



# Prevalence of visual impairment among older Chinese population: A systematic review and meta-analysis

Minjie Zou<sup>1\*</sup>, Dongwei Guo<sup>1\*</sup>,  
Aiming Chen<sup>2\*</sup>, Charlotte Aimee  
Young<sup>3</sup>, Yi Li<sup>4</sup>, Danying Zheng<sup>1</sup>,  
Guangming Jin<sup>1</sup>

<sup>1</sup>State Key Laboratory of Ophthalmology,  
Zhongshan Ophthalmic Center, Sun Yat-sen  
University, Guangzhou, China

<sup>2</sup>The Fifth Affiliated Hospital of Sun Yat-sen  
University, Zhuhai, China

<sup>3</sup>Department of Ophthalmology, Third  
Affiliated Hospital, Nanchang University,  
Nanchang, Jiangxi Province, China

<sup>4</sup>Department of Applied Biology and  
Chemical Technology, Hong Kong  
Polytechnic University, Hongkong, China

\*Joint first authors.

**Background** To evaluate the prevalence of visual impairment (VI) among elderly Chinese population.

**Methods** All population-based studies on VI prevalence among elderly Chinese populations were searched and only studies with clear definitions of diagnosis were selected. Meta-analysis methods were used to estimate the pooled prevalence and its 95% confidence interval (95%CI) of moderate and severe visual impairment (MSVI) and blindness both by presenting visual acuity (PVA) and best corrected visual acuity (BCVA). Subgroup analysis of gender, district, geographical location, age, education level and examined year were also conducted.

**Results** 72 studies with 465 039 individuals were included and analyzed. Using PVA, the pooled prevalence of MSVI is 10.9% (95% CI=9.4%-12.6%) and blindness is 2.2% (95% CI=1.8%-2.8%), while prevalence of MSVI and blindness by BCVA was 5.4% (95% CI=4.6%-6.2%) and 2.2% (95% CI=1.9%-2.5%), respectively. Females, rural residents, older age and lower educational level were risk factors for MSVI and blindness.

**Conclusions** VI causes a great health burden among Chinese populations, particularly affecting female subjects, subjects dwelling in rural area, older subjects and subjects with lower educational level.

## Correspondence to:

Guangming Jin  
State Key Laboratory of Ophthalmology  
Zhongshan Ophthalmic Center  
Sun Yat-sen University  
Guangzhou  
China, 510060  
jingm@mail2.sysu.edu.cn

Danying Zheng  
State Key Laboratory of Ophthalmology  
Zhongshan Ophthalmic Center  
Sun Yat-sen University  
Guangzhou  
China, 510060  
zhengdy@163.com

China, with the largest and fastest aging population in the world, faces a significant challenge in managing age-related eye diseases which can ultimately cause visual impairment (VI) [1-4]. According to the Global Burden of Disease Study 2017, the Disease Adjusted Life Years (DALYs) of VI among Chinese populations has an upward trend, rising from 31.52 (95% CI=20.55, 47.29) billion in 1990 to 55.12 (95% CI=36.47, 82.49) billion in 2017, which contributes greatly to the disease burden worldwide [5]. Moreover, the increased life expectancy and the population increase indicates that the prevalence of VI is yet to rise, which would result in heavy economic burden to societies and individuals [6-8].

As a contributing member of the global movement Visual 2020, China has been taking significant strides toward reducing the prevalence of VI [9]. Plenty of past epidemiologic studies have reported on VI prevalence [9,10], and there have been several meta-analyses evaluating the VI prevalence among Chinese population in the past decades [2,11,12]. However, in recent years, many new stud-

ies have been conducted, which implies that an update concerning the magnitude of VI prevalence is necessary. Also, as many of the studies reporting VI prevalence are written in Chinese, this information is not accessible to researchers worldwide to assess the current situation of VI prevalence among older Chinese populations.

Therefore, we performed this systematic review and meta-analysis to evaluate the magnitude of VI among older Chinese populations (individuals above 50 years old). Time trends and pooled prevalence of VI together with subgroup analyses by demographic characteristics in older Chinese populations will be investigated in this meta-analysis. We aim to produce results that will provide useful information for appropriate preventive strategies to reduce the disease burden caused by VI in China and beyond.

## METHODS

### Literature search strategy

This meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. Publications reporting prevalence of VI among Chinese populations were reviewed and assessed. Two investigators (ZMJ and GDW) searched for literature independently in both English (Embase, PubMed and Web of science) and Chinese (SinoMed, VIP and Chinese National Knowledge Infrastructure) databases from January 1, 1999 until June 16, 2020. The search terms were as follows:

1. (“Vision Disorders”[Mesh]) OR “Blindness”[Mesh] OR (“Vision, Low”[Mesh]) OR (“Visually Impaired Persons”[Mesh]) OR blindness OR visual impairment OR low vision OR visual loss OR visually impaired OR visual disability
2. (“Prevalence”[Mesh]) OR (“Epidemiology”[Mesh]) OR (prevalence OR Epidemiology OR incidence)
3. “China”[Mesh] or China or Chinese
4. Combine 1 AND 2 AND 3

### Study selection

Studies were included if they met the following criteria: 1) population-based study; 2) utilized recognized definitions and standardized grading method to diagnose and classify VI; 3) accessible full text in Chinese or English; 4) explicit survey year; 5) age-specific prevalence data. Population-based studies are those which have a clear sampling frame of the community. The most common definition of VI is as follows: normal vision, visual acuity better than 6/12; moderate and severe visual impairment (MSVI), visual acuity better than 3/60 but worse than 6/18; and blindness, visual acuity worse than 3/60. One sub-lesion of VI, severe visual impairment (SVI), is defined as 3/60 to 6/60. Low vision is defined as having blindness or VI [13]. The prevalence by presenting visual acuity (PVA) and best corrected visual acuity (BCVA) were pooled separately.

Titles and abstracts of all initial searched results were screened independently by two investigators (ZMJ and GDW). If there was more than one publication based on the same study, the study with more thorough information was selected.

### Data extraction and quality assessment

Two investigators (ZMJ and GDW) conducted the data extraction independently and any disagreements were resolved by a discussion with a third investigator (JGM). The following information was extracted and tabulated: first author, study setting, sampling method, survey time, sample size, basic demographic data, the prevalence of MSVI, SVI, VI and SVI if available. For the multicenter surveys, we used the pooled prevalence provided by the original study. If the studies did not provide pooled prevalence, the prevalence data of the single location in the study was used.

The quality of all selected articles was evaluated by two investigators (ZMJ and GDW) with a commonly used 8-item assessment tool [14,15] According to the quality evaluation tool, each study was given a score of 0-8. We consider a score of 7-8 as high quality, 4-6 as moderate quality, and 0-3 as low quality. The coding of assessment has been described previously.

