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# Vision impairment and cognitive decline among older adults: a systematic review

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## ABSTRACT

**Objectives** There has been increasing epidemiological research examining the association between vision impairment (VI) and cognitive impairment and how poor vision may be a modifiable risk factor for cognitive decline. The objective of this systematic review is to synthesise the published literature on the association of VI with cognitive decline, cognitive impairment or dementia, to aid the development of interventions and guide public policies pertaining to the relationship between vision and cognition.

**Methods** A literature search was performed with Embase, Medline and Cochrane library databases from inception to March 2020, and included abstracts and articles published in peer-reviewed journals in English. Our inclusion criteria included publications that contained subjective/objective measures of vision and cognition, or a diagnosis of VI, cognitive impairment or dementia. Longitudinal or cross-sectional studies with ≥100 participants aged >50 years were included. The search identified 11 805 articles whose abstracts underwent screening by three teams of study authors. Data abstraction and quality assessment using the Effective Public Health Practice Project Quality Assessment Tool were performed by one author (NN). 10% of the articles underwent abstraction and appraisal by a second author (LA/VV), results were compared between both and were in agreement.

**Results** 110 full-text articles were selected for data extraction, of which 53 were cross-sectional, 43 longitudinal and 14 were case–control studies. The mean age of participants was 73.0 years (range 50–93.1). Ninety-one (83%) of these studies reported that VI was associated with cognitive impairment.

**Conclusion** Our systematic review indicates that a majority of studies examining the vision–cognition relationship report that VI is associated with more cognitive decline, cognitive impairment or dementia among older adults. This synthesis supports the need for additional research to understand the mechanisms underlying the association between VI and cognitive impairment and to test interventions that mitigate the cognitive consequences of VI.

## Strengths and limitations of this study

- ► There was heterogeneity in the measurement of cognitive and visual function among all included studies.
- ► The quality assessment tool used for assessing quality of included studies penalised longitudinal studies that lost over 40% of participants due to drop-outs/withdrawals, which is common in studies that span over many years.
- ► Majority of the included studies were cross-sectional, and these are prone to selection bias.

## INTRODUCTION

Dementia is among the most pressing public health challenges of the 21st century.[1] In 2015, 46.8 million people were living with dementia, and the number is expected to double every 20 years.[2] Vision impairment (VI), another major global health problem, affects at least 2.2 billion people worldwide,[3] most of whom are aged 50 years and older.[4] Both cognitive and VI are projected to affect an increasing number of people over time, primarily due to population ageing.[4 5]

Prior work has suggested that cognition and vision are associated,[6 7] and while there are shared risk factors (neuropathological/vascular),[8] there is also longitudinal evidence that VI is associated with cognitive changes.[9] The mechanisms underlying the vision-cognition relationship have not yet been fully characterised, but it is hypothesised that sensory loss, such as hearing impairment and VI, may lead to increased cognitive load, structural and functional changes in the brain, and decreased emotional and social well-being, all of which could potentially increase the risk of cognitive impairment.[9 10] While the role of treating hearing loss in preventing cognitive impairment has been acknowledged, VI has not yet been recognised as a potentially modifiable risk factor for cognitive impairment.[1 11]

Since the majority of VI is due to correctable conditions, namely refractive error and cataract,[12] establishing the existence of an association between vision and cognitive impairment could present an additional opportunity to prevent cognitive impairment

and dementia through interventions that optimise vision. In this systematic review of the literature, we examined the association between cognitive and vision impairment among older adults in existing observational studies. This qualitative review summarises the existing research examining the vision–cognition relationship, providing insight on data gaps and areas for continued investigation, as well as highlighting differences in methodological approaches that may impact the interpretation of results across studies.

## METHODS/LITERATURE SEARCH

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (online esupplemental file 1).

Cross-sectional and longitudinal studies reporting a measure of association between visual function and cognitive impairment were included if they had ≥100 participants aged of ≥50 years (mean) at baseline. Reasons for exclusion of studies were: (1) Outcome measure was not vision or cognition, (2) Association between vision and cognition was not explored, (3) Sample size <100, (4) Publication not in English, (5) Mean age <50 years, (6) No cognitive measure, (7) No vision measure and (8) Outcome was not part of inclusion criteria.

An academic librarian searched: Ovid Medline, Embase, Cochrane and PubMed from their inception to March 2020, and developed a search strategy that combined controlled vocabulary and keywords related to geriatrics, cognition and vision (online esupplemental file 2-complete Ovid Medline search strategy). Searches were limited to human studies published in English. Conference and poster abstracts, and short oral presentations were also included.

Search results were exported to Covidence (Veritas Health Innovation, Melbourne, Australia). Three teams of two reviewers each worked independently and in duplicate to screen titles, abstracts and full-text articles to determine inclusion (NN and MM; EC and YS; VV and LA). Disagreements were adjudicated by a member of the other study team.

Data were extracted from the included publications by one author (NN), and another (LA) extracted data from a random sample of 10% to compare results. Any discrepancies were adjudicated by a third author (VV). Data collected for each publication included: study design, participant characteristics, vision and cognition assessment methods and the summary measure that described the vision–cognition association.

The methodological quality of included studies was assessed by one author (NN) using the Effective Public Health Practice Project Quality Assessment Tool (EPHPP)[13] and the global quality ratings and findings were summarised qualitatively. A random 10% sample was reviewed by another author (VV) to ascertain consistency in quality assessment (QA).

**Table 1** Patient demographics and study characteristics

| Demographics and study characteristics | No |
|---|---|
| Total no of studies | 110 |
| Total no of participants | 9 799 329 |
| Mean age, year, IQR | 73.0 (50–93.06) |
| Study design | |
| Cross-sectional | 53 (48%) |
| Longitudinal | 43 (39%) |
| Case-control | 14 (13%) |
| Country | |
| USA | 30 (27%) |
| Japan | 6 (5%) |
| UK | 6 (5%) |
| China | 6 (5%) |
| Australia | 5 (4.5%) |
| France | 5 (4.5%) |
| Germany | 5 (4.5%) |
| Singapore | 5 (4.5%) |
| Ireland | 3 (3%) |
| Canada | 3 (3%) |
| Spain | 2 (2%) |
| Taiwan | 2 (2%) |
| Sweden | 1 (<1%) |
| Nordic Countries | 1 (<1%) |
| New Zealand | 1 (<1%) |
| Switzerland | 1 (<1%) |
| Netherland | 1 (<1%) |
| Others | 27 (25%) |

## RESULTS

### Study Selection

Online esupplemental file 3 is a PRISMA flow chart that describes the results of the search strategy of articles that examined the association between VI and cognitive impairment or decline. Of the 11 805 studies that were imported for screening, 110 articles were included in our final systematic review.[7 14–122]

### Description of included studies

Table 1 describes the characteristics of the studies included. The total number of participants in this review was 9 799 329 (range: 112–7 210 535 per study), with a mean age of 73.0 years, (range: 50.0–93.1). Of the total 110 studies included, 53 were cross-sectional, 43 were longitudinal and 14 had a case–control study design. The range of follow-up time for the longitudinal studies was 2 months to 10 years.

Of the 110 studies included, 51 reported findings from participants enrolled in population-based studies. There were five studies each from the following large population

Table 2 Measures of vision and cognition assessed in studies

| Outcome measures | No of studies |
|---|---|
| **Cognition (n, %)** | |
| Objective assessment n=89 (81%) | |
| MMSE | 42 (47%) |
| MoCA | 5 (6%) |
| Global cognition scale | 6 (7%) |
| Others | 36 (40%) |
| Other assessment methods n=13 (12%) | |
| Self-report | 4 (31%) |
| ICD diagnosis/from records | 9 (69%) |
| Combination of Objective+Subjective (5%) | 7 |
| No info (<1%) | 1 |
| **Vision (n, %)** | |
| Objective n=66 (70%) | |
| Acuity | 42 (65%) |
| Acuity+others | 16 (23%) |
| Others | 8 (12%) |
| Other assessment methods n=34 (22%) | |
| Self-report | 24 (71%) |
| ICD diagnosis/from records | 10 (29%) |
| Combination of Objective+Subjective (7.5%) | 8 |
| No info (<1%) | 2 |

MMSE, Mini-Mental State Examination; MoCA, Montreal-Cognitive Assessment.

based longitudinal studies: English Longitudinal Study of Aging (ELSA) and The Three-City Study. Three studies each from Fujiwara-Kyo Study, Salisbury Eye Evaluation Study, Irish Longitudinal Study on Aging and Singapore Epidemiology of Eye Diseases. Two studies each came from The Newcastle 85+ study, Study of Osteoporotic Fractures, Blue Mountain Eye Study, Australian Longitudinal Study on Aging, Health and Retirement Study, National Health and Aging Trends Study (NHATS), Leiden 85+ study, Health ABC study and the Singapore Malay Eye Study. Additionally, 10 studies used insurance claims data from different countries.

