothesise that both pre-existing and new VI are associated with all-cause mortality, while either cataract surgery or refractive correction with glasses would show protective effects among older adults with pre-existing and new VI.

METHODS

Data and sampling

This study used data from the 2011 baseline and 2013 (wave 2), 2015 (wave 3) and 2018 (wave 4) follow-up surveys of the China Health and Retirement Longitudinal Study (CHARLS). CHARLS is a nationally representative, biennial prospective cohort study of Chinese adults aged≥45 years and their spouses. Using stratified multistage probability-proportional-to-size sampling,[19] CHARLS covered 28 provinces, 150 counties/districts and 450 villages/communities, enrolling 17 708 participants in 10 257 households, at an overall response rate of 80.5%, in the baseline survey. Of the 17 708 baseline participants, 1332 (11.4%) were excluded from our analyses due to lack of self-reported distance vision, and 440 (3.8%) due to ineligible or missing age data. Therefore, our analytical cohort consisted of 15 808 participants (table 1). Follow-up rates were 87.1% (13 775/15 808) in 2013, 83.6% (13 209/15 808) in 2015 and 77.8% (12 293/15 808) in 2018.

Conceptual framework

Following a recently published systematic review on global eye health and meta-analysis on the association between VI and mortality,[5 20 21] our empirical analysis is based on the following framework (online supplemental figure S1):

1. Direct pathways through the effect of VI on systemic health: increased risk of chronic disease, decreased functional status, frailty.
2. Indirect pathways through activity and participation: reduced access to healthcare, increased injuries, limitations in physical activity, increased risk of social isolation, leading to depression and dementia.
3. Shared common risk factors (individual-level traits, environmental and health system characteristics) including smoking, alcohol consumption, socioeconomic status (SES) and conditions with both ocular and systemic manifestations (eg, cardiovascular disease, diabetes, hypertension, stroke).

The richness of the variables in the CHARLS questionnaire allowed us to include important potential covariates and confounders that were unavailable in previous studies.

Assessment of outcomes and predictors

Exposures: self-reported VI and vision correction

In CHARLS, self-reported VI and vision correction were assessed at the baseline and following two follow-up waves (2011, 2013 and 2015). Self-reported VI is assessed using the following question: 'how good is your eyesight for seeing things at a distance, such as recognising a friend from across the street (with glasses or corrective lenses if you wear them)? Would you say your eyesight for seeing things at a distance is excellent, very good, good, fair or poor?' Following previous studies, a binary classification of VI (Unless specifically stated, we do not distinguish between 'self-reported VI' and 'VI' in the following description of the CHARLS results.) was defined by self-reported 'poor' vision.[22] Otherwise, the participants were classified as having 'normal vision' (when participants self-reported their eyesight for seeing things at a distance was 'excellent', 'very good', 'good' or 'fair').

In addition, two questions on vision correction were asked: 'do you usually wear glasses or corrective lenses?' and 'have you ever had cataract surgery?' Thus, we were able to distinguish between participants with normal vision who had had vision correction and those who had not. Specifically, we divided the sample into four categories: normal vision without vision correction, normal vision after cataract surgery, normal vision regularly wearing eyeglasses and VI. If the participant had cataract surgery or wore glasses but had remaining VI, we would still classify him/her as 'VI'.

Outcome: all-cause mortality

Mortality data were collected in the three follow-up waves (2013, 2015 and 2018). In the 2013 wave, the mortality status of the interviewee (dead, alive, do not know), the interview date (year and month) and the date of death (year and month) were recorded. For those who had died by the time of the 2013 wave (wave 2), survival time was calculated as the interval between the date of interview in wave 1 and the date of death. However, in the following 2015 and 2018 waves, only the interviewee's mortality status was available for those who died during this wave, but not the date of death. To address this, the survival times of participants who had died were estimated as the median of the interval between the prior interview and the interview during the follow-up wave. For example, for those who were alive at the time of the 2013 interview, but had died by the 2015 wave, the survival time was the median interval between the interview dates in the 2013 and 2015 waves.[23]

Other covariates

Covariates were collected at the baseline survey and in the next two follow-up waves (2011, 2013 and 2015). Demographic and SES covariates included age, sex, official residential status (rural vs urban), marital status, education and geographic census region. Health status covariates included body mass index (BMI), hypertension and the number of other comorbidities (including diabetes, cancer, lung disease, heart problem, stroke, arthritis, dyslipidaemia, liver disease, kidney disease, stomach disease, asthma and memory problem).[24] Behavioural covariates included alcohol consumption and tobacco use.