### Statistical analysis

The meta-analysis was conducted using the Comprehensive Meta-Analysis software, Version 2 (Biostat Inc., Englewood, New Jersey, USA). The prevalence of MSVI, SVI (if applicable), VI and blindness with 95% confidence intervals (CI) were calculated using random-effects models if considered of high heterogeneity, otherwise

the fixed-effects model was applied. Heterogeneity between studies was assessed by  $I^2$  statistic, with  $I^2 > 50\%$  regarded as high heterogeneity. Age-specific pooled prevalence of MSVI and blindness by 50-59, 60-69, 70-79, 80 and above years old age groups was conducted. To explore the possible sources of heterogeneity associated with gender, district (rural/urban), geographical location (central/eastern/western China), education level (illiterate/primary school and lower/middle school and above) and survey year (1999-2009/2010-2017), subgroup analyses were performed using Q-tests separately. Continuous variables were dichotomized using median splitting method in subgroup analyses. Publication bias was assessed by the Funnel plots, Begg's tests and Egger's tests. Significance level was set at  $P < 0.05$  (two-tailed) [16].

## RESULTS

### Selection and inclusion of the studies

72 studies with 465 039 individuals out of 14 676 initial records were identified according to the inclusion criteria for analysis (Figure 1). There were 90 data sets in total as four studies conducted multi-center surveys with different samples [9,10,17,18]. Basic characteristics of the included studies are given in Table 1. Of these 72 studies, 20 were written in English [9,10,17,19,20,25,27-32,55,56,67-69,75,83,84] and the rest were in Chinese [18,21-24,26,33-54,57-66,70-74,76-83,85-95]. The target population of all selected studies was clearly defined, and all the samples were representative of the general population. 38 studies used BCVA [18,28-64], 9 studies used PVA [19-27] and the rest used both BCVA and PVA [9,10,17,65-95] in the diagnoses of blindness and MSVI. The data of several subgroup analyses (gender, district, geographical location, age, education and examined year) were not available in some included studies; the sum of the individuals may not agree with the total number given by 72 studies.

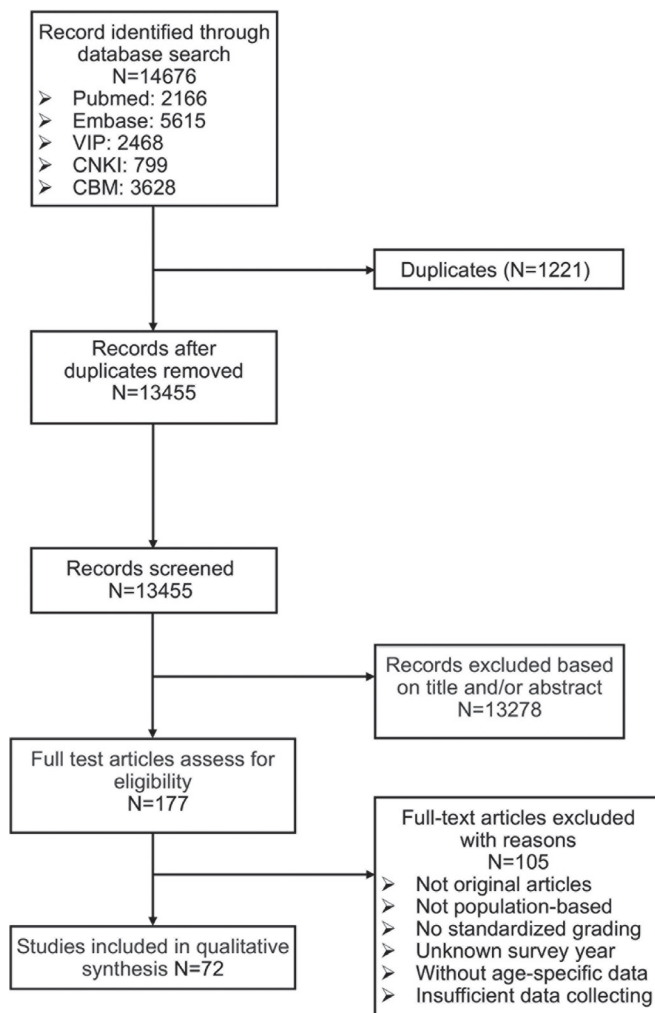


Figure 1. Flowchart of the study selection process.

### Quality assessment and publication bias

The 8-item assessment tool was used to evaluate the quality of the included studies, ranging from 4 to 8, with an average assessment score of 6.2. 7 studies were given the highest score [10,38,55,68,74,75,86], and 23 studies were classified as high quality, while the rest were considered moderate quality. The most common problem of the included studies in the meta-analysis was unclear description of non-responders.

After removing each study sequentially for sensitivity analysis, the pooled prevalence of remaining studies did not change significantly compared to the initial results. According to the results of the Begg's test (MSVI:  $Z = 1.524$ ,  $P = 0.127$ ; blindness:  $Z = 1.676$ ,  $P = 0.094$ ), Egger's tests (MSVI:  $t = 0.547$ ,  $P = 0.588$ ; blindness:  $t = 0.648$ ,  $P = 0.521$ ) and funnel plot (Figure S1 in the Online Supplementary Document, Panels A and B), we concluded that there was no publication bias in both the prevalence of blindness and MSVI by PVA. Concerning the prevalence of blindness and MSVI by BCVA, although the Begg's tests indicated potential bias may exist (MSVI:  $Z = 2.940$ ,  $P = 0.003$ ; blindness:  $Z = 2.525$ ,  $P = 0.012$ ), the Egger's tests (MSVI:  $t = 0.878$ ,  $P = 0.383$ ; blindness:  $t = 1.305$ ,  $P = 0.197$ ) and funnel plot (Figure S1 in the Online Supplementary Document, Panels C and D) did not suggest any publication bias.

### Prevalence of blindness and VI among Chinese population by using PVA

The pooled prevalence using PVA is given by Table 2 and Figure S1 in the Online Supplementary Document (Panels E and F), with 250 080 individuals in total. MSVI prevalence reported in original studies varied from 1.8% to