The studies in this review included participants from over 17 different countries (table 1), 30 studies (27%) from the USA, followed by 25 studies from Europe (23%) including the UK, Germany, Ireland, Finland, Switzerland, France and Netherlands. Ninety of the studies were published between 2009 and 2020. All papers provided a description of sampling methods. 16 studies were included which were either conference abstracts or short oral presentations.[24 32 45 49–51 53 56 92 93 96 112–116]

### Assessment of cognitive function

To assess cognitive function, 89 studies used objective assessments, 13 used other assessment methods such as self-report and diagnosis codes, and 7 studies used a combination of both (table 2); one study did not provide information about cognitive function assessment.[92] Mini-Mental State Examination (MMSE) was the most commonly used objective method to assess cognitive function (42 studies). Other methods used to objectively measure cognition included: Montreal-Cognitive Assessment test,[28 32 34 53 93] Addenbrooke's Cognitive Examination-Revised,[45 61 79] Cognitive Performance Scale,[42 49 65] Blessed-Orientation-Memory-Concentration test,[25 62] Abbreviated Mental Test,[72 74 89 100 110 119] Blessed Dementia Scale,[86] Digit Symbol Substitution Test [22 122] and Cambridge Cognitive Examination test.[88] For the studies that used other assessment methods, four used self-reported cognitive measures,[18 22 39 105] and nine used diagnostic codes to define cognitive decline and/or dementia.[19–21 51 69 99 103 115 117] Among the studies that used a combination of objective and subjective methods, four used self-reported cognitive function along with an objective measure.[22 30 48 55]

### Assessment of visual function

In order to assess visual function, 66 studies used objective assessments, 34 used other assessment methods such as self-report and diagnosis codes, and 8 studies used a combination of both (table 2); no information was available from two studies.[24 116] Visual acuity (VA) was the most commonly measured visual function (42 studies), of which the Snellen acuity chart was the most commonly used method (18 studies). VA was also measured in combination with other visual functions, including: visual fields (VF) (six studies),[20 51 70 90 102 118] contrast sensitivity (CS) (eight studies),[29 52 86 93 94 102 118 122] macular pigment optical density (two studies)[14 34] and fundus photography (two studies).[63 118] Other methods used to objectively measure visual functions included: colour vision,[17] VF only,[28] CS only,[35 76] fundus photo with grading[38 100] and autorefraction.[74] Other assessment methods included: self-reported vision (24 studies) and diagnostic codes or patient records to define VI (10 studies).[19 21 46 69 83 99 104 115 117 121] The studies that used a combination of methods, eight studies used self-report along with an objective measure of visual function.[22 40 53 59 68 71 107 113]

## Quality of studies

The methodological quality of included studies was assessed using the EPHPP.[13] The tool assessed each study on five domains: (1) Selection bias, (2) Study design, (3) Confounders, (4) Data collection methods and (5) Analysis. For each included study the five relevant domains were ranked on a three-point Likert scale with three representing a low risk of bias ('strong'), two a possible risk of bias ('moderate') and one a high risk of bias ('weak'). An overall rating was derived following the EPHPP methodology. A study consisting of at least one 'weak' rating in a domain received an overall rating of 'moderate,' while those with two or more domains with 'weak' ratings were automatically classified as 'weak' overall. We present

**Table 3** Studies with a 'strong' rating

| Author, title and year | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dearborn *et al*[27] | US (Maine-Syracuse Longitudinal Study (MSLS) | Longitudinal cohort, wave 6&7 | 655 | Normal VA 60.34 | 40%/60% | Cognition | Visual-Spatial Organisation and Memory, Scanning and Tracking, Verbal Episodic and Working memory | Acuity: Snellen eye test (log transformed) | Cross-sectional (CSA) and prospective analysis (PA) using multiple linear and multiple logistic regression | Poorer VA associated with lower cognitive function and 5 year decline | Strong |
| 2018 | compared sixth (2001–2006) wave and | | | VI 70.6 | 40%/60% | | Global composite score-loaded equally across domains, z-transformed | | Global OR: CSA 1.512 (0.71 to 3.23), PA 1.539 (0.74 to 3.21), VSMO OR: CSA 1.28 (0.63 to 2.59), PA 2.26 (1.16 to 4.4) | in cognitive function over a range of domains incl the global measurements | |
| | seventh (2006–2010) wave) | | | | | | | | Working OR: CSA 1.73 (0.85 to 3.51), PA 1.55 (0.78 to 3.08), VEM OR: CSA 0.55 (0.25 to 1.24), PA 1.43 (0.73 to 2.81) | Visual-spatial organisation, verbal episodic memory | |
| Diniz-Filho *et al*[28] | USA | Longitudinal cohort | 115 | 67.4 | | Cognitive Decline | Montreal-Cognitive Assessment test (MoCA); assesses atten and concentration, executive functions | Standard Automated Perimetry (SAP) using 24–2 SITA | Univariate: 5-point decline in MoCA=0.18 dB increase of residuals of SAP MD, R2=4.3% (0.06 to 0.30) p0.003 | Statistically significant association between change in | Strong |
| 2017 | | | | | | | memory, language, visuoconstructional skills, conceptual thinking, calculations and orientation | <33% fixation loss and<15% FP only included | Multivariate: 5-point decline in MoCA=0.23 dB inc of residuals of SAP MD, (0.11 to 0.35) p<0.001 | MoCA scores and VF variability over time | |
| Fischer *et al*[35] | USA (The Epidemiology of Hearing Loss Study) | Longitudinal cohort. Baseline info was from EHLS-2 (1998–2000), CI data from EHLS-3 (2003–05) and EHLS-4 (2009–10) | 1884 | 66.7 | 40.9/49.1 | Cognition | MMSE | Contrast sensitivity using Pelli-Robson letter charts. VI was defined as | Cox discrete time proportional hazard analyses performed to model relationship btwn CI and Sensory Imp. | Hearing, Visual and Olfactory impairment were independently | Strong |
| 2016 | | | | | | | | score<1.55 log units in the better eye | Vision: HR=2.05 (1.24, 3.38); Olfaction: HR=3.92 (2.45, 6.26), Hearing: HR=1.90 (1.11, 3.26) | associated with cognitive impairment risk | |

Continued

**Table 3** Continued

| Author, title and year | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hall[43] | USA (Impact of Cataract on Mobility (ICOM) study) | Longitudinal cohort study. 3 groups identified: No cataract, with cataract and undergoing surgery, with cataract and declined surgery | No Cat: 92 | 66.8 | 48.9/51.1 | Cognition | Mattis Organic Mental Syndrome Screening Examination (MOMSSE)-evaluates 14 domains (abstraction, | Acuity: Dist VA ETDRS chart, Log Contrast senstivity: Pelli-Robson chart | Cat+no Sx & cat+surgery grps signifcantly less CI (p<0.001 and p=0.009, respectively) than at baseline. | Cataract surgery does not affect cognitive function | Strong |
| 2005 | | | W Cat+Sx: 122 | 70.9 | 41.8/58.2 | | orientation, memory, speech, comprehension). Scored 0 to 28 (lower score higher functioning) | Ophthalmologist/ optometrist graded cataract at clinic visit | No cataract group=no change in Cog status, association between change in VA in the better and worse eye and | | |
| | | | W cat+no SX: 87 | 71.1 | 59.8/40.2 | | | | change in MOMSSE observed (p=0.003 &p=0.03, respectively) | | |
| Lin *et al*[47] | USA (Study of Osteoporotic Fractures) | Longitudinal cohort | Vision testing sample:1668 | 75.9 | 0/100 | Cognition | 3MS-Modified version of MMSE | Acuity: Bailey Lovie Target | VI (worse than 20/40): Cog decline - 1.78 (1.21 to 2.61), Functional decline- 1.79 (1.15 to 2.79) | Vision impairment is associated with greater odds of cognitive and | Strong |
| 2004 | | | Overall 6112 | 76.1 | | | | | DSI: Cog decline - 2.19 (1.26 to 3.81), Functional decline- 1.87 (1.01 to 3.47) | functional decline over time in older women | |
| Jefferis *et al*[46] | UK | Longitudinal cohort. | 112 | Normal cog: 80 (3.8) | 20/80 | Vision | Addenbrooke's Cognitive Examination (which includes the MMSE) | Acuity: LogMAR, Other: VFQ-25 | Normal cog group: Mean at baseline 0.13 (0.09), 1 year FU 0 (0.09), 95% CI for difference: 0.09 to 0.16<0.001 | Patients with impaired cognition benefit from cataract surgery, but not to the same extent as patients with normal cognition. Cognitive impairment may, however, limit visual improvements | Strong |
| 2015 | | | | Impaired cog: 81.2 (3.9) | 30/70 | | | | Impaired cog group: Mean at baseline 0.18 (0.14), 1 year FU 0.06 (0.11), 95% CI for difference: 0.08 to 0.16 | following cataract surgery | |