Table 1 Baseline characteristics

	Full sample	No self-reported VI	Self-reported VI	
	N=15 808	N=12 164	N=3644	P value
Demographic characteristics				
Age at surgery, mean (SD), years	59.2 (9.7)	58.1 (9.3)	62.8 (10.1)	<0.001
Sex: male, n (%)	7547 (47.7%)	6124 (50.3%)	1423 (39.1%)	<0.001
Marriage status: married or partnered, n (%)	13 761 (87.1%)	10 792 (88.7%)	2969 (81.5%)	<0.001
Official residential status: rural, n (%)	12 222 (77.3%)	9176 (75.5%)	3046 (83.6%)	<0.001
Education: high school and above, n (%)	1990 (12.6%)	1762 (14.5%)	228 (6.3%)	<0.001
Area of residence, n (%)				
1. Eastern China	5000 (31.6%)	4006 (32.9%)	994 (27.3%)	<0.001
2. Middle	4484 (28.4%)	3349 (27.5%)	1135 (31.1%)	
3. Western China	5155 (32.6%)	3861 (31.7%)	1294 (35.5%)	
Health status				
Body mass index, mean (SD), years	23.5 (4.0)	23.6 (4.0)	23.1 (3.9)	<0.001
Ever had hypertension, n (%)	6296 (40.0%)	4635 (38.3%)	1661 (45.8%)	<0.001
Number of comorbidities, mean (SD)	1.2 (1.2)	1.1 (1.1)	1.6 (1.3)	<0.001
Health-related lifestyle				
Heavy consumption of alcohol, n (%)	1308 (8.3%)	1048 (8.6%)	260 (7.1%)	0.004
Current smoker, n (%)	6252 (39.6%)	4944 (40.7%)	1308 (35.9%)	<0.001
Direct pathways				
Frailty, n (%)				
1. Not frail	4450 (36.6%)	3817 (40.5%)	633 (23.2%)	<0.001
2. At risk for frailty	7262 (59.8%)	5355 (56.8%)	1907 (69.9%)	
3. Frail	441 (3.6%)	252 (2.7%)	189 (6.9%)	
Disability, n (%)				
1. Activities of daily living (ADLs) disability	860 (5.4%)	456 (3.7%)	404 (11.1%)	<0.001
2. Instrumental ADLs disability	2019 (12.8%)	1104 (9.1%)	915 (25.1%)	<0.001
Indirect pathways				
Injuries				
Have fallen in the last 2 years, n (%)	2508 (15.9%)	1650 (13.6%)	858 (23.7%)	<0.001
Healthcare utilisation				
Not seeking medical care in last month, n (%)	1121 (7.1%)	753 (6.2%)	368 (10.1%)	<0.001
Undergoing physical examination in the last year, n (%)	7225 (45.8%)	5580 (46.0%)	1645 (45.3%)	0.416
Wearing glasses, n (%)	1821 (11.5%)	1361 (11.2%)	460 (12.6%)	0.017
Had cataract surgery, n (%)	295 (1.9%)	150 (1.2%)	145 (4.1%)	<0.001
Social engagement and mental well-being				
Social isolation, n (%)				
1. Not isolated	5925 (38.5%)	4862 (40.9%)	1063 (30.1%)	<0.001
2. Moderate isolation	7810 (50.7%)	5936 (50.0%)	1874 (53.1%)	
3. Severe isolation	1669 (10.8%)	1077 (9.1%)	592 (16.8%)	
Depression present	5789 (37.1%)	3765 (31.3%)	2024 (56.6%)	<0.001

Source: CHARLS 2011 Baseline.
VI, visual impairment.

According to our conceptual framework, we used frailty and disability (activities of daily living (ADLs), instrumental ADLs) to capture direct pathways for the effect of self-reported VI on systemic health. Indirect pathways were measured by healthcare utilisation (including having sought medical care in the past month and undergoing physical examination in the past year), injuries (had fallen in the last 2 years) and mental and social well-being (depressive symptoms and social isolation). We followed previous studies in our analysis of hypertension and disability in CHARLS[25 26]: depressive symptoms were assessed using the 10-item short form of the Centre for Epidemiologic Studies Depression Scale-10[27 28]; social isolation was measured using the social integration index[24]; frailty was measured with the Physical Frailty Phenotype Score, which included assessments of weakness, slowness, exhaustion and inactivity.[29 30]

Statistical analyses

Time-varying covariance commonly occurs when covariates change over a period of follow-up. In this case, a covariate's effect on the outcome (HR) may not be constant over time, which is a violation of the proportional hazard assumption for traditional Cox regression models.[31–34] Following previous studies,[35–39] we used two analytic approaches. We first used traditional Cox regression models to investigate the effects of pre-existing VI (defined as VI reported by participants at baseline) on mortality, then we employed the time-dependent covariates Cox regression model[40] to investigate the mortality impact of new VI (defined as VI occurring during follow-up and before death), treating self-reported VI as a time-varying exposure.