Table 1. Characteristics of included studies

FIRST AUTHOR	PROVINCE	DISTRICT	REGION	LANGUAGE	SURVEY YEAR	AGE RANGE	N	MEASURE OF VISUAL ACUITY	RESPONSE RATE (%)	DEFINITION OF OLDER ADULTS	NO. OF OLDER ADULTS	ASSESSMENT*
Emmy Y. Li [19]	Hainan	E	R	EANG	2010	≥50	6482	PVA	95.3	≥50	6482	6
CW Pan [20]	Jiangsu	E	R	ENG	2013-2014	≥60	4579	PVA	82.1	≥60	4579	6
JF Chen [21]	Shanghai	E	R & U	CHN	NA	≥50	5090	PVA	87.8	≥50	5090	5
H Hu [22]	Yunnan	W	R	CHN	2014	≥50	5592	PVA	93.2	≥50	5592	7
XJ Zhang [23]	Tianjin	E	R	CHN	2001	≥40	1776	PVA	89.4	≥50	1026	5
S Liu [24]	Chongqing	W	U	CHN	2005	≥50	5079	PVA	89.4	≥50	5079	6
L Li [25]	Jiangsu	E	U	ENG	2003	≥60	3040	PVA	90.7	≥60	3040	6
S Wu [26]	Zhejiang	E	R & U	CHN	2012-2013	≥60	3428	PVA	99.0	≥60	3428	6
ZJ Li [27]	Heilongjiang	E	R	ENG	2006-2007	≥50	5057	PVA	91.0	≥50	5057	6
Nancy Chen [28]	Taiwan	E	R	ENG	2006	≥65	2316	BCVA	61.2	≥65	2316	6
T Li [29]	Shanxi	C	R & U	ENG	2006	0-80	75016	BCVA	85.5	≥50	17473	6
Y Yao [30]	Jiangsu	E	U	ENG	2010	≥50	6155	BCVA	91.5	≥50	6155	6
GS Zhang [31]	Inner Mongolia	C	R & U	ENG	2013	≥40	5770	BCVA	80.1	≥50	4928	7
YG Zhang [32]	Heilongjiang	C	R	ENG	2008-2009	All	10384	BCVA	88.1	≥50	2728	7
GP Duan [33]	Hunan	C	R	CHN	2008-2009	≥50	4857	BCVA	92.3	≥50	4857	6
GP Duan [34]	Hunan	C	R	CHN	2008-2009	≥50	4402	BCVA	88.8	≥50	4402	7
J Fu [35]	Xinjiang	W	R & U	CHN	2009-2010	≥40	8295	BCVA	83.8	≥50	5235	6
YH Gu [18]	Anhui	C	U	CHN	2008	All	3336	BCVA	91.4	≥50	987	7
XY Huang [36]	Guangdong	E	R	CHN	2012	≥50	4329	BCVA	93.7	≥50	4329	6
Y Huang [37]	Shanghai	E	R	CHN	2016-2017	≥60	4260	BCVA	70.8	≥60	4260	6
JP Liu [38]	Yunnan	W	R	CHN	2008	All	2460	BCVA	80.1	≥50	705	8
XP Liu [39]	Guangdong	E	R & U	CHN	2014-2015	≥50	4539	BCVA	NA	≥50	4539	5
XY Ma [40]	Shanghai	E	U	CHN	2009	≥65	2299	BCVA	92.0	≥65	2299	6
M NA Bijiang [41]	Xinjiang	W	U	CHN	2010	≥40	4104	BCVA	81.6	≥50	2853	6
M Yusup [42]	Xinjiang	W	R	CHN	2009	≥40	4191	BCVA	86.0	≥50	2382	7
YJ Meng [43]	Tianjin	E	R & U	CHN	2014	≥60	5520	BCVA	94.0	≥60	5520	6
JZ Pei [44]	Shaanxi	W	R	CHN	2010-2012	All	4394	BCVA	85.0	≥50	1912	7
H Qi [45]	Shanghai	E	U	CHN	2009	≥60	4785	BCVA	91.3	≥60	4785	6
LF Qiao [46]	Sichuan	W	R	CHN	2011	≥50	2817	BCVA	98.8	≥50	2817	6
FR Shen [47]	Shanxi	C	R	CHN	NA	≥50	6769	BCVA	96.7	≥50	6769	6
B Shen [48]	Shanghai	E	U	CHN	2010	≥60	6302	BCVA	91.8	≥60	6302	6
W Sun [49]	Jiangsu	E	U	CHN	2010	≥50	6150	BCVA	91.5	≥50	6150	6
GM Wang [50]	Shandong	E	R	CHN	2008	≥50	4916	BCVA	98.2	≥50	4916	6
XL Wu [51]	Zhejiang	E	U	CHN	2015-2016	≥50	5448	BCVA	89.9	≥50	5448	6
LJ Tang [52]	Chongqing	W	U	CHN	2009-2011	≥55	2600	BCVA	NA	≥55	2600	6
SS Zhang [53]	Jiangsu	E	U	CHN	2013	≥60	5564	BCVA	94.9	≥60	5564	6
J Zhang [54]	Shaanxi	W	R	CHN	2007	All	8725	BCVA	96.0	≥60	1284	5

Table 1. Continued

FIRST AUTHOR	PROVINCE	DISTRICT	REGION	LANGUAGE	SURVEY YEAR	AGE RANGE	N	MEASURE OF VISUAL ACUITY	RESPONSE RATE (%)	DEFINITION OF OLDER ADULTS	NO. OF OLDER ADULTS	ASSESSMENT*
XJ Zhang [55]	Guangdong	E	R & U	ENG	2012	>50	3484	BCVA	94.2	≥50	3484	8
L Xu [56]	Beijing	E	R & U	ENG	2001	≥40	4439	BCVA	83.4	≥50	2987	7
L Chen [57]	Shaanxi	W	R	CHN	2003	>50	1765	BCVA	80.2	≥50	1765	6
CX Qi [58]	Guangdong	E	U	CHN	2007	>50	4126	BCVA	91.0	≥50	4126	6
LL Yang [59]	Guangdong	E	U	CHN	2008	>60	11210	BCVA	88.2	≥60	11210	6
M Wei [60]	Sichuan	W	R & U	CHN	2006	ALL	125641	BCVA	NA	≥50	41441	5
XF Gao [61]	Heilongjiang	E	U	CHN	1999	>60	7499	BCVA	92.0	≥60	7499	6
X Zhao [62]	Beijing	E	U	CHN	2006	>50	2410	BCVA	85.1	≥50	2410	5
TY Xie [63]	Xinjiang	W	R	CHN	2005	>40	2955	BCVA	80.0	≥50	1929	6
TZ Zhang [64]	Xinjiang	W	R	CHN	2001	>45	1208	BCVA	91.3	≥55	736	5
J Zhou [65]	Jiangsu	E	R	CHN	2008	>60	1305	PVA&BCVA	93.8	≥60	1305	7
XW Tong [66]	Shanghai	E	U	CHN	2009	>60	4545	PVA&BCVA	87.4	≥60	4545	6
YT Tang [67]	Zhejiang	E	R & U	ENG	2012-2013	>45	10234	PVA&BCVA	78.1	≥50	8317	7
J Li [68]	Yunnan	W	R	ENG	2010	>50	2133	PVA&BCVA	77.8	≥50	2133	8
XF Li [69]	Hebei	E	R	ENG	2010	>7	20298	PVA&BCVA	82.7	≥50	4012	7
M Yang [70]	Jiangsu	E	R	CHN	2010-2011	>50	5947	PVA&BCVA	96.8	≥50	5947	7
MC Yi [71]	Sichuan	W	U	CHN	2013	>50	3086	PVA&BCVA	93.7	≥50	3086	7
JY Hu [72]	Jiangsu	E	R	CHN	2006	>50	653	PVA&BCVA	92.0	≥50	653	6
W Zhou [73]	Shanghai	E	R & U	CHN	2015	>50	3497	PVA&BCVA	86.3	≥50	3497	5
LH Wang [74]	Shandong	E	R	CHN	2008	>50	17816	PVA&BCVA	91.0	≥50	17816	8
SS Huang [75]	Guangdong	E	U	ENG	2003	>50	1399	PVA&BCVA	75.3	≥50	1399	8
BJ Hou [76]	Tibet	W	R	CHN	2000	>40	3071	PVA&BCVA	97.4	≥50	2060	6
JL Zhao [9]	Multicenter	NA	R	ENG	2014	>50	51310	PVA&BCVA	90.6	≥50	51310	7
RR Zhu [17]	Jiangsu	E	R	ENG	2010	>50	5947	PVA&BCVA	96.8	≥50	5947	7
			U				6106		90.8		6106	
W Wang [77]	Shanghai	E	R	CHN	2008-2009	>60	2150	PVA&BCVA	81.0	≥60	2150	6
CJ Liu [78]	Shanghai	E	U	CHN	2012	>70	15238	PVA&BCVA	NA	≥70	15238	4
LL Deng [79]	Jiangxi	C	R	CHN	2015	>50	5119	PVA&BCVA	94.1	≥50	5119	6
JH Zhou [80]	Yunnan	W	R	CHN	2011-2012	>50	5151	PVA&BCVA	92.4	≥50	5151	5
M Wu [81]	Yunnan	W	R	CHN	2008	>50	2842	PVA&BCVA	94.7	≥50	2842	5
JL Zhao [10]	Multicenter	NA	R	ENG	2006	>50	47547	PVA&BCVA	91.5	≥50	47547	8
M Wu [82]	Yunnan	W	R & U	CHN	2006	>50	2588	PVA&BCVA	93.8	≥50	2588	5
XB Huang [83]	Shanghai	E	U	CHN	2007-2008	>60	3851	PVA&BCVA	92.7	≥60	3851	6
WL Song [84]	Heilongjiang	E	R	ENG	2007	>40	4956	PVA&BCVA	86.0	≥50	3525	6
XJ Xiong [85]	Chongqing	W	R	CHN	NA	>50	2122	PVA&BCVA	83.0	≥50	2122	7
YB Liang [86]	Hebei	E	R	ENG	2006-2007	≥30	6830	PVA&BCVA	90.4	≥50	4241	8