Continued

**Table 3** Continued

| Author, title and year | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Reyes-Ortiz *et al*[7] | USA (Hispanic Established Populations for Epidemiologic Studies of the Elderly) | Longitudinal cohort. | 2140 | Near VI: 73.5 | 39.3/60.7 | Cognition | MMSE-blind | Acuity: subjects hold cards at least seven inches from their eyes and asking them to read the numbers | Near vision impairment, −0.62±0.29, .03, Interaction btwn near VI & time=−0.13 +/- 0.07, .045 | Results showed that near vision impairment was predictive of | Strong |
| 2005 | | | | Distance VI: 75.3 | 35/65 | | | Each card had 7-digit ''telephone numbers'' of three different type sizes: 7, 10, and 23 points | Distance vision impairment=−0.06 +/- 0.36, .87, Interaction btwn distance VI & time, −0.12±0.08, .14 | cog decline in older Mexican Americans independent of other health factors | |
| Haan *et al*[67] | USA (Women's Health Initiative MS-MRI) | Longitudinal cohort | 511 | 69 | 0/100 | Cognition | Modified Mini Mental State (3 MS) | Acuity: Snellen with pinhole | Acuity slope in model of 3MSE score (β slope // 0.33, p=0.06). Covariate-adjusted mean 3MSE scores for women | Retinopathy as a marker of small vessel disease is a risk factor for cerebrovascular disease that may influence cognitive performance and related brain changes | Strong |
| 2012 | | | | | | | | | with retinopathy compared with others throughout follow-up: mean (SE) difference 1.01 (0.43), p=0.019 | Very mild association between acuity and 3MSE scores | |
| Trick *et al*[70] | USA | Case-control. Visually and cognitively normal controls (n=61), and senile dementia of Alzheimer's type (SDAT) n=61 | 122 | SDAT: 73.4 | NA | Cognition | each patient was assigned a clinical dementia rating (CDR) based on a scale developed and tested at Washington Uni | Acuity: ETDRS. VF analysis using 30–2 HFA | Patient groups, Foveal threshold, Mean deviation, Pattern SD, Corrected pattern SD. | We found that the frequency of potentially unreliable VF was significantly higher (chisquare, | Strong |
| 1995 | | | | Control: 72.8 | | | i.e CDR scale ranges from 0.0 (individual without dementia) to 3.0 (severely demented). | | Control (n=44): 33.2±3.05,−2.81+/−3.45, 3.48±2.05, 2.58±2.30<br>SDAT (n=34): 30.79+4.00 (p=0.0027), −5.11+/−3.17(p=0.0057), 4.461+/−2.49(NS), 3.91+/−2.73(p=0.0408)<br>CDR=0.5(n=25): 31.12+/−3.54, −4.25+/−2.23, 4.47+/−2.60, 3.83+/−2.89 | p=0.0232) in SDAT patients (44.3%) than in controls (27.9%) | |

Continued

**Table 3** Continued

| Author, title and year | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Helmer *et al*[80] | France (The Three-City-Alienor Cohort) | Longitudinal, cohort | 812 | 79.7 | 35/65 | Cognition | MMSE; Free and Cued Selective Reminding Test Isaacs Set Test the Trail Making Test parts A and B Then suspected cases were assessed by a neurologist | Acuity: No chart name provided, IOP: pneumotonometer | Association of OAG and incident dementia: Model 1: OR 4.3 95% CI 1.7 to 10.8 p 0.0020, Model 2: OR 4.2 95% CI 1.6 to 10.9 p 0.0030 | Yes. Results show that OAG participants were at an increased risk for developing dementia during the 3 year follow-up time period. | Strong |
| 2013 | | | | | | | | | Model 3: OR 3.9 95% CI 1.5 to 10.4 p 0.0054, Association of Vertical cup:disk ratio and incident dementia: ≥0.65: OR 3.7 95% CI 1.4 to 9.7 p 0.0083 ≥0.70: OR4.4 95% CI 1.5 to 12.5 p 0.0055 Association of Minimal rim:disk ratio =< 0.1 and incident dementia: OR 2.7 95%CI 1.005–7.1 p 0.0489 | | |
| de la Fuente *et al*[97] | UK (English Longitudinal Study of Ageing) | Longitudinal, cohort | 3508 | 69 | 43.2/56.8 | Cognition | Four measured tests of verbal fluency, processing speed, | Three self-reported items covering eyesight in far, near, and general vision | Visual (β=0.140, p<0.001) difficulties predicted cognitive difficulties 8 years later | Yes. Visual difficulties were identified as predictors of | Strong |
| 2018 | | | | | | | and short-term and long-term memory | Dichotomized, collapsing "Excellent," "Very good," and "Good" as "Absence of difficulties". | The latent increase in cognitive difficulties was steeper in people with visual impairment (*d*=0.52, p<0.001) | subsequent cognitive decline in the old age | |
| Hamalainen *et al*[98] | Canada (Canadian Longitudinal Study on Ageing) | Cross-sectional cohort | 30 029 | No info | No info | Cognition | five cognitive tests: Mental Alternation Test, Animal Fluency test, Controlled Oral Word Association Test, Stroop test | Vision was measured as the better-seeing eye pinhole-corrected VA (reported in logMAR) | VA was a predictor of only executive function (b=−0.785, p<0.001) but not memory | Yes, greater executive function scores were associated with better vision | Strong |
| 2019 | | | | | | | and Rey Auditory Verbal Learning Test with immediate and 5 min recall | | | | |
| Chuanying Huang | UK (English Longitudinal Study of Ageing) | Cross-sectional cohort | 4197 | Optimal:70.21 | 58.6/41.4 | Cognition | Memory (immediate and delayed), verbal fluency, and time orientation | Self-report: 'Is your eyesight (using glasses or corrective lens as usual) excellent, very good, good, fair, poor, or registered blind?' | poor vision (= −1.309, p=0.004), and poor dual sensory function (= −2.442, p=0.013) was associated with worse cognition | Yes. | Strong |
| 2019 | | | | Good: 71.84 | 51.2/48.8 | | Global cognition was the sum of scores for the three domains, and higher score indicates better cognitive performance | Answer of 'excellent' or 'very good'was defined as optimal vision. Answer of 'fair' or 'poor' was | | | |

Continued

**Table 3** Continued

| Author, title and year | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Poor: 74.75 | 47.2/52.8 | | | defined as poor vision. Thus vision was classified as optimal, good, and poor vision | | | |
| Virginie Naël | France (The Three-City-Alienor Cohort) | Longitudinal, cohort | 7736 | Incident dem:76.9 | 34.8/65.2 | Cognition | 3-step procedure: 1. MMSE, the Isaacs set test and the Benton Visual Retention Test | Near VA assessed using the Parinaud scale. Mild near VI was classifed by Parinaud three or 4 (Snellen equivalent 20/30–20/60) | Moderate to severe near VI was associated with an increased risk of dementia in the frst 2 years (HR2.0, 95% CI 1.2 to 3.3) | Yes. Near VI may represent an indicator of dementia risk at | Strong |
| 2019 | | | | No inci dem: 73.6 | 39.2/60.8 | | 2.senior neurologist to establish a clinical diagnosis, 3.an independent committee of | and moderate to severe near VI by Parinaud>4 (Snellen equivalent<20/60) | and from 2 to 4 years (HR 1.8, 95% CI 1.1 to 3.1). distance VF loss was associated with an increased risk beyond 4 years (HR 1.5, 95% CI 1.1 to 2.0) | short and middle-term, mostly in depressedelderly people | |
| | | | | | | | neurologists and geriatricians reviewed all potential cases of dementia obtain a consensus on the diagnosis and aetiology, according to the DSM-IV and the NINCDS-ADRDA criteria | Dist VA was selfreported, defned as an inability or diffculty in recognising a familiar face at 4 m | but the association was no longer signifcant after taking into account baseline cognitive performances | | |
| Zhi Wei Lim | Singapore (Singapore Epidemiology of Eye Diseases) | Longitudinal cohort | 2478 | 67.6 | 50.7/49.3 | Cognition | A locally validated Abbreviated Mental Test (AMT) | VA was measured at 4 m using the logMAR number chart | Baseline VI was associated with a decrease in AMT score over 6 years (β = −0.27; 95% CI, −0.37 to −0.17; p<0.001) | Yes,poor vision was independently associated with a decline in cognitive function | Strong |
| 2020 | | | | | | | | (Lighthouse International).VI was defined as presenting VA worse than 20/40. | When change in vision over 6 years was evaluated, unchanged or deteriorated VI was associated<br><br>with a decrease in AMT score over 6 years (β = −0.29; 95% CI, −0.40 to −0.18; P < .001) | | |
| Bernard Michalowsky | Germany (NA) | Case-control study | 122 708 | 81 | 39/61 | Cognition | ICD-10 diagnosis code for dementia | ICD-10 codes for visual impairment | Visual impairment was not significantly associated with dementia (OR=0.97, CI=95% 0.97 to 1.02, p=0.219) | No, but DSI was significantly associated with risk of dementia | Strong |

Continued

**Table 3** Continued

| Author, title and year | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019 | | | | | | | | | Combination of both visual and hearing impairments and the risk of dementia (OR=1.14, CI=95% 1.04 to 1.24, p=0.005) | | |
| Jung-Yu Liao[121] | Taiwan (National Health Insurance Research database) | Case-control study | 9200 | NA | LOAD 36.7/63.3 | Cognition | LOAD cases diagnosed as dementia and prescribed any acetylcholinesterase inhibtiors (AChEIs) | ICD-9 codes | Disorders of refraction and accomodation with LOAD OR for Year 1,2,3,4: 1.2, Year 6:1.3 | Yes, in the path analysis model, disorders of ref and acc | Strong |
| 2020 | 1997–2013 | | | | Without LOAD 36.7/63.3 | | | | Total effect reflects an association between prior diseases and LOAD incidence via all paths in the model: 0.042 | had a significant positive effect on LOAD incidence | |

DSI, dual sensory impairment; MMSE, Mini-Mental State Examination; VA, visual acuity; VF, visual field.

our studies in three different tables which is categorised based on the overall ratings, with 'strong', 'moderate' and 'weak' studies in tables 3–5, respectively. In our sample, 17 studies received a rating of strong, 70 moderate and 23 weak.