Following our conceptual framework, our empirical analysis incorporates six models (online supplemental figure S2). Model

1 is our base model, the longitudinal relationship between self-reported VI and death are reported adjusted for age and sex, the two commonly used confounders for mortality and VI in previous analyses.[5 8 9] Model 2 is our fully adjusted model, we reported our main analysis results further adjusted for demographic and SES variables, health status and behavioural covariates. Based on model 2, we also created four different models to test for potential mediation of direct pathway (model 3) and three different indirect pathways (models 4–6) following our analytical framework[41]: variables characterising frailty and disability were analysed to test the impact of the direct pathway (model 3). Regarding the indirect pathway, model 4 included the additional variable describing whether the participant fell over the past year. Care-seeking and participation in general health screenings in the past year were included in model 5 to assess the effects of healthcare utilisation. In model 6, we have included adjustment for mental and social well-being covariates. To assess effect modification by SES, analyses in table 2 were stratified by sex, official residence status and educational level (tables 2 and 3).

To examine the protective effect of vision correction (cataract surgery and refractive correction with glasses) on mortality risk, we divided participants into four categories: normal vision without vision correction, normal vision after cataract surgery, normal vision while regularly wearing eyeglasses and vision impaired. Each of the four categories was treated as fixed (for pre-existing VI at baseline) or time-varying (for new VI), through the application of traditional or time-dependent Cox regression models, respectively.

All analyses were performed using the 'survival' package of R software V.4.0.2 (R Core Team) and STATA V.16.0 (StataCorp LLC, Texas, USA).

RESULTS

Baseline characteristics

Among the baseline cohort of 15 808 Chinese adults aged 45 years and older followed for an average period of 6.4 years, the mean age was 59.2 years, 52.3% were women and 23.1% (n=3644) had VI (table 1). Participants without self-reported VI had higher SES: they were younger (58.1 vs 62.8, p<0.001), and more likely to be men (50.3% vs 39.1%, p<0.001), urban dwellers (24.5% vs 16.4%, p<0.001), married (88.7% vs 81.5%, p<0.001) and have graduated from high school (14.5% vs 6.3%, p<0.001). Regarding health status, participants with pre-existing VI had lower BMI (23.1 vs 23.6, p<0.001), and a higher prevalence of hypertension (45.8% vs 38.3%, p<0.001), frailty (6.9% vs 2.7%, p<0.001), disability (11.1% vs 3.7%, p<0.001) and other chronic conditions (number of comorbidities: 1.6 vs 1.1, p<0.001). Participants with pre-existing VI were significantly less likely to have sought medical care in the last month (6.2% vs 10.1%, p<0.001), but were significantly more likely to wear glasses (12.6% vs 11.2%, p=0.017) or have had cataract surgery (4.1% vs 1.2%, p<0.001). In addition, participants with pre-existing VI were significantly more likely than those without to be depressed (56.6 vs 31.3%, p<0.001) and to experience severe social isolation (16.8% vs 9.1%, p<0.001) (table 1).

Association between self-reported pre-existing and new VI and mortality

Compared with participants without self-reported VI, there was a larger increase in all-cause mortality for participants with VI at baseline (between 2011 and 2013: 4.2% vs 2.1%, p=0.001;

Table 2 Association between all-cause mortality and VI: stratified by socioeconomic status