E – Eastern China, C – Central China, W – Western China, R – rural area, U – urban area, ENG – English, CHN – Chinese, NA – not applicable

\*The assessment of the studies was conducted using the 8-item assessment tool [14,15]

**Table 2.** Pooled prevalence of visual impairment by presenting visual acuity

FIRST AUTHOR	NO. OF OLDER ADULTS	PRESENTING VISUAL ACUITY			
		MSVI	SVI	VI	Blindness
Emmy Y. Li [19]	6482	11.8 (11.0-12.6)	1.9 (1.6-2.2)	16.2 (15.3-17.1)	4.4 (3.9-4.9)
CW Pan [20]	4579	6.3 (5.6-7.0)	–	6.8 (6.1-7.5)	0.5 (0.3-0.8)
JF Chen [21]	5090	3.4 (2.9-3.9)	–	3.7 (3.2-4.2)	0.3 (0.2-0.5)
H Hu [22]	5592	14.7 (13.8-15.7)	1.6 (1.3-1.9)	20.1 (19.0-21.1)	5.4 (4.8-6.0)
XJ Zhang [23]	1026	–	–	–	2.0 (1.3-3.0)
S Liu [24]	5079	7.6 (6.9-8.4)	–	12.9 (12.0-13.9)	5.3 (4.8-6.0)
L Li [25]	3040	1.8 (1.4-2.4)	–	3.2 (2.6-3.9)	1.4 (1.0-1.8)
S Wu [26]	3428	7.9 (7.1-8.9)	2.6 (2.1-3.2)	10.6 (9.6-11.7)	2.7 (2.2-3.3)
ZJ Li [27]	5057	8.3 (7.6-9.1)	–	10.2 (9.4-11.1)	1.9 (1.6-2.3)
J Zhou [65]	1305	18.6 (16.6-20.8)	–	25.8 (23.4-28.2)	7.1 (5.9-8.7)
XW Tong [66]	4545	8.8 (8.2-9.4)	–	9.7 (8.9-10.6)	0.9 (0.6-1.2)
YT Tang [67]	8317	8.8 (8.2-9.4)	–	10.0 (9.3-10.6)	1.2 (1.0-1.5)
J Li [68]	2133	15.2 (13.8-16.8)	–	18.8 (17.2-20.5)	3.6 (2.9-4.5)
XF Li [69]	4012	9.5 (8.6-10.4)	–	10.9 (10.0-11.9)	1.2 (0.9-1.6)
JL Zhao (2014) [9]	51310	10.3 (10.0-10.6)	–	12.0 (11.7-12.2)	1.7 (1.6-1.8)
RR Zhu [17]	5947	23.6 (22.6-24.7)	2.0 (1.7-2.4)	26.0 (24.9-27.1)	2.3 (2.0-2.7)
	6106	5.4 (4.8-6.0)	0.5 (0.3-0.7)	6.3 (5.7-6.9)	0.9 (0.7-1.2)
M Yang [70]	5947	23.6 (22.6-24.7)	2.0 (1.7-2.4)	25.9 (24.8-27.1)	2.3 (2.0-2.7)
MC Yi [71]	3086	12.5 (11.3-13.7)	2.3 (1.8-2.9)	15.3 (14.1-16.6)	2.9 (2.3-3.5)
JY Hu [72]	653	16.5 (13.9-19.6)	–	22.5 (19.5-25.9)	6.0 (4.4-8.1)
W Zhou [73]	3497	14.8 (13.6-16.0)	–	15.9 (14.7-17.1)	1.1 (0.8-1.5)
LH Wang [74]	17816	7.0 (6.6-7.4)	–	8.6 (8.2-9.0)	1.6 (1.4-1.8)
W Wang [77]	2150	21.7 (20.0-23.5)	–	23.7 (22.0-25.6)	2.0 (1.5-2.7)
CJ Liu [78]	15238	14.5 (14.0-15.1)	1.0 (0.7-1.2)	16.2 (15.6-16.8)	1.7 (1.5-1.9)
LL Deng [79]	5119	17.0 (16.0-18.1)	–	19.2 (18.1-20.3)	2.2 (1.8-2.6)
JH Zhou [80]	5151	14.1 (13.2-15.1)	–	17.8 (16.8-18.9)	3.7 (3.2-4.3)
M Wu [81]	2842	–	–	–	2.0 (1.6-2.6)
JL Zhao (2006) [10]	45747	10.8 (10.5-11.1)	–	13.1 (12.8-13.4)	2.3 (2.2-2.4)
SS Huang [75]	1399	10.1 (8.6-11.8)	0.6 (0.3-1.2)	10.7 (9.2-12.4)	0.6 (0.3-1.2)
BJ Hou [76]	2060	7.9 (6.8-9.2)	–	18.5 (16.9-20.3)	10.6 (9.4-12.0)
M Wu [81]	2588	–	–	–	3.7 (3.0-4.5)
XB Huang [83]	3851	26.8 (25.4-28.2)	–	33.9 (32.4-35.4)	7.2 (6.4-8.0)
WL Song [84]	3525	9.8 (8.9-10.8)	–	12.3 (11.3-13.5)	2.6 (2.1-3.2)
XJ Xiong [85]	2122	11.2 (9.9-12.6)	0.9 (0.5-1.3)	15.2 (13.7-16.8)	4.0 (3.3-4.9)
YB Liang [86]	4241	8.5 (7.7-9.4)	–	10.0 (9.1-10.9)	1.5 (1.2-1.9)
Pooled prevalence	250080	10.9 (9.4-12.6)	2.7(1.9-3.8)	13.6 (11.8-15.6)	2.2 (1.8-2.8)