### Study findings

Of the 110 studies included (tables 3–5), 91 found a significant positive association between VI and cognitive decline, cognitive impairment or dementia, and 13 studies found no significant association.[26 30 43 44 60 61 68 81 82 90 94 115 117] There were six studies that were inconclusive.[23 37 67 70 79 83] Of the 91 studies that found a significant association, 77 used objective methods to assess their vision or cognitive outcome. Of the 43 longitudinal studies, 35 found a significant association between VI and cognitive decline, cognitive impairment or dementia. The most commonly presented statistical measures were ORs and HRs. The random 10% of the study sample that was separately extracted by an independent author (LA) was found to be similar to elements from the primary extraction.

## DISCUSSION

In this systematic review, we evaluated and synthesised the literature examining the association between VI and cognitive function among older adults, and found strong agreement that VI is associated with cognitive impairment, cognitive decline or dementia. Results from the longitudinal studies that found a positive association between vision and cognition supports our hypothesis that VI may be a risk factor for cognitive impairment, cognitive decline or dementia.

Ninety-one studies reported associations between decline in visual and cognitive functions. Garin *et al*,[40] who received a 'moderate' rating in the QA, performed a cross-sectional analysis in a representative sample of Spanish population and measured cognition objectively. They also measured distance and near vision and found that objective and subjectively measured poor distance and near VA were associated with worse cognitive functioning. Lin *et al*[47] used data from a large longitudinal cohort study of older women and found that VI was associated with greater odds of cognitive and functional decline over 2 years. This study used objective measures of assessment for both vision and cognition and received a 'strong' rating in the bias assessment. Luo *et al*,[48] who received a 'moderate' rating in QA, performed a cross-sectional analysis on a large population sample from China. They reported that those with VI and Dual Sensory Impairment (DSI) were more likely to have severe to extremely severe dementia compared with those without any sensory impairment. Another longitudinal study that received a 'moderate' rating in QA from Germany by Hajek *et al*[58] with a large sample size (n=2394) showed that the onset of severe VI was associated with a decline in cognitive function scores. Uhlmann *et al*[64] in their paired case–control study between VI and dementia patients