	HR	95% CI
Model 1		
New VI	1.42	1.28 to 1.58
Pre-existing VI	1.29	1.17 to 1.44
New VI: male	1.46	1.27 to 1.68
Pre-existing VI: male	1.29	1.17 to 1.44
New VI: female	1.37	1.17 to 1.60
Pre-existing VI: female	1.27	1.08 to 1.48
New VI: rural	1.32	1.17 to 1.49
Pre-existing VI: rural	1.20	1.07 to 1.35
New VI: urban	1.59	1.24 to 2.04
Pre-existing VI: urban	1.59	1.24 to 2.04
New VI: finished high school and above	0.91	0.49 to 1.68
Pre-existing VI: finished high school and above	0.90	0.49 to 1.67
New VI: finished middle school and below	1.41	1.27 to 1.57
Pre-existing VI: finished middle school and below	1.28	1.15 to 1.43
Model 2		
New VI	1.36	1.21 to 1.51
Pre-existing VI	1.22	1.08 to 1.37
New VI: male	1.38	1.19 to 1.60
Pre-existing VI: male	1.20	1.02 to 1.40
New VI: female	1.32	1.11 to 1.56
Pre-existing VI: female	1.25	1.05 to 1.50
New VI: rural	1.32	1.17 to 1.49
Pre-existing VI: rural	1.15	1.02 to 1.31
New VI: urban	1.52	1.17 to 1.99
Pre-existing VI: urban	1.55	1.16 to 2.08
New VI: finished high school and above	0.85	0.43 to 1.67
Pre-existing VI: finished high school and above	0.69	0.31 to 1.53
New VI: finished middle school and below	1.38	1.23 to 1.54
Pre-existing VI: finished middle school and below	1.23	1.09 to 1.39
Model 3		
New VI	1.09	0.96 to 1.24
Pre-existing VI	1.08	0.95 to 1.23
New VI: male	1.15	0.98 to 1.36
Pre-existing VI: male	1.11	0.93 to 1.31
New VI: female	1.00	0.82 to 1.22
Pre-existing VI: female	1.04	0.85 to 1.28
New VI: rural	1.06	0.94 to 1.21
Pre-existing VI: rural	1.02	0.89 to 1.18
New VI: urban	1.21	0.88 to 1.67
Pre-existing VI: urban	1.27	0.90 to 1.79
New VI: finished high school and above	0.46	0.19 to 1.14
Pre-existing VI: finished high school and above	0.52	0.20 to 1.34
New VI: finished middle school and below	1.13	0.99 to 1.28
Pre-existing VI: finished middle school and below	1.10	0.97 to 1.26
Model 4		
New VI	1.34	1.20 to 1.49
Pre-existing VI	1.22	1.08 to 1.37
New VI: male	1.37	1.18 to 1.58
Pre-existing VI: male	1.20	1.02 to 1.40
New VI: female	1.29	1.09 to 1.53
Pre-existing VI: female	1.25	1.04 to 1.50
New VI: rural	1.30	1.15 to 1.47
Pre-existing VI: rural	1.16	1.02 to 1.32
New VI: urban	1.49	1.14 to 1.95
Pre-existing VI: urban	1.58	1.18 to 2.12
New VI: finished high school and above	0.72	0.35 to 1.48

Continued

Table 2 Continued

	HR	95% CI
Pre-existing VI: finished high school and above	0.67	0.30 to 1.49
New VI: finished middle school and below	1.36	1.22 to 1.52
Pre-existing VI: finished middle school and below	1.24	1.10 to 1.39
Model 5		
New VI	1.34	1.20 to 1.50
Pre-existing VI	1.22	1.08 to 1.37
New VI: male	1.37	1.18 to 1.58
Pre-existing VI: male	1.20	1.02 to 1.40
New VI: female	1.30	1.10 to 1.54
Pre-existing VI: female	1.25	1.04 to 1.49
New VI: rural	1.31	1.16 to 1.47
Pre-existing VI: rural	1.16	1.02 to 1.31
New VI: urban	1.49	1.14 to 1.95
Pre-existing VI: urban	1.59	1.19 to 2.14
New VI: finished high school and above	0.80	0.40 to 1.59
Pre-existing VI: finished high school and above	0.69	0.30 to 1.54
New VI: finished middle school and below	1.36	1.22 to 1.52
Pre-existing VI: finished middle school and below	1.23	1.10 to 1.39
Model 6		
New VI	1.26	1.12 to 1.41
Pre-existing VI	1.14	1.01 to 1.29
New VI: male	1.29	1.11 to 1.50
Pre-existing VI: male	1.12	0.95 to 1.32
New VI: female	1.22	1.02 to 1.45
Pre-existing VI: female	1.17	0.97 to 1.41
New VI: rural	1.21	1.07 to 1.38
Pre-existing VI: rural	1.08	0.95 to 1.23
New VI: urban	1.45	1.09 to 1.91
Pre-existing VI: urban	1.50	1.10 to 2.03
New VI: finished high school and above	0.66	0.32 to 1.37
Pre-existing VI: finished high school and above	0.58	0.25 to 1.37
New VI: finished middle school and below	1.28	1.14 to 1.44
Pre-existing VI: finished middle school and below	1.16	1.02 to 1.31

Data source: China Health and Retirement Longitudinal Study 2011, 2013, 2015, 2018. Model 1 was the unadjusted VI-only model; model 2 includes VI with the additional covariates of age, sex, other demographic variables (marriage status, residential status, education, area of residence), health status (body mass index, hypertension, number of other comorbidities) and health-related lifestyle (drinking and smoking); based on model 2, models 3–6 further include variables to test the impact of direct/indirect pathways. Model 3 included frailty and disability (direct pathway). Model 4 included the additional variable describing whether the participant fell over the past year (indirect pathway 1). Model 5 included having sought medical care and undergoing a medical examination in the past year (indirect pathway 2), while model 6 included depression and social isolation (indirect pathway 6).
VI, visual impairment.

between 2015 and 2018: 13.6% vs 7.9%, p<0.001) (figure 1). The mean annual increase in death from 2011 to 2018 was only 5.8% in the normal vision group compared with 9.4% in those with VI (p<0.001).