MSVI – moderate and severe visual impairment, SVI – severe visual impairment, VI – visual impairment

43.7%[9,25], while blindness was 0.3% to 10.6%[21,76]. The pooled prevalence of MSVI was 10.9% (95% CI=9.4%-12.6%) and blindness was 2.2% (95% CI=1.8%-2.8%). As for SVI and VI, the pooled rate was 2.7% (95% CI=1.9%-3.8%) and 13.6% (95% CI=11.8%-15.6%).

### Prevalence of MSVI and blindness among Chinese population by using BCVA

Table 3 and Figure S1 in the **Online Supplementary Document** (Panels G and H) shows the reported prevalence of MSVI ranged from 1.3% to 32.0% in terms of BCVA [47,96], and for blindness from 0.4% to 8.7% [56,76]. The pooled prevalence of MSVI and blindness was 5.4% (95% CI=4.6%-6.2%) and 2.2% (95% CI=1.9%-2.5%), respectively. Meanwhile, the pooled prevalence of SVI was 1.4% (95% CI=1.0%-1.9%) and VI prevalence was 7.8% (95% CI=6.9%-8.9%).

### Subgroup analyses of the pooled prevalence of VI and blindness

Table 4 shows the subgroup analyses of MSVI and blindness among Chinese population by PVA and BCVA.

For MSVI, subgroup analyses using PVA for diagnosis presented similar results with that of BCVA. Gender difference is of statistical significance, as the prevalence of females (15.6%, 95% CI=12.7%-18.9% for PVA; 7.1%, 95% CI=5.9%-8.4% for BCVA) surpassed those of male (12.3%, 95% CI=10.0%-15.2% for PVA; 5.6%,

**Table 3.** Pooled prevalence of visual impairment by best corrected visual acuity

FIRST AUTHOR	NO. OF OLDER ADULTS	BEST CORRECTED VISUAL ACUITY			
		MSVI	SVI	VI	Blindness
Nancy Chen [28]	2316	4.1 (3.3-4.9)	–	4.9 (4.1-5.8)	0.8 (0.5-1.3)
T Li [29]	17473	1.4 (1.2-1.6)	–	2.0 (1.8-2.2)	0.6 (0.5-0.8)
Y Yao [30]	6155	3.5 (3.1-4.0)	–	6.8 (6.1-7.4)	3.3 (2.9-3.7)
GS Zhang [31]	4928	13.2 (12.3-14.2)	–	19.8 (18.7-20.9)	6.6 (5.9-7.3)
YG Zhang [32]	2728	4.6 (3.9-5.5)	–	6.8 (5.9-7.8)	2.2 (1.7-2.8)
GP Duan [33]	4857	4.5 (4.0-5.2)	–	6.5 (5.8-7.2)	1.9 (1.6-2.3)
GP Duan [34]	4402	4.9 (4.3-5.6)	–	7.2 (6.5-8.0)	2.3 (1.9-2.7)
J Fu [35]	5235	7.2 (6.5-8.0)	–	10.8 (10.0-11.7)	3.6 (3.1-4.1)
YH Gu [18]	987	2.5 (1.7-3.6)	–	7.8 (6.3-9.6)	5.3 (4.1-6.9)
	1386	2.0 (1.4-2.9)	–	4.9 (3.9-6.2)	2.9 (2.1-3.9)
XY Huang [36]	4329	6.8 (6.1-7.6)	–	9.0 (8.2-9.9)	2.2 (1.8-2.7)
Y Huang [37]	4260	7.7 (7.0-8.6)	–	10.5 (9.6-11.5)	2.8 (2.3-3.3)
JP Liu [38]	705	5.3 (3.8-7.2)	–	9.4 (7.4-11.7)	4.1 (2.9-5.9)
XP Liu [39]	4539	7.0 (6.3-7.7)	–	9.1 (8.3-10.0)	2.2 (1.8-2.6)
XY Ma [40]	2299	7.2 (6.2-8.4)	–	10.0 (8.8-11.3)	2.8 (2.2-3.5)
M NA Bijiāng [41]	2853	4.7 (4.0-5.5)	–	6.8 (6.0-7.8)	2.1 (1.7-2.7)
Mehriban Yusup [42]	2382	9.0 (7.9-10.2)	–	14.8 (13.4-16.3)	5.8 (5.0-6.9)
YJ Meng [43]	5520	5.3 (4.7-5.9)	–	10.1 (9.3-10.9)	4.8 (4.3-5.4)
JZ Pei [44]	1912	8.1 (7.0-9.4)	–	9.6 (8.3-11.0)	1.5 (1.0-2.1)
H Qi [45]	4785	13.5 (12.6-14.5)	–	15.9 (14.9-16.9)	2.3 (1.9-2.8)
LF Qiao [46]	2817	15.1 (13.8-16.5)	2.5 (1.9-3.1)	19.1 (17.7-20.6)	3.9 (3.3-4.7)
FR Shen [47]	6769	1.3 (1.1-1.6)	–	2.5 (2.1-2.9)	1.2 (0.9-1.5)
B Shen [48]	6302	9.3 (8.6-10.0)	–	10.7 (10.0-11.5)	1.5 (1.2-1.8)
W Sun [49]	6150	3.5 (3.0-4.0)	–	6.8 (6.1-7.4)	3.3 (2.9-3.7)
GM Wang [50]	4916	5.3 (4.7-6.0)	–	7.7 (7.0-8.4)	2.4 (2.0-2.8)
XL Wu [51]	5448	3.3 (2.9-3.9)	–	4.3 (3.8-3.9)	1.0 (0.7-1.2)
LJ Tang [52]	2600	17.7 (16.3-19.2)	–	21.7 (20.2-23.4)	4.0 (3.3-4.9)
SS Zhang [53]	5564	12.7 (11.9-13.6)	–	13.6 (12.7-14.5)	0.9 (0.7-1.2)
J Zhang [54]	1284	–	–	–	5.1 (4.1-6.5)
XJ Zhang [55]	3484	8.0 (7.2-9.0)	1.1 (0.8-1.5)	10.5 (9.5-11.5)	2.4 (2.0-3.0)
L Xu [56]	2987	1.5 (1.1-2.0)	–	1.9 (1.5-2.5)	0.4 (0.2-0.7)
L Chen [57]	1765	3.5 (2.7-4.5)	–	6.2 (5.2-7.4)	2.7 (2.0-3.6)
CX Qi [58]	4126	8.4 (7.6-9.3)	–	14.4 (13.3-15.5)	6.0 (5.3-6.7)
LL Yang [59]	11210	8.3 (7.8-8.8)	–	12.7 (12.1-13.4)	4.5 (4.1-4.8)
M Wei [60]	41441	1.4 (1.3-1.5)	–	3.8 (3.6-4.0)	2.4 (2.2-2.5)
XF Gao [61]	7499	1.3 (1.1-1.6)	–	2.0 (1.7-2.4)	0.7 (0.5-0.9)
X Zhao [62]	2410	5.9 (5.1-6.9)	–	9.3 (8.2-10.6)	3.4 (2.7-4.2)
TY Xie [63]	2955	10.1 (8.8-11.5)	–	16.9 (15.2-18.6)	6.7 (5.7-7.9)
TZ Zhang [64]	1208	8.4 (6.6-10.7)	–	10.6 (8.6-13.0)	2.2 (1.3-3.5)
J Zhou [65]	1305	9.4 (7.9-11.1)	–	13.4 (11.7-15.4)	4.1 (3.1-5.3)
XW Tong [66]	4545	3.2 (2.7-3.7)	–	3.9 (3.3-4.5)	0.7 (0.5-0.9)
YT Tang [67]	10234	5.9 (5.4-6.4)	–	7.0 (6.5-7.6)	1.1 (0.9-1.4)
J Li [68]	2133	7.8 (6.7-9.0)	–	10.6 (9.4-12.0)	2.9 (2.2-3.7)
XF Li [69]	20298	5.7 (5.1-6.5)	–	6.6 (5.9-7.4)	0.9 (0.6-1.2)
JL Zhao (2014) [9]	51310	4.5 (4.3-4.6)	–	5.9 (5.7-6.1)	1.4 (1.3-1.5)
	5947	6.4 (5.8-7.1)	0.7 (0.6-1.0)	8.1 (7.4-8.8)	1.7 (1.4-2.0)
RR Zhu [17]	6106	2.4 (2.1-2.8)	0.2 (0.1-0.4)	3.2 (2.7-3.6)	0.8 (0.6-1.0)
	5947	6.4 (5.8-7.1)	0.7 (0.6-1.0)	8.0 (7.3-8.7)	1.6 (1.3-1.9)
M Yang [70]	5947	6.4 (5.8-7.1)	0.7 (0.6-1.0)	8.0 (7.3-8.7)	1.6 (1.3-1.9)
MC Yi [71]	3086	6.5 (5.7-7.4)	1.0 (0.7-1.4)	8.8 (7.9-9.9)	2.3 (1.8-2.9)
JY Hu [72]	653	4.3 (3.0-6.1)	–	7.5 (5.7-9.8)	3.2 (2.1-4.9)
W Zhou [73]	3497	4.0 (3.4-4.7)	–	4.9 (4.2-5.6)	0.7 (0.5-1.1)
LH Wang [74]	17816	3.7 (3.4-4.7)	–	5.0 (4.7-5.3)	1.3 (1.2-1.5)
W Wang [77]	2150	8.2 (7.1-9.4)	–	9.8 (8.6-11.1)	1.6 (1.2-2.3)
CJ Liu [78]	15238	3.5 (3.3-3.8)	–	5.0 (4.6-5.3)	1.4 (1.2-1.6)
LL Deng [79]	5119	7.2 (6.5-7.9)	–	8.6 (7.9-9.4)	1.5 (1.2-1.8)
JH Zhou [80]	5151	7.7 (7.0-8.5)	–	13.1 (12.2-14.0)	5.3 (4.8-6.0)
M Wu [81]	2842	–	–	–	2.3 (1.8-2.9)