**Table 4** Studies with a 'moderate' rating

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ajana *et al*[14] | France (ALIENOR study, 3 City-Bordeaux cohort) France | Cross-sectional study | 184 | 82.3 | 31.5%/68.5% | Cognition | MMSE, Isaacs Set test (IST15), Benton Visual Retention test, Free and Cues Selective Reminding Test | Acuity: Measured but no mention of method | MPOD 0.5 degree, Z score (b)=0.12 (0.01, 0.23). MPOD 1 degree, Z score (b)=0.11 (0.01, 0.22) | Yes- Between MPOD and Global cognitive z score | Moderate |
| 2018 | | | | | | | Summarised by a composite global cognitive Z-score | MPOD: Measured using confocal scanning laser Ophthalmoscope | Regression models | | |
| Anstey *et al*[15] | Australia (Australian Longitudinal Study of Ageing) | Longitudinal | 1823 | 77.77 | 51.2%/49.8% | Cognition and vision | MMSE, Verbal ability, Processing speed and Memory | Acuity: Distance using Snellen chart at 3 m, Near at 20 cm | N/A | Yes- significant moderate-sized association between rates of | Moderate |
| 2003 | | | | | | Analysis of change using growth curves | | using chart containg short passages in font size 5 to 18. Left and Right eye were tested separately. Score was the smallest font size | Latent growth curve analysis | change in Memory and Vision | |
| Anstey *et al*[16] | Australia (Australian Longitudinal Study of Ageing) | Longitudinal | 3766 | 76.34 | Wave 1: 56%/44% | Cognition | Verbal ability, Processing speed and Memory | Acuity: Distance using Snellen chart at 3 m | Sensory status x group interaction for memory comparing participants who declined on Vision vs not declined | Yes- Decline in visual performance had a significant | Moderate |
| 2001 | | | | | Wave 3: 33%/67% | | | Wilks A=0.98, F=2.94, p<0.05, n2=0.054 | | effect on decline in memory performance | |
| | | | | | | | | | Two-factor repeated measures MANCOVA (sensory status*wave) | | |
| Arnaoutoglou *et al*[17] | Greece | Longitudinal, Case-control | Total 103 AD group n=32 | AD 73.3 | 38%/62% | Vision | MMSE, Dementia blood screening, Reisberg AD scale, MRI and NINDS-AIREN to diagnose VaD | Colour vision using Ischihara colour deficiency test | Difference in ischihara scores between two groups F(1,161)=9.558, p=0.003. AUC 0.819 (0.70, 0.93) | Yes- Ischihara a promising test to differentiate AD and | Moderate |
| 2017 | | | VaD group n=36 | VaD 75.6 | | | | Consists of 38 pseudoisochromaric plates | ANOVA to estimate any sig variations between three groups within their age, MMSE, Resiberg and | VaD | |
| | | | Healthy controls n=35 | Controls 74.2 | | | | six errors suggests definite colour blindness | total Ischihara score | | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Arrighi *et al*[18] | US (National Health interview survey (NHIS)2001–05) | Cross-sectional study using nationally available survey data | 23 474 | With dementia 80.72 | With dementia 36%/64% | Vision | Self reported surveys. Was categorised as With dementia if patient reported :senile" | Self reported vision problems | Prevalence OR 1.46 vision problems with funtional limitations among americans aged>60 | Yes- Higher odds of vision problems being prevalent | Moderate |
| 2010 | | | Person with dementia 443 | Without dementia 72.3 | Without 39%/61% | | | with and without limitations related to dementia | | among people with funtional limitation | |
| | | | Without dementia 23 031 | | | | | | | | |
| Bauer *et al*[19] | German statutory health insurance fund data (2006) | Cross-sectional study using claims data from insurance company | 37 753 | 80.1 | 28.4%/71.6% | Comorbidity complex | ICD codes with diagnoses of dementia | ICD codes with diagnoses of severe vision reduction | OR 0.59 persons with severe vision problems were less likely to have dementia | Yes- significantly lesser odds of vison problems among | Moderate |
| 2014 | | | Dementia group 9139 | 81.6 | 25.4%/74.6% | Patient having a diagnosis of vision prob | | | | cases with dementia | |
| | | | Without dementia 28 614 | 79.6 | 29.4%/70.6% | Using ICD codes | | | | | |
| Chen *et al*[21] | Taiwan National Health Insurance | Case-control. Randomised sample data of one million patients who made claims from insurance | Eye disease 4097 | 50 y | AMD 60.9%/39.1% | Alzheimer's disease | ICD codes with diagnoses of Alzheimer's Disease | ICD codes with diagnoses of AMD, Diabetic retinopathy and Glaucoma | Cumulative IR of 1.22% ADE among eye disease group vs 0.04% among controls | AMD, DR and Glaucoma were asso with an increased | Moderate |
| 2016 | Research database (HIRD) | | Controls 20 745 | | DR 52.9%/47.1% | | | | HR for DR 39.31 (4.79, 332.67), HR for AMD 36.94 (4.62, 295.46), HR for Glau 34.08 (13.37, 86.84) | risk of Alzheimer's disease | |
| | | | | | Glaucoma 45.9%/54.1% | | | | | | |
| Chen *et al*[22] | US (NHANES and NHATS) | Cross-sectional analysis of two datasets: 1999–2002 NHANES data and 2011–2015 NHATS data | NHANES 2975 | 72 | 48%/52% | Cognition | NHANES: Cog testing done using Digit symbol substitution test (DSST). </=28 indicated poor cognition | NHANES: Dist-Snellen VA chart, Near- 5-linr near vision card | NHANES: Dist VI b=−5.1 (-8.6,−1.6), OR 2.8 (1.1, 6.7), Near VI b=−3.8*, OR 1.7*, Subj VI b=−5.3*, OR 2.7* | Yes, VI significantly associated with worse cognitive fn | Moderate |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2017 | | | NHATS 30202 | NA | 42%/58% | | NHATS: Probable/ possible dementia vs No dementia based on NHATS classification scheme (self-report) | NHATS: Vision tested via questionnaires | NHATS: Subj Near VI: OR 2.6 (2.2–3.1), Subj Dist VI: OR 3.9 (3.4–4.4) | | |
| Chriqui[23] | Canada | Longitudinal cohort | 150 | 86.7 | 27%/73% | Vision | MMSE | Dist vision- Snellen chart, 6 m. VI was Vn<6/12 | Presenting VI: 37.3 (29.1–46.1) | 37.3% of dementia participants had VI. | Moderate |
| 2017 | | | | | | | | Near vision- Topcon paragraph/lighthouse | VI after refraction: 20.1 (13.7–27.9) | Just prevalence study, no correlation tested | |
| De Celis *et al*[25] | US (Hurria et al. JCO 2011 & 2016) | Cross-sectional analysis of 2 prospective studies | 750 | Median age 72 (65-94) | No info | Cognition | Blessed OMC test (>11 on this test) | self-reported visual impairment (fair, poor or blind) | OR for association between VI and Cognition deficit. | Older pts with cancer and hearing/visual impairment | Moderate |
| 2017 | | | | | | | | | Univariate model: 2.0 (0.8–4.7), Multivariate model: 1.9 (0.75–5) | at higher risk of funtional and cognitive deficits | |
| de Kok *et al*[26] | New Zealand (Life and Living in Advanced Age: A | Cross-sectional baseline data | 661 | Maori: 82.3 | 40%/60% | Cognitive decline | MMSE-blind version, cognitive test for the visually impaired | Acuity: ETDRS | Generalised linear models and structural equation modelling | No direct association found in this population | Moderate |
| 2017 | Cohort Study in New Zealand (LiLACS NZ) | | | Non-Maori: 84.6 | 47%/53% | | | | Maori: Dis VA (logmar) b=0.103 (-0.21,0.42), Self reported VI b=0.110 (-0.030, 0.251) | | |
| | | | | | | | | | Non-Maori: Dis VA (logmar) b=0.197 (-0.12, 0.51), Self-report VI b=0.065 (-0.056, 0.187) | | |
| Elliott *et al*[29] | US | Cross-sectional cohort | 238 | No info | 26%/74% | Vision | MMSE | Dist VA: ETDRS, Near VA: Lighthouse near VA card. VI<20/40 one eye | β MMSE in Multiple linear Regression for Predicting Vn; Dist VA: −0.015, Near VA: −0.013 both(p 0.00) | Cognitive status contributed to the prediction of VI | Moderate |
| 2015 | | | | | | | | Mars CS to assess CS. Score worse than 1.50 in one eye | Contrast sen: 0.17 (p0.00) | | |
| Elliott *et al*[30] | US | Longitudinal case-control | 78 | REC: 79.2 | 23.1%/76.9% | Cognition | Self-report and MMSE | Distance: ETDRS | Intervention group: MMSE baseline 20.2 (4.4), follow-up 19.4 (4.8), p=0.05 | Vision-enhancing interventions did not lead to short | Moderate |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | | | 64 | Delayed corrc: 78 | 25%/75% | | | Near: Lighthouse Near VA Test | Control group: MMSE baseline 21.7 (4.5), follow-up 20.5 (5.5), p=0.015 | term improvements in physical function/cognitive status in sample. | |
| | | | 30 | Cataract Sx: 81 | 26.7%/73.3% | | | | Pre&post-intervention measures of Phy fn &cognitive status compared within treatmnt groups paired t-tests | | |
| | | | 15 | No cat sx: 87 | 13.3%/86.7% | | | | | | |
| Elyashiv *et al*[31] | US (The Religious Orders Study and The Memory snd Ageing Project) | Longitudinal cohort study of ageing and AD | 2716 | 78.13 | 28.6%/71.4% | Cognition | Global cognitive scale (GCS), summary of raw scored of 19 tests incl episodic, semantic and working mem | Tested with both eyes open with a card held at 14 inches and measured | Mixed model for assoc with global cog score: VA b=−0.03312 (p<0.0001) | Significant positive correlation between GCS and VA | Moderate |
| 2014 | | | | | | | Scores converted, avergd and normalised-categorised into no,mild,mild CI+otherdiag, AD and AD+diag | at 7 increments from 20/40 or better to 20/400 or worse | Pearson and spearmann correlation coeff to assess relationship btwn GCS and VA | | |
| Elliott *et al*[30] | US | Cross-sectional | 382 | Range: 60 to<=100 | No Impairmnt 26.8/73.2 | Vision | MMSE | Acuity- Lighthouse near VA test | Multiple linear regression used to estimate assoc btwn vision and cognition | VI affected HRQoL both with and without CI | Moderate |
| 2009 | | | | | VI only 5.9%/94.1% | | | | NHVQoL, mean: No VI+CI=72.8, VI only=75.2, CI only=76.5, VI+CI=65.2. p=0.02 | | |
| | | | | | CI only 16.7%/83.3% | | | | | | |
| | | | | | VI+CI: 20.4%/79.6% | | | | | | |