Table 2 shows the Cox models for the association between self-reported pre-existing and new VI and mortality. In adjusted analyses (model 2), both self-reported pre-existing and new VI were independently associated with increased mortality risk (HR) for pre-existing VI, 1.22; 95% CI, 1.08 to 1.37; HR for new VI, 1.36; 95% CI, 1.21 to 1.51). In model 3 (direct pathway model), after adjusting for frailty and disability, the effects of pre-existing and new VI on mortality are no longer significant. In the three indirect pathway models, the effect sizes of pre-existing and new VI are slightly attenuated after adjustment for falls (model 4) and access to healthcare (model 5), while there is an appreciable

Table 3 Association between all-cause mortality and vision impairment, stratified by having received vision treatment

Model 1	HR	95% CI
Reference group: normal vision, uncorrected	Ref.	Ref.
New cases of VI		
New VI: uncorrected	1.42	1.27 to 1.58
Normal vision: corrected by glasses	0.87	0.70 to 1.09
Normal vision: corrected by cataract surgery	0.87	0.63 to 1.20
Pre-existing cases of VI		
Pre-existing VI: uncorrected	1.26	1.13 to 1.40
Normal vision: corrected by glasses	0.79	0.65 to 0.96
Normal vision: corrected by cataract surgery	1.05	0.71 to 1.54
Model 2	**HR**	**95% CI**
Reference group: Normal vision, uncorrected	Ref.	Ref.
New cases of VI		
New VI: uncorrected	1.37	1.22 to 1.53
Normal vision: corrected by glasses	1.01	0.78 to 1.24
Normal vision: corrected by cataract surgery	0.95	0.68 to 1.31
Pre-existing cases of VI		
Pre-existing VI: uncorrected	1.19	1.06 to 1.35
Normal vision: corrected by glasses	0.82	0.65 to 1.02
Normal vision: corrected by cataract surgery	1.12	0.74 to 1.69
Model 3	**HR**	**95% CI**
Reference group: normal vision, uncorrected	Ref.	Ref.
New cases of VI		
New VI: uncorrected	1.11	0.98 to 1.26
Normal vision: corrected by glasses	0.87	0.72 to 1.19
Normal vision: corrected by cataract surgery	0.87	0.62 to 1.24
Pre-existing cases of VI		
Pre-existing VI: uncorrected	1.06	0.93 to 1.21
Normal vision: corrected by glasses	0.77	0.60 to 0.98
Normal vision: corrected by cataract surgery	1.26	0.82 to 1.93
Model 4	**HR**	**95% CI**
Reference group: normal vision, uncorrected	Ref.	Ref.
New cases of VI		
New VI: uncorrected	1.35	1.20 to 1.51
Normal vision: corrected by glasses	0.99	0.78 to 1.25
Normal vision: corrected by cataract surgery	0.94	0.68 to 1.31
Pre-existing cases of VI		
Pre-existing VI: uncorrected	1.20	1.06 to 1.35
Normal vision: corrected by glasses	0.82	0.65 to 1.02
Normal vision: corrected by cataract surgery	1.12	0.74 to 1.68
Model 5	**HR**	**95% CI**
Reference group: normal vision, uncorrected	Ref.	Ref.
New cases of VI		
New VI: uncorrected	1.35	1.21 to 1.52
Normal vision: corrected by glasses	0.99	0.79 to 1.26
Normal vision: corrected by cataract surgery	0.95	0.69 to 1.31
Pre-existing cases of VI		
Pre-existing VI: uncorrected	1.20	1.06 to 1.35
Normal vision: corrected by glasses	0.82	0.65 to 1.02
Normal vision: corrected by cataract surgery	1.12	0.74 to 1.68