Table 3. Continued

FIRST AUTHOR	NO. OF OLDER ADULTS	BEST CORRECTED VISUAL ACUITY			
		MSVI	SVI	VI	Blindness
JL Zhao (2006) [10]	45747	5.3 (5.1-5.5)	–	7.23 (7.0-7.5)	1.9 (1.8-2.1)
SS Huang [75]	1399	3.1 (2.3-4.1)	0.1 (0-0.5)	3.6 (2.7-4.7)	0.5 (0.2-1.0)
BJ Hou [76]	3071	4.8 (4.0-5.8)	–	13.6 (12.1-15.1)	8.7 (7.6-10.0)
M Wu [82]	2588	–	–	–	3.2 (2.6-3.9)
XB Huang [83]	3851	14.6 (13.5-15.7)	–	17.1 (15.9-18.3)	2.5 (2.0-3.0)
WL Song [84]	4956	6.6 (5.9-7.5)	–	9.1 (8.1-10.0)	2.4 (2.4-2.0)
XJ Xiong [85]	2122	6.2 (5.2-7.3)	0.8 (0.5-1.2)	8.0 (6.9-9.2)	1.8 (1.3-2.5)
YB Liang [86]	6830	2.6 (2.2-3.1)	–	3.8 (3.3-4.4)	1.2 (0.9-1.6)
Pooled prevalence	438927	5.4 (4.6-6.2)	1.4 (1.0-1.9)	7.8 (6.9-8.9)	2.2 (1.9-2.5)

MSVI – moderate and severe visual impairment, SVI – severe visual impairment, VI – visual impairment

Table 4. Subgroup analysis of blindness and visual impairment of Chinese population by presenting visual acuity and best corrected visual acuity