| Feeney *et al*[32] | Ireland (The Irish Longitudinal Study on Ageing) | Cross-sectional cohort | 4453 | fourth quartile 62.8 | 42.5/57.5 | Cognition | MMSE, MoCA, Neuropsyh battery, CAPI for word-recall, CAMDEX-R for picture memory | Acuity:ETDRS, MPOD measured using Macular metrics densitometer | Multivariate regression to analyse assoc btwn Cog test performance and MPOD(continuous variable) | Lower MPOD associated with poorer performance in MMSE & MoCA | Moderate |
| 2013 | | | | third quartile 62.4 | 46.3/53.7 | | | Pt was asked if diagnosed with ARMD and Diabetes | MMSE: b=0.48 (0.06, 0.90) p=0.026, MoCA: b=0.83 (0.15, 1.50) p=0.016, Memory: OR=2.24 (1.2, 4.15)p0.01 | | |
| | | | | second quartile 62.2 | 53.9/46.1 | | | | | | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | first quartile 62.3 | 53.8/46.2 | | | | | | |
| Formiga *et al*[36] | Spain (NonaSantfeliu population-based study) | Cross-sectional design | 186 | 93.06 | 23.5/76.5 | Cognition | MEC (Spanish version of the MMSE), Functional status: Lawton-Brody Index (LI) and Barthel Index (BI) | Acuity: Snellen Eye test | T-test and chi-square test. MEC (±SD): group with visual deficit:16.5±11, w/o visual deficit:23.6±11, p<0.001 | Functional status and cognition significantly asso with sensory | Moderate |
| 2006 | | | | | | | | | Lower LI was asso with: VI OR=1.86 (1.44, 2.39) and combined impairment OR=1.995 (1.32, 3.01) | Impairment | |
| Friedman *et al*[37] | US (The Salisbury Eye Evaluation in Nursing Home | Cross-sectional | 656 | 83.4 | 25/75 | Vision | MMSE | ETDRS charts or Lea symbols and grating acuity tests using Teller cards | Bland-Altman plot to measure how strongly grating acuity and recognition acuity relate to one another. | Grating acuity testing appears to be useful in | Moderate |
| 2002 | Groups (SEEING)) | | | | | | | | MMSE (5-point decline)with Teller acuity cards: OR=2.67 (2.14, 3.31). Teller and recognition ICC=0.79 | cognitively impaired individuals | |
| Frost *et al*[38] | Australia (Australian Imaging Biomarkers and Lifestyle | Cross-sectional case control | 123 | AD 70.2 | 59.1/40.9 | Vision (ARMD) | MMSE and PET scan | Digital, non-stereoscopic retinal colour photographs, both eyes with a | Logistic regression: Medium Drusen:(N (%)): CN: 13 (13), AD: 9 (41), OR: 4.69 (1.67–13.13) | A logistic model for early AMD found a | Moderate |
| 2016 | study of ageing (AIBL)) | | | CN 71.3 | 39.6/60.4 | | | Canon CR-1 Non-Mydriatic retinal camera with digital Canon camera at the back | Early AMD:(N (%)): CN: 3 (3.0), AD: 8 (36), OR: 18.67 (4.42–78.80) | significant association with AD diagnosis (p<0.0001) | |
| | | | | | | | | Grader (masked) evaluated images for signs of ARMD | | | |
| Fuller *et al*[39] | US (The American Community Survey (ACS)) | Cross-sectional survey data | 7210535 | 61.31 | 47.1/52.9 | Cognition | Self-report: Because of a physical, mental or emotional condition, does this person have difficulty | Self report: serious visual impairment- is this person blind or does | Cog Imp: NSI reference group, SHI: 45-64y: 3.55–3.67, 65-79y: 2.86–2.95, 80y+: 1.81–1.86, SVI alone: 45-64y: | Cognitive difficulty greatly associated with sensory impairment when | Moderate |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2018 | | | | | | | concentrating, remembering or making decisions? Yes/No | he/she have serious difficulty seeing even when wearing glasses?yes/no | 4.42–4.57, 65-79y: 4.71–4.91, 80y+: 2.33–2.44, DSI: 45-64y: 12.03–13.77, 65-79y: 11.19–12.84, 80y+:4.69–5.35 | compared with NSI, esp greatest with SVI alone. | |
| Garin *et al*[40] | Spain (COURAGE) | Cross-sectional cohort | 50–64: 1760 | 57 | 47.7/52.3 | Vision | Global standardised score from five performance tests: learning and short-term mem, attention & working | Obj: Snellen, Subjective: two questions to the participant, 1. how much | Asso btwn poor VA and Cognition (OR): Dist VA: 1.47 (1.17–1.86), Near VA: 1.72 (1.46–2.02) | Objective and subjective poor distance and near VA | Moderate |
| 2014 | | | >65: 1865 | 74.9 | 44.95/55.05 | | mem and language. Lower score indicates worse cognitive functioning | diffculty seeing object or recognising at 20 m 2. at arm's length | Subjective distance VA: 2.05 (1.44–2.90), Subjective near VA: 2.96 (1.92–4.55) | were associated with worse cognitive functioning. | |
| Gaynes *et al*[41] | US (Rush memory and ageing project (1997–2007)) | Cross-sectional cohort | 714 | VI present: 82 | 26.1/73.9 | Cognition | Global cog fn summary contructed from 19 neuropsychological tests that assessed episodic, semantic, | Near VA: Rosenbaum Pocket Vision Screener positioned 14 inches from | X2 test, pooled t-test for equal variance. Divided analytic cohort into VI present and VI not present. Linear reg | Each unit higher in neuroticism level worsened association | Moderate |
| 2014 | | | | VI not present: 78.8 | 23.6/76.4 | | working memory, perceptual speed and visuospatial ability. Raw scores converted to Z-scores & averag | the eye. VI was defined as BCVA<20/40 | Global cog fn: VI b=−0.147, SE=0.086, p=0.09, Neuroticism b=−0.001, p=0.04, VIxNeurot b=−0.017, SE=0.005, p0.001 | between vision impairment and lower global cognitive func | |
| Guthrie *et al*[42] | Canada (Resident Assessment Instrument for Home Care) | Cross-sectional study | Home care: 291824 | 82.8 | 38.9/61.1 | Physical, social and emotional | Cognitive Performance Scale (CPS) which has four terms pertaining to short-term memory, independence | Data from RAI-HC, particpants interviewed on the use of glasses | HC: CI+VI highest rate of procedural mem problems (56.1%) and highest prevalence of depression (28.2%) | CI+DSI had highest rate of functional impairments, communication | Moderate |
| 2018 | (RAI-HC) | | Longterm care: 110578 | 86.9 | 30.5/69.5 | functioning | in eating, expressive communication and decision making. Scale of 0–6, intact to very severe impairmnt | 0 adequate Vn and four severely impaired(can see only lights and colours) | LTC: All three impairments showed highest rates on indicators of delirium. | problems and difficulty understanding others | |
| Hoferl[44] | Nordic Research on Ageing Study (NORA) | Cross-sectional study | 1041 | 75 y | 42.7/57.3 | Cognition, Vision | WAIS-R- Digit Symbol test, Raven's Progressive Matrices- test of inductive reasoning, | Acuity: Computerised refractometer (Topcon RMA2300). | Of the correlations with the set of cognitive variables, the highest correlations were with corrected vision | no consistent associations were found across sensory, balance, | Moderate |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | | | | | | | Word Fluency Task,The Digit Span Forward and Backward test, Reaction time to vis/audi stimuli | Composite scores derived using avg of right and left vision scores | between .20 and .40 (visual choice reaction time), with the highest asso on visuomotor performance tests. | strength, and cognitive domains. | |
| Jefferis *et al*[45] | UK (Newcastle 85+Cohort study) | Cross-sectional study | 839 | Diag cataract: 85.5 | 30/70 | Cognition | Standardised MMSE, Mmblind (blind version) | Review of family practice records, any pre-existing diagnosis of glauco, | Diagnosed Glau: 1.76 (1.05, 2.95), Diagnosed Glau or drops: 1.73 (1.05, 2.85) | Association between recorded glaucoma diagnosis and cognitive | Moderate |
| 2013 | | | | Diag Glaucoma: 85.4 | 36/64 | | | cataract, cataract surgery (uni/ or bilateral) sight impaired registration | | scores and record of previous cataract surgery & better cognition | |
| Luo *et al*[48] | China (Second National Sample Survey on Disability) | Cross-sectional study | 250752 | Total: 72.9 | 47.5/52.5 | Cognition | Dementia ascertained using combo of self-report/family member report and on-site psychiatrist eval | Acuity: Trained Ophthalmologist assessed VI according to WHO BCVA | Dementia: Only VI- 1.54 (1.27–1.86), p<0.001, Only HI- 1.04 (0.88–1.22), DSI- 1.63 (1.25–2.11), p<0.001 | VI & DSI were more likely to have severe to extremely severe | Moderate |
| 2018 | | | | With dementia: 77.2 | 38.6/61.4 | | Questionnaire tested: poor memory, diff concentrating, diff controlling emotions, strange language/beha | criteria (low vision: 0.05≤BCVA ≤ 0.29; blindness: no light perception | | dementia than those without sensory impairment. | |
| | | | | | | | Positive on any one- then tyested by psychiatrist. Disablity diagnosis based on WHO DASII (score>52) | ≤BCVA < 0.05, VF less than 10 degrees; the betterseeing eye) | | | |
| Rovner *et al*[52] | US (AMD Trial) | Cross-sectional study | 241 | 82.8 | 36.5/63.5 | Vision function | Animal Fluency Test-brief assessment of cognitive function relevant to the completion of daily activities | Acuity: BCVA using ETDRS chart, NEI-VFQ near vision subscale | Predictors of Visual function: VA b=−1.93(−2.59 to −1.27),<0.001, Animal fluency b=0.054 (0.019 to 0.090), .003 | Visual ability was highly correlated with VA. Multivariate | Moderate |
| 2011 | | | | Range 65 and older | | | Name as many animals as possible in 60 secs. Requires semantic knowledge, speed mental processing | CS using Pelli-Robson chart | CS b=0.20 (−0.210 to 0.610), .33, PHQ-9 severity: −0.032 (−0.100 to 0.035), .35, Age b= −0.008 (−0.033 to 0.016) | model revealed coping startegies and cog fn contributed to Near Vn | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Spierer *et al*[54] | US | Cross-sectional study | 190 | 81.6 | 30.5/69.5 | Cognition | MMSE for the visually impaired (removed eight items from the original MMSE) max score of 22 | Corrected near VA was tested using the Jaeger chart. Refraction using | Asso VA & High MMSE blind score: Bad near VA (>J3): 1.0, good near VA (<J3); OR=3.18 (1.57–6.43) p0.001 | Good VA and Wearing reading glasses were significantly associated | Moderate |
| 2016 | | | | Range 75–101 | | | | Autorefractometer | | with high MMSE-blind score | |