Continued

Table 3 Continued

Model 6	HR	95% CI
Reference group: normal vision, uncorrected	Ref.	Ref.
New cases of VI		
New VI: uncorrected	1.27	1.13 to 1.43
Normal vision: corrected by glasses	0.96	0.75 to 1.22
Normal vision: corrected by cataract surgery	0.95	0.68 to 1.31
Pre-existing cases of VI		
Pre-existing VI: uncorrected	1.12	0.99 to 1.27
Normal vision: corrected by glasses	0.83	0.66 to 1.04
Normal vision: corrected by cataract surgery	1.16	0.77 to 1.75

Data source: China Health and Retirement Longitudinal Study 2011, 2013, 2015, 2018. Model 1 was the unadjusted VI-only model; model 2 includes VI with additional covariates of age, sex, other demographic variables (marriage status, residential status, education, area of residence), health status (body mass index, hypertension, number of other comorbidities) and health-related lifestyle (drinking and smoking); based on model 2, models 3–6 further include variables to test the impact of direct/indirect pathways. Model 3 included frailty and disability (direct pathway). Model 4 included the additional variable describing whether the participant fell over the past year (indirect pathway 1). Model 5 included having sought medical care and undergoing a medical examination in the past year (indirect pathway 2), while model 6 included depression and social isolation (indirect pathway 6).
VI, visual impairment.

reduction (about 1/3) in the effect size of VI after adjustment for mental health and social connectedness (model 6).

We also performed stratification analyses based on SES (table 2). The mortality risk associated with pre-existing and new VI did not differ significantly for man versus woman (pre-existing VI, aHR: 1.20 vs 1.25, p=0.413; new VI, aHR: 1.38 vs 1.32, p=0.855) or urban versus rural dwellers (pre-existing VI, aHR: 1.55 vs 1.15, p=0.094; new VI, aHR: 1.52 vs 1.32, p=0.418). However, VI was independently associated with higher mortality risk among participants with middle school education or lower (pre-existing VI, low vs high education aHR: 0.69 vs 1.23, p=0.039; new VI, aHR: 0.85 vs 1.38, p=0.043). We also performed stratification analyses based on age groups and comorbidities (online supplemental file 3, table S1) and the association between mortality risk and VI did not differ significantly for these groups.

Protective effect of vision correction on mortality

Between 2011 and 2015, the proportion of participants with uncorrected normal vision decreased from 67.6% to 53.4% (p<0.001), while the figure for those with corrected vision, due to wearing eyeglasses or having received cataract surgery, increased from 9.4% to 27.8% (p<0.001) (figure 2). Compared with participants with normal vision, those with self-reported VI had poorer age and sex-corrected survival (p<0.001, log-rank test), while those with corrected normal vision had no significant reduction in survival (p=0.361, log-rank test, figure 3).

Compared with participants with normal vision, those whose vision problems were corrected with eyeglasses or cataract surgery did not have a significantly higher mortality risk in our various models (table 3). In the adjusted time-to-event analyses (model 2), neither pre-existing nor new corrected vision problems were independently associated with risk of death (HR for VI corrected by glasses at baseline: 0.82; 95% CI, 0.65 to 1.02; HR for VI corrected by cataract surgery at baseline: 1.12; 95% CI, 0.74 to 1.69; HR for new VI corrected by glasses: 1.01; 95% CI, 0.78 to 1.24; HR for new VI corrected by cataract surgery: 0.95; 95% CI, 0.68 to 1.31). Compared with the estimated HRs for VI, in the most conservative measure, the VI correction can reduce the risk of mortality by 12%. The mediation effects in tables 2 and 3 were very similar.

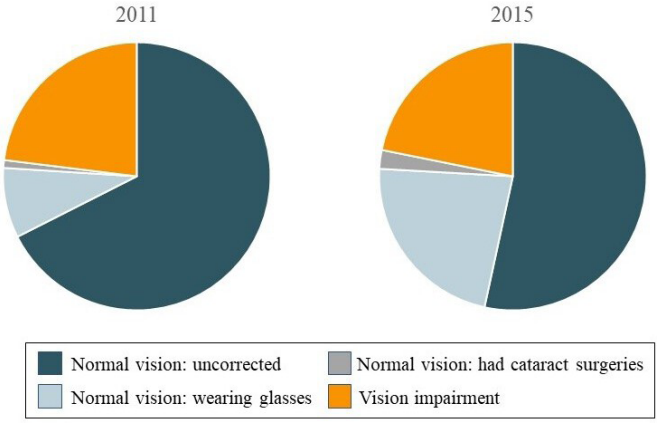


Figure 2 Visual status among participates in 2011 and 2015. Note: Although China Health and Retirement Longitudinal Study provided data on survival status in all follow-up waves (2013, 2015 and 2018), data on incident visual impairment were not available for the 2018 follow-up wave.