SUBGROUP	MODERATE AND SEVERE VISUAL IMPAIRMENT					BLINDNESS				
	N	Prevalence and 95% CI (%)	Heterogeneity, I <sup>2</sup> (%)	Q-value	P-value	N	Prevalence and 95% CI (%)	Heterogeneity, I <sup>2</sup> (%)	Q-value	P-value
<b>Present by present visual acuity</b>										
<b>Gender:</b>										
Female	34	15.6 (12.7-18.9)	99.568	7639.915	<0.001	37	2.2 (1.9-2.7)	96.271	965.294	<0.001
Male	34	12.3 (10.0-15.2)	99.378	5307.023		37	1.7 (1.3-2.1)	96.596	1057.694	
<b>District:</b>										
Rural	35	14.9 (12.0-18.4)	99.734	12760.453	<0.001	38	2.2 (1.8-2.7)	97.946	1801.707	<0.001
Urban	6	9.0 (5.4-14.8)	99.584	1202.177		7	2.2 (1.2-4.0)	98.923	557.320	
<b>Geographical location:</b>										
Central China	3	19.7 (12.0-30.6)	99.535	430.343	<0.001	3	1.7 (1.3-2.4)	85.850	14.134	<0.001
Eastern China	32	12.3 (9.4-15.9)	99.770	13482.959		33	1.6 (1.3-2.1)	97.447	1253.332	
Western China	13	14.1 (10.6-18.3)	99.480	2308.491		15	3.3 (2.5-4.4)	97.901	666.884	
<b>Age:</b>										
50-59	36	5.4 (4.3-6.9)	98.914	3223.944	0.165	38	0.7 (0.5-0.9)	91.569	438.851	<0.001
60-69	43	10.3 (8.1-12.9)	99.318	6156.620		45	1.4 (1.0-1.9)	96.445	1237.792	
70-79	39	25.3 (20.9-30.3)	99.356	5902.461		41	3.5 (2.9-4.1)	94.389	712.873	
80+	39	44.2 (36.3-52.4)	99.286	5319.924		41	8.8 (7.1-11.0)	96.407	1113.256	
<b>Educational level:</b>										
Illiterate	16	19.1 (15.9-22.8)	98.598	1070.033	<0.001	16	4.8 (3.6-6.4)	96.551	434.917	<0.001
Primary school and lower	20	9.7 (7.7-12.3)	98.364	1161.541		19	1.7 (1.1-2.5)	94.095	423.386	
Secondary school and above	25	6.9 (4.8-9.7)	97.691	1161.378		26	1.7 (1.1-2.7)	96.310	487.763	
<b>Examined year:</b>										
1999-2009	27	9.9 (8.4-11.8)	99.027	2670.885	<0.001	30	2.4 (1.9-3.0)	97.858	1353.906	<0.001
2010-2017	24	16.2 (12.6-20.5)	99.763	9699.090		24	1.6 (1.2-2.1)	97.647	977.293	
<b>Prevalence by best corrected visual acuity</b>										
<b>Gender:</b>										
Female	48	7.1 (5.9-8.4)	99.029	4840.553	<0.001	49	1.9 (1.6-2.3)	97.391	1839.996	<0.001
Male	48	5.6 (4.7-6.8)	98.637	3447.731		49	1.6 (1.3-1.9)	95.571	1083.737	
<b>District:</b>										
Rural	53	6.2 (5.2-7.3)	99.199	6492.752	<0.001	54	1.9 (1.6-2.3)	97.563	2174.966	<0.001
Urban	23	4.6 (3.5-6.2)	99.280	3053.625		23	1.7 (1.3-2.3)	97.807	1002.969	
<b>Geographical location:</b>										
Central China	11	4.3 (2.6-7.0)	99.466	1872.103	<0.001	11	2.0 (1.2-3.3)	98.552	690.498	<0.001
Eastern China	45	5.9 (4.9-7.1)	99.312	6459.533		45	1.6 (1.3-1.9)	97.311	1636.031	
Western China	22	7.2 (5.4-9.7)	99.388	3429.291		25	2.9 (2.3-3.6)	97.463	946.153	
<b>Age:</b>										
50-59	56	1.8 (1.5-2.2)	95.091	1120.306	<0.001	56	0.6 (0.4-0.8)	94.379	978.466	<0.001
60-69	67	4.3 (3.7-4.9)	96.857	2100.172		68	1.4 (1.1-1.8)	96.959	2203.248	
70-79	56	10.9 (9.0-13.0)	98.793	4556.433		56	2.9 (2.4-3.5)	96.118	1416.784	
80+	56	22.5 (18.1-27.6)	99.086	6020.206		56	7.6 (6.2-9.3)	96.149	1428.325	

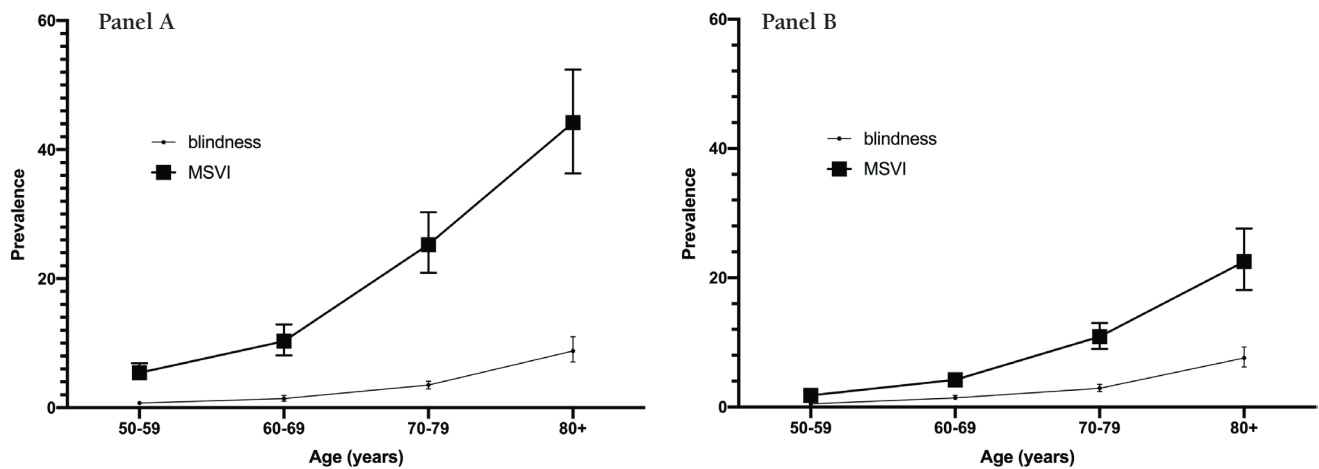


Table 4. Continued

SUBGROUP	MODERATE AND SEVERE VISUAL IMPAIRMENT					BLINDNESS				
	N	Prevalence and 95% CI (%)	Heterogeneity, I <sup>2</sup> (%)	Q-value	P-value	N	Prevalence and 95% CI (%)	Heterogeneity, I <sup>2</sup> (%)	Q-value	P-value
<b>Education:</b>										
Illiterate	16	9.7 (8.2-11.5)	96.010	375.901		16	3.4 (2.5-4.5)	96.217	396.544	
Primary school and lower	17	4.4 (3.2-5.2)	97.325	598.045	<0.001	17	1.4 (1.0-2.0)	92.566	215.214	<0.001
Secondary school and above	23	3.6 (4-5.2)	96.319	597.665		23	1.1 (0.7-1.7)	89.597	211.484	
<b>Examined year:</b>										
1999-2009	40	4.9 (4.1-6.0)	98.993	3873.349		43	2.1 (1.8-2.6)	97.764	1878.643	
2010-2017	34	7.9 (6.5-9.6)	99.321	4859.186	<0.001	34	1.8 (1.4-2.2)	97.915	1582.527	<0.001

CI – confidence interval

95% CI=4.7%-6.8% for BCVA). In geographical subgroup analysis, MSVI prevalence among the rural part of China is higher than the urban area ( $P<0.001$ ). Meanwhile, for the subgroup analysis of age group using PVA for diagnosis, the MSVI prevalence rose from 5.4% (95% CI=4.3%-6.9%) in the 50-59 age group to 44.2% (36.3%-52.4%) in the 80+ age group, given by **Figure 2**, Panel A. As for BCVA, prevalence of MSVI increased from 1.8% (95% CI=1.5%-2.2%) to 22.5% (95% CI=18.1%-27.6%) ( $P<0.001$ ). In terms of education level, populations that had obtained higher education were at a lower risk of developing MSVI both by PVA and BCVA ( $P<0.001$ ). As for survey year, studies conducted in early years (1999-2009) had a lower MSVI prevalence than those conducted later (2010-2017) with statistical significance by PVA and BCVA ( $P<0.001$ ). Studies conducted during 2010 and 2017 had a lower prevalence compared to those conducted between 1999 and 2009 with statistical significance ( $P<0.001$ ).