| Varin *et al*[55] | Canada | Cross-sectional case-cohort | 303 | AMD 83.6 | 30.2/69.8 | Total cognitive activities | Victoria Activity Questionnaire, which is a 70-item survey assessing older adults' participation in various | Acuity: ETDRS chart, VF: Humphrey frequency doubling | Total cognitive activities: Normal vision b=0 (ref), AMD: −4.19 (−5.96,−2.43) *p<0.05. | Patients with AMD and glaucoma participated in fewer cognitive | Moderate |
| 2017 | | | | Glaucoma 77.5 | 40.9/59.1 | | cognitive activities over the past 2 years. Ex. Gardening, exercise,prep meals, doing housework,etc | technology full-threshold N-30 testing each eye. Medical chart reviewed | Glaucoma: −1.80 (−3.34,−0.26) *p<0.05. | activities compared with older adults with normal vision potentially | |
| | | | | Normal 72.8 | 48.3/51.7 | | Cognition was tested with the MMSE-blind version | for diagnosis of AMD and any co-existing eye disease | | putting them at risk for cognitive impairment | |
| Gussekloo *et al*[57] | Netherland (Leiden 85+study) | Cross-sectional cohort | 459 | 85 | 34/66 | Cognition | MMSE, The 12-Word Learning Test was used as a visual test of long-term memory. Cognitive speed | Acuity: ETDRS chart | MMSE and VI: beta=−1.2 (-1.6 to -0.84), Immediate word-learning test beta=−1.3 (-1.8 to -0.69) | VI was associated with lower MMSE scores. Increasing VI was asso with | Moderate |
| 2005 | | | | | | | was measured with the Letter Digit Coding Test (processing speed) | | Delayed word-learning test beta=−0.62 (-0.9 to -0.35), Letter digit coding test beta=−2.1 (-2.8 to -1.4) | woth poorer scored on memory and cog speed. | |
| | | | | | | | | | Stroop test beta=4.7 (1.1 to 8.4) | | |
| Hajek *et al*[58] | Germany (German Study on Ageing, Cognition and Dementia in Primary Care Patients) | Longitudinal cohort | 2394 | 82.5 | 34.2/65.8 | Cognition | Cognitive activities included reading, writing, solving crossword puzzles, memory training, games | Patient graded their vision on three level Likert scale | Onset of mild visual impairment: beta (SE)=−0.065 (0.026) | Linear fixed-effects regression showed that the onset of severe | Moderate |
| 2016 | | | | | | | (eg, card games, board games), playing music, and social engagement (eg, in church, volunteering, in a club) | (with optical aid if necessary) as no impairment, mild, severe or profound VI | Onset of severe or profound visual impairment: beta (SE)=−0.376 (0.062) | VI was associated with a decline in physical & cognitive function score in the total sample | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hidalgo *et al*[59] | Spain | Cross-sectional cohort | 1160 | 73.3 | 44.1/55.9 | Vision | Short portable Mental Status questionnaire | Acuity: Essilor visiotest instrument with snellen optotypes | VA <6/18 in the better eye −0.344 (−0.392 to −0.295), Self-reported vision: average/poor/very poor | Using multiple regression analysis, the variables associated with VF status | Moderate |
| 2009 | | | | | | | | Self reported vision as very good, good, average, poor and very poor. | −0.077 (−0.101 to −0.054), Dependence in activities of daily living: −0.121 (−0.160 to −0.081), Cognitive impairment −0.073 (−0.117 to −0.029) | were: visual impairment, self-reported poor vision, dependence in daily activities, cognitive | |
| | | | | | | | | | | impairment, depressive symptoms, female gender and older age | |
| Pham TQ *et al*[63] | Australia (The Blue Mountains Eye Study) | Cross-sectional case control | 3509 | Late AMD: 79 | 34/66 | Cognition | Modified MMSE: omitted vision-dependent items, with a max score of 22. | Acuity: LogMAR chart, Macula photo using Zeiss FF3 fundus camera | OR for MMSE 24–27 and: NO AMD 1, Late AMD 2.3 (1.1–5.0), Early AMD 1.0 (0.7–1.4) | Significant association found between Late AMD and cognitive impairment | Moderate |
| 2006 | | | | Early AMD: 75.1 | 38.1/61.9 | | | Amd lesions were assesed from the photos based on Wisconsin AMD grading system | For MMSE 0–23 and: NO AMD 1, Late AMD3.7 (1.3–10.6), Early AMD 1.4 (0.8–2.6) | | |
| | | | | No AMD: 65.7 | 43.7/56.3 | | | | | | |
| Uhlmann *et al*[64] | US | Cross-sectional case control | 174 | 77 | 42/58 | Cognition | MMSE | Acuity: was measured with the Snellen and Rosenbaum methods for far and near vision. | Relative Odds for Dementia of Far-vision Impairment: 1.9 (95% CI=0.8–4.6), RR of dementia and near Vn: | Visual impairment is associated with both an increased | Moderate |
| 1991 | | | | | | | | | 20/100-20/200 1.5 (0.5–4.7),>=20/200 1.8 (0.5–6.1), RR of dementia and far Vn: 20/70-20/100 1.5 (0.3–6.1), | risk and an increased clinical severity of Alzheimer's disease | |
| | | | | | | | | | >=20/200 1.5 (0.3–6.0) | Consistent with the hypotheses that VI excerbates Cog dysfucntion in dementia | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Guthrie *et al*[65] | four countries | Cross-sectional | Canada: Comparison: 138 650, DSI 48 210 | NA | F 67.2, 67.9 | Cognition | CPS, captures issues with memory, independence in eating and decision-making | inter RAI assessment inlcudes items measuring the presence of impairments | individuals with DSI were more likely than all others to have moderate to severe cognitive impairment (between 3.8% and 9.0% higher rate), | Yes. DSI significantly associated with CI | Moderate |
| 2016 | | | US: comparison 60 971, DSI 6577 | | F 66.8, 68.6 | | (Established validity against MMSE) | in vision. The vision item captures the person's ability to see close objects in adequate light while using their typical assistive device. Scored on a five-point scale where 0=adequate, 1=impaired, 2=moderately impaired, 3=highly impaired and 4=severely impaired | highly compromised independence with ADLs (5.2% to 11.4% higher), instrumental ADLs (8.8% to 21.4% higher). Those with DSI were not more likely to experience social isolation | | |
| | | | Belgium: comparison 500, DSI 256 | | F 74.9, 78.9 | | | | | | |
| | | | Finland: comparison 4765 DSI 1358 | | F 70.9, 76.2 | | | | | | |
| Harrabi *et al*[66] | Canada | Cross-sectional cohort | 420 | AMD 82.5 | 25/75 | Cognition | MMSE | Acuity: ETDRS chart with illuminated light box at 2 m, at 1 m if patient could | Model 1*: Binocular Logmar acuity, per 0.1 unit, –0.11 (-0.18,–0.04), | People with AMD, Fuch's corneal dystrophy, and glaucoma had lower cognitive | Moderate |
| 2015 | | | | Fuch's 78.5 | 17/83 | | | not see at 2 m. Letter by letter scoring done, converted to logMAR | Model 2*: Log CS, per 0.1 unit, 1.40, (0.72, 2.13) | scores, on average, than controls ($p<0.05$). | |
| | | | | Glaucoma 76.6 | 42/58 | | | CS measured using Pelli-Robinson chart 1 m | Model 3*: VF in better eye, per 1 dB, 0.04, (-0.003, 0.08) | Scores were between 0.7 and 0.8 units lower than the control group | |
| | | | | Control 74.0 | 41/59 | | | VF: Humphrey frequency doubling technology (FDT) | | | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Holmen *et al*[68] | Sweden (Kungsholmen project) | Case-control | Cog imapired 55 | 82 | | Loneliness, but measured interaction between | MMSE | Acuity: Snellen, self-report questions: Do you have any problems with your sight? Yes or No" was used to assess the problems | There were no significant differences in the cognitive groups between subjects with slight to moderate | NO. In a multiple regression analysis, higher MMSE score and visual improvement were significantly related to lower levels of self-reported loneliness among the elderly with their cognition intact, but not | Moderate |
| 1994 | | | Cog intact 92 | 83 | | Cognition & vision | | | habitual VA (ie, those who could read newspapers with glasses and visually orient themselves | among the subjects with impaired cognition. | |
| | | | | | | | | | without difficulty), and subjects with pronounced to severe visual impairment with residual vision (x2=2.28, p=0.13). The same differences were found | | |
| | | | | | | | | | when corrected VA was compared analytically between the cognitive groups (x2=1.15, p=0.28) | | |
| Su *et al*[69] | Taiwan (Taiwan National Health Insurance programme) | Cross-sectional cohort | Glaucoma 6509 | 59.4 | 45.5/56.5 | Cognition | Dementia patients enrolled using ICD codes | Glaucoma cohort formed enrolling patients who were newly diagnosed with it | HR=1.13 (1.01–1.27) | The patients with glaucoma exhibited a significantly higher risk of | Moderate |
| 2016 | | | Control 26 036 | 59.2 | 42.4/54.6 | | | | | dementia than the individuals without glaucoma did (HR | |
| | | | | | | | | | | (HR)¼1.13, 95% CI (CI)¼1.01–1.27) | |
| Miyata *et al*[71] | Japan (Fujiwara-kyo Study) | Cross-sectional cohort | 2764 | 76.3 | 52.6/47.4 | Cognition | MMSE | Acuity, Landolt ring chart at 5 m, converted to logMAR. refractive errors were measured by an autoref/keratometer | OR for MCI: no cataract surgery 1.00 (ref) / cataract surgery 0.79 (0.64–0.97) p 0.025 | The subjects who had prior cataract surgery had significantly lower OR of having MCI | Moderate |
| 2018 | | | | | | | | A prior cataract surgery was determined by the selfadministered questionnaire | OR for dementia: no cataract surgery 1.00 (ref) / cataract surgery 1.20 (0.64–0.97) p 0.36 | Cataract surgery may be important in reducing the risk of developing MCI but not for dementia independently | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ong *et al*[72] | Singapore (Singapore Malay Eye Study (SiMES)) | Cross-sectional cohort | 1032 | Cognitive dysfunction 70.5 | 24/76 | Cognition | Abbreviated Mental Test (AMT) | Acuity: number chart at a distance of 4 m converted to logMAR. VI logMAR>0.3 in the better eye | Cog Dysfunction OR: Model 2 :Myopia 1.78 (1.02–3.10) Hyperopia 1.11 (0.68–1.80) Emmetropia 1.0 | Yes. Compared with individuals with emmetropia, persons with myopia were | Moderate |
| 2013 | | | | No Cog dysfunction 67.7 | 66.5/33.5 | | [cognitive dysfunction was defined as a score less than or equal to 6 of 10 for those with 0 to 6 years of formal education | | Model 3 : Myopia 1.86 (1.01–3.42) Hyperopia 0.92 (0.54–1.55) Emmetropia 1.0 | almost twice as likely to have cognitive dysfunction | |