DISCUSSION

Considering China's population size, its rapidly ageing population, and the rising prevalence of chronic diseases, the burden of vision loss among Chinese people is and will remain an

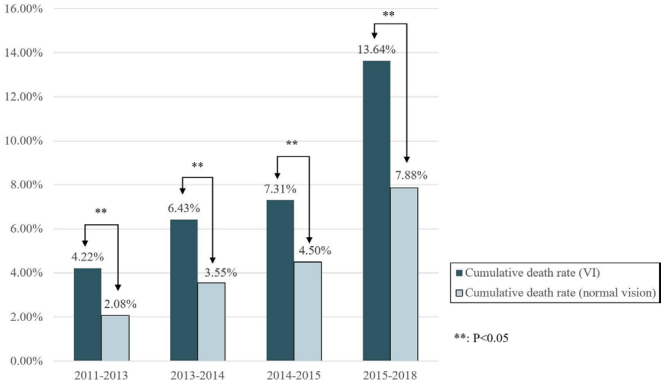
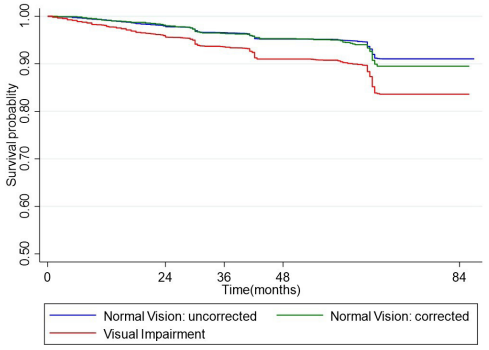


Figure 1 Eight-year mortality among participants with and without visual impairment (VI) at baseline.



No. at risk:

Normal vision (uncorrected)	10,679	9,352	8,971	8,867	8,481
Normal vision (corrected)	1,485	1,246	1,179	1,151	1,076
Visual Impairment	3,644	3,177	3,052	3,011	2,736

Figure 3 Kaplan-Meier survival curves (2011–2018).

important public health problem in the future .[42] To our knowledge, this is the first nationally representative study to estimate the impact of self-reported VI on all-cause mortality among middle-aged and elderly adults in China. Our results show that both pre-existing and new VI are associated with a higher risk of mortality, especially among those with lower education levels. Importantly, correction of VI with eyeglasses or cataract surgery reduced the risk of mortality by at least 12%, which is equivalent to 220 000–240 000 avoidable deaths in China every year.

We conducted a systematic literature search for published papers on the longitudinal association between VI and all-cause mortality in China on 1 February 2022. We used search terms related to VI, mortality and China on PubMed and Web of Science. Our search resulted in no nationally representative study and seven studies that used samples collected from specific geographic regions or age groups. Among them, five studies using regional data have found mixed results. Two studies using the sample from the Harbin Eye Study[43] and the Liwan Eye Study[44] have found that VI was independently associated with an increased risk of mortality. However, three studies using the sample for the Beijing Eye Study found no independent relationship between VI and either 5-year[45]/6-year[46] or 10-year mortality.[47] These contradictory results may be due to differences in the study populations and statistical analyses. Since VI is a time-varying variable, the results of traditional Cox regression with baseline characteristics or covariates may be biased. For example, in highly vulnerable populations, persons with VI may die soon after developing visual impairment. In that case, traditional Cox model analyses may underestimate the mortality effects of VI.[48] A Chinese cohort study of a very elderly population (80 years and older) which applied a time-varying analysis also found the risk of death was higher with new VI.[49] To our best knowledge, our study makes an important contribution by providing the first estimates of the impact of self-reported VI on all-cause mortality in a nationally representative cohort of older Chinese adults.

We also explored detailed pathways through which VI might cause death. It appears that VI may exert its impact through increased burdens of frailty, disability, depression and social isolation, but not through increased risk of injury or reduced care-seeking behaviour, findings which are consistent with several prior studies.[50] Our findings that the risk of self-reported VI on mortality is no longer significant after adjusting for the direct pathway variables (overall health conditions, including frailty and disability). Earlier studies have linked VI with many systemic conditions, which suggest that the VI per se is a sign of decline in physical functions.[51] Others have concluded that VI is linked to depression, dementia, social isolation and other mental/social disorders.[22] These conditions are all independent risk factors for mortality. However, due to the methodological challenges of mediation analysis in time-varying models, we cannot perform a rigorous mediation analysis in our study. Future research is needed to investigate the causal mediation between VI and all-cause mortality.