**Figure 2.** Age- and gender-specific prevalence of MSVI and Blindness. **Panel A.** Age- and gender-specific prevalence of MSVI in term of PVA and BCVA. **Panel B.** Age- and gender-specific prevalence of blindness in term of PVA and BCVA. See also Figure S1 in the [Online Supplementary Document](#).

In the blindness subgroup analyses, some results were similar to MSVI, as females, rural residents, and lower educational level were risk factors of developing blindness ( $P<0.001$ ). For example, the blindness prevalence by PVA climbed up from 0.7% (95% CI=0.5%-0.9%) among 50-59 age group to 8.8% (7.1%-11.0%) among individuals over 80 years old (**Figure 2**, Panel-B). However, people dwelling in Western China were more likely to develop blindness by PVA (3.3%, 95% CI=2.5%-4.4%,  $P<0.001$ ). Unlike MSVI, studies conducted during 2010 and 2017 had a lower prevalence compared to those conducted between 1999 and 2009 with statistical significance ( $P<0.001$ ).

## DISCUSSION

In our study, 72 studies with 90 data sets conducted in different parts of China were included, and the pooled prevalence of VI, MSVI, SVI and blindness among older Chinese populations (aged 50 years and above) were assessed. Using PVA as the classification index, prevalence of MSVI, SVI, VI and blindness were, 10.9% (95% CI=9.4%-12.6%), 2.7% (95% CI=1.9%-3.8%), 13.6% (95% CI: 11.8%-15.6%) and 2.2% (95% CI=1.8%-2.8%), respectively. As for BCVA, the pooled MSVI, SVI, VI and blindness prevalence were, 5.4% (95% CI=4.6%-6.2%), 1.4% (95% CI=1.0%-1.9%), 7.8% (95% CI=6.9%-8.9%) and 2.2% (95% CI: 1.9%-2.5%), respectively. Generally, the results of this meta-analysis are consistent with prior studies showing that blindness and MSVI occur more frequently among the older Chinese population [2,11,12].

In the subgroup analysis of gender, the pooled prevalence of females was much higher than that of male, in accordance with most of the original investigations. One possible explanation could be the longer life expectancy of females, which accounts for higher risk of developing age-related ocular diseases [1,3]. Additionally, anatomical and hormonal differences may contribute to the gender difference, as females are proved to be at higher risk of developing cataract, one of the common ocular diseases that leads to MSVI and blindness, but the mechanism is yet to be elucidated [97-99]. Also, the social status of females is much lower in some remote areas, leading to lower quality of health care.

Residing in specific geographical area may contribute to the development of blindness and MSVI; in this study dwelling in rural areas or Western China is considered to be an important risk factor. One explanation is the shortage of health care services in less developed and geographically remote places. Lack of health awareness is also a significant factor among rural residents [100]. The pooled MSVI prevalence of Central China seems higher than those of Western and Eastern China by PVA, however, this may be caused by the limited included studies conducted in Central China. Therefore, these results could assist in guiding the development and implementation of health care resources and policies to focus more on rural populations and promoting health awareness.

The significant difference of the prevalence of MSVI and blindness in the 4 age groups should be highlighted. The pooled prevalence rate were 10 times higher in the 80+ age group than the 50-59 age group. As we know, MSVI and blindness are mainly caused by age-related ocular diseases [1,3,4]. Screenings and early diagnosis methods are vital for reducing the prevalence of MSVI and blindness, and will improve the quality of life of older populations.

When comparing groups of education levels, individuals with higher education were less likely to suffer from MSVI and blindness. Education level is considered to be strongly correlated with socioeconomic status, which is correlated with access to quality medical services [101,102]. Higher education may also be linked to a better understanding and awareness of MSVI and blindness, resulting in timely treatment after the appearance of relevant symptoms [103,104]. Educational intervention plays an important role in raising awareness of the severity of MSVI and blindness in the general population.

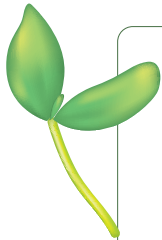
In our study, the prevalence of MSVI is trending upward while the prevalence of blindness is downward trending when comparing studies surveyed in 1999-2009 with those conducted in 2010-2017. While the cataract surgery rate is trending upward, and the awareness of blindness prevention may help with the reducing of MSVI prevalence [105], the aging population is linked with more individuals at risk of blindness causing ocular diseases, such as age-related macular degeneration and diabetic retinopathy, where treatment in late-stage progression is often of limited efficacy [16,106]. Multiple strategies should be utilized to mitigate these problems, such as better screening strategies and improved education around preventing MSVI and blindness to the general public.

The strength of this meta-analysis lies in the large pooled sample size from a wide geographical distribution. In addition, this is one of the few meta-analyses that includes a significant amount of recently published Chinese studies, allowing for researchers worldwide to assess the current situation of MSVI and blindness among older Chinese populations. Moreover, our study is the first to include both PVA and BCVA. The quality assessment of all included studies with clearly defined evaluation tools should also be highlighted, ensuring the quality of this meta-analysis.

However, several limitations should be considered. Some relevant information in subgroup analysis, such as education level, was not available in all selected articles, which could affect the results to a certain extent. Meanwhile, although the Egger's tests and funnel plot did not suggest any publication bias, Begg's tests indicated potential bias may exist in pooled prevalence of blindness and MSVI by BCVA, which may have some impact on the results. Additionally, although we have included both PVA and BCVA as a diagnosis index, using PVA

and BCVA in one study is not as common, which may influence the analysis process. The comparison of the accuracy and practicability of PVA and BCVA was not able to be conducted this time, though we will consider this in future studies.

In conclusion, this meta-analysis offers a comprehensive and up-to-date estimate of MSVI and blindness among older Chinese populations, with the subgroups of gender, district, geographical location, education level and survey year analyzed. The results of this meta-analysis indicate that the prevalence of MSVI and blindness remains high and with discrepancy in different subgroups. Further studies are needed to explore improved diagnosis methods and the mechanism of risk factors affecting MSVI and blindness prevalence.



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**Additional material**

Online Supplementary Document

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