With the rich socioeconomic and health data from CHARLS, our study was able to provide a thorough description of people living with VI as well as to test the heterogeneity of treatment effects among different sex, education, and residential areas. It is also worth noticing that elder people in China living with VI had a lower average BMI (participants with vs with VI: 23.1 vs 23.6). Previous studies among elderly Chinese have shown that being older, widowed and having poor health were associated with malnutrition, which is consistent with the baseline characteristics of the VI population in our study.[52 53]

Our results have profound public health implications for eye health in China and other LMICs: the fact that both pre-existing and new VI are linked with a higher risk of mortality demonstrates that we should view the treatment of existing VI and prevention of new VI as important public health issues. Due to traditional beliefs,[54] older Chinese adults often view age-related eye disease as an inevitable process of ageing and are reluctant to receive formal diagnosis or treatment. Since most vision loss is preventable or treatable, VI can be a modifiable risk factor for mortality. Our results suggest that VI among the elderly population should be treated more actively. In early 2022, the Chinese government issued its '14th Five-Year' National Eye Health Plan.[55] Visual health among the elderly population is one of the prioritised areas listed in the Plan. In addition, the Plan set 'eCSC' (effective cataract surgery coverage) and "eREC" (effective refractive error coverage) as two key eye health service indicators which highlight the importance of eye care associated with cataract and refractive error. Based on the findings that VI correction with glasses and cataract surgery can reduce mortality by 12%, our results call for developing and delivering comprehensive eye health services that cover the full range of health promotion, prevention, detection, management and rehabilitation strategies, and that are integrated into the general health system of China and other LMICs to achieve people-centred integrated care. These health-system arrangements would also support further actions to achieve the goals set in the National Plan for Eye Health and the Sustainable Development Goals in China and other LMICs.

Strengths of the present study included the longitudinal design and large sample size, assessing the longitudinal association between self-reported VI and all-cause mortality, as well as the protective effect of vision correction among older Chinese adults. Compared with previous studies, our study followed a theory-based empirical strategy that allowed us to explore detailed pathways through which VI might cause death. Finally, our statistical analysis combined traditional Cox regression models with time-dependent covariates Cox regression models that enable us to capture the time-varying changes in exposure and potential confounders.

Despite these strengths, our study has several limitations. (1) Missing data: some data are missing for covariates including VI, BMI and hypertension, which may lead to selection bias. In addition, complete data concerning the date of death were not available. The interval censoring of survival time may cause a biased estimate for the impact of VI. (2) Non-objective measurement of VI: although previous studies have shown a strong correlation between self-reported eyesight and objective measurements,[56 57] some discrepancies may exist.[58] For example, the Salisbury Eye Evaluation Study has shown that visual acuity is not the only dimension of the association with subjective VI among old populations. Contrast and glare sensitivity, stereoacuity and visual fields are significant factors as well.[59] In addition, it is also common for older adults to claim that they have good eyesight even when they have clinically significant visual impairments. Factors such as ageing, cultural background, psychological and personality traits may be related to overestimation or underestimation of their conditions.[60] Nevertheless, CHARLS only acquired self-reported vision measures, which limited our ability to explore the complexity of objective and self-reported VI. (3) Relatively short follow-up period with a low number of events: fewer than 10% of participants died during the 8-year follow-up, so we cannot report a median survival in our study. In addition, a small number of events of interest can also result in low

statistical power (higher probability for type 2 error). Further studies are needed to investigate whether VI predicts mortality over a longer period of follow-up. (4) We were unable to quantify the net effect of VI working through different pathways on mortality, due to the complexity of mediation analysis with time-varying exposures and mediators. Instead, our results using Baron and Kenny's mediation steps approach suggested the importance of different pathways, and suggested that the direct pathway through systemic health, including frailty and disability, may be the predominant mechanism linking VI and mortality.[61] (5) Finally, being illiterate or unable to read due to severe VI might influence our measurement. However, recent publications using the CHARLS survey assessment have shown that these instruments were valid even among people who had experienced sensory impairments or learning difficulties.[22] We also acknowledge that the cohort profile of CHARLS only represents the context of community dwellings, we were not able to account for those who are homeless.

Nevertheless, this present study makes an important contribution by providing the first estimates of the impact of VI on all-cause mortality in a nationally representative cohort of older Chinese adults. Our finding that VI treatment with glasses and cataract surgery can reduce mortality by 12% provides a strong impetus for further government investment in these services in China and other LMICs.

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Contributors XM has full access to all data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: ZW and XM. Data analysis: XM. Interpretation of data: XM and NC. Drafting of the manuscript: ZW and XM. Critical revision of the manuscript for important intellectual content: XM and NC. Supervision: XM. XM is guarantor.

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Patient consent for publication Not applicable.

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