| | | | | | | | and less than or equal to 8 of 10 for those with more than 6 years of formal education.] | | | | |
| Soler *et al*[73] | France | Cross-sectional cohort | 1648 | 82.6 | 35.6/64.4 | Vision | MMSE | Acuity. Snellen decimal chart for distant vision, Parinaud chart for near vision | model one for distant vision: MMSE OR (CI) 0.94 (0.92–0.97) p<0.001 | Yes. Results show that visual impairment is independently associated | Moderate |
| 2016 | | | | | | | ADL, IADL, Fried score, SPPB class (Short Physical Performance Battery), | Amsler grid testing | model two for near vision: MMSE OR (CI) 0.92 (0.89–0.94) p<0.001 | with lower educational level, cognitive impairment, and lower ADL-assessed autonomy | |
| Sun *et al*[74] | China | Cross-sectional cohort | 4123 | 67.5 | 48.8/51.2 | Cognition | AMT | Objective refraction was measured using an autorefractor (Canon RK-5) | OR of cog dysfunction for myopia: Before propensity score matching, OR 1.98 (1.61–2.44) | Results of this PSM analysis support a small, but positive association of | Moderate |
| 2016 | | | | | | | | Spherical equivalent (SE) (Myopia: a SE of less than −0.50 dioptre (D) in the right eye. High myopia: a SE of less than −6.00 D.) | After matching: OR 1.31 (1.00–1.71). Multivariate logistic regression | myopia with cognitive dysfunction among elderly Chinese in China | |
| | | | | | | | | | model on the association between myopia and cognitive dysfunction, OR (95% CI): | | |
| | | | | | | | | | Myopia (Yes vs No) 1.52 (1.23–2.06), Age-related cataract (Yes vs No) 2.06 (1.57–2.98) | | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Zheng *et al*[75] | US (The Salisbury Eye Evaluation Study) | Longitudinal cohort | 2520 | 73.5 | 42/58 | Cognition | MMSE | Acuity. ETDRS chart refraction was performed on participantswith | Worse baseline VA was associated with worse baseline MMSE score | Worse baseline VA was associated with worse baseline MMSE score | Moderate |
| 2018 | | | | | | | | 20/32 VA orworse using a forced-choice procedure. | (r = –0.226; 95% CI, –0.291 to –0.16; p<0.001). The rate of worsening VA was associated with | The rate of worsening VA was associated with a significant | |
| | | | | | | | | Presenting binocular distanceVAwas converted to logMAR with a higher score indicating worse VA. | the rate of declining MMSE score (r = –0.139; 95% CI, –0.261 to –0.017; p=0.03). | the rate of declining MMSE score | |
| Ward *et al*[76] | US (Study of Osteoporotic Fractures) | Longitudinal cohort | 1352 | 77.7 | 0/100 | Vision | Global cognition (3MS), verbal memory (California Verbal Learning Test II, short form (CVLT)), | CS, using a VISTECH (Hartford, CT) VCTS 6500 wall chart and light mete | OR of MCI/dementia for lowest quartile of baseline CS | These data support an association between impaired CS and future MCI/ dementia. | Moderate |
| 2018 | | | | | | | executive function (Trails B, Digit Span Forward, Digit Span Backward), and semantic memory (category and verbal fluency) | Self-reported AMD, glaucoma, and cataract | compared with women in the highest quartile: OR 2.16 (95% CI=1.58–2.96) | | |
| | | | | | | | Clinical adjudication if person was positive in the above tests. | | OR of MCI/dementia for every 10 point decrease in CS: | | |
| Mitoku K, Masaki N *et al*[78] | Japan (Gujo City Long-Term Care Insurance database) | Cross-sectional cohort | 1754 | 80.89/82.42 | 34.5/65.5 | Cognition | The assessment measures include communication, short-term memory, | Acuity: No chart name provided | Logistic regression: OR of CI was 1.389 (95% CI 1.04 to 1.85) in those with VI | Yes. Supports the relationship between DSI and CI, increased risk of mortality in thise with DSI & CI. | Moderate |
| 2016 | | | | | | | location awareness and understanding of daily tasks, remembering own name and date of birth, and recognising the | Other: Vision at baseline five levels, “normal sight”, “able to see chart at 1 m” | 1.581 (95 % CI 1.24 to 2.01) in those with HI, and 2.349 (95 % CI 1.79 to 3.09) in those with DSI | | |
| | | | | | | | season of year in addition to 18 problem behaviours | able to see chart in front, “very little sight”, “indeterminable” | | | |
| | | | | | | | CI classified as none, mild, moderate, severe | | | | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jefferis JM *et al*[79] | UK | Longitudinal, cohort | 112 | 80.7 | 45/55 | Cognition | The ACE-R (which includes the MMSE), is scored from 0 (worst cognition) to 100 (best cognition); | logMAR VA in the better eye corrected with up-to-date refraction and/or pinhole | Group, Mean±SD:Baseline, Postop, 1 Year. P Value*: 3-Way†, Baseline vs Postop, Baseline vs 1 Year, Postop vs 1 Year | Significant improvements in ACE-R scores were seen between baseline and 1 year | Moderate |
| 2015 | | | | | | | 38 of these points pertain to vision-dependent items and 62 to vision-independent items | | Normal (n=46): 92.5±2.8, 92.6±3.8, 93.7±3.4, 0.018, 0.9, 0.009, 0.004::: Mildly impaired cognition (n=22): 84.5±1.4, 84.8±4.3, 88.0±3.5,<0.001, 0.75,<0.001 0.002 | postoperatively (95% CI for improvement, 0.5–2.8; P Z .005). Improved | |
| | | | | | | | | | Moderately impaired cognition (n=23): 72.6±8.7, 73.6±10.4, 73.3±14.4, 0.75, --, --,-- | cognition did not correlate with improved VA (r Z 0.13, P Z .22) | |
| | | | | | | | | | All participants (n=91): 85.6±9.5, 85.9±10.0, 87.2±11.4, 0.004, 0.45, 0.005, 0.006, *p<0.05 statistically significant | | |
| Lindenberger *et al*[81] | Germany (BASE (Berlin Ageing Study)) | Longitudinal, cohort | 516 | 85 | NA | Cognition | MMSE | Acuity: Snellen decimal units. Close VA (close vision) was measured separately for the left and the right eye with a standard reading table presented at reading distance. Distance VA (distant vision) was assessed binocularly with a reading table presented to the participants at a minimum distance of 2.5 metres | Multivariate Multilevel Modelling Results With Control for Age, Time to Death, and Risk of Dementia Construct, Mean (Level, Linear change, Quadratic change), Variance (Level, Linear change), Age, Dementia status, Age X Linear Change, Residual variance. | Contrary to expectations, the correlations between cognitive and sensory declines were only moderate in size, underscoring the need to delineate both domain-general and function-specific mechanisms ofbehavioral when controlling for age at first measurement, distance to death, and risk of dementia senescence | Moderate |
| 2009 | | | | | | | | | Close vision: 47.33 (0.30),–1.37 (0.11), ---, 34.17 (2.95), 0.83 (0.16),–0.44 (0.04), ---, –0.03 (0.01), 25.87 (1.42) | | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Distant vision: 48.47 (0.32),–0.56 (0.11), ---, 28.14 (3.17), 1.20 (0.25),–0.59 (0.04), ---, ---, 44.79 (2.45) | | |
| Hong *et al*[82] | Australia (Blue Mountain Eye Study) | Longitudinal, cohort | 2334 | No Sensory impairment 66.9 (7.4), | No SI 58.4/41.6 | Cognition | MMSE | Acuity: Distance VA at 244 cm followed by pinhole acuity (VA was recorded as the number of letters read correctly) If no letters could be read count fingers, hand movements, light perception, or no light perception | association between Decline>=3 MMSE blind score and visual impairment (adjusted for age and sex). OR after 5 years: Visual impairment 0.84 95% CI 0.40 to 1.79 DSI 1.41 95% CI 0.54 to 3.72 after 10 years: Visual impairment 1.09 95% CI 0.52 to 2.30 DSI 1.15 95% CI 0.28 to 4.73 | No.The presence of VI, HL or DSI was not associated with possible cognitive decline over 5 years or 10 years. | Moderate |
| 2016 | | | | Visual impairment 74.3 (8.4), | VI 65.8/34.2 | | | | | There were no changes to these findings after adjustment for other potential confounder | |
| | | | | Dual impairment 80.4 (7.0) | Dual impairment 57/43 | | | | | | |
| | | | | | | | | | | | Moderate |
| Mandas *et al*[85] | Italy | Case-Control | 1168 | 78.4 | 29/71 | Cognition | MMSE | Acuity: Snellen Chart | Total(n=1168), Control1 (n=436), All types of dementia (n=732), MCI (n=181), AD (n=230), MD (n=126), VD (n=195) | | |
| 2014 | | | | | | | | IOP, fundus examination under slit-lamp and fundu photograph | All vision disorders: No, n=297, n=433, n=117, n=135, n=68, n=113 yes, n=139, n=299, n=64, n=95, n=58, n=82 $\chi 2$, 9.37, 0.70, 5.87, 8.60,6.12 P-value, 0.002, 0.40, 0.015,0.003, 0.013 OD (95% CI), 1.5 (1.1–1.9), 1.2 (0.8–1.7), 1.5 (1.1–2.1), 1.8 (1.2–2.7), 1.5 (1.1–2.2) | Subjects with any type of age-related vision disorders(n D438), cataract, | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Macular degeneration, glaucoma, and diabetic retinopathy,were more likely be depressed | |
| | | | | | | | | | | and had significantly lower MMSE scores than Control 2 | |
| Mendola *et al*[86] | US | Case-Control | 188 | NA | NA | Vision | Blessed Dementia Scale (BDS) | Acuity: Snellen, CS: two-alternative forced-choice format, | Test, Prevalence in AD, Correlation with BDS, % variance from BDS. | The results indicate that visual dysfunction, especially on Backward Masking, is a common sign of AD. | Moderate |
| 1995 | | | | | | | | Stereopsis: binocular disparity stereopsis, as a clue to depth perception(Stereo Optical) | Backward Pattern Masking: 58% r=0.22; p=0.106; df=55, 13%, Gollin Incomplete Pictures: 30%, r=0.33; p=0.03; df=17, 6% | | |
| | | | | | | | | funduscopy, evaluation of fixation, pupillary function, extraocular movement, | Luria Mental Rotation: 39%, rb=0.74; p=0.004; df=36, 13% | | |
| | | | | | | | | Backward Masking. Gollin Incomplete Pictures. City University Colour Vision. | Log CS at one cpd: 39%, rb=0.69; p=0.002; df=17, 52%, Log CS at 2cpd: 6%, rb=0.55; p=0.022; df=17, 7% | | |
| | | | | | | | | Luria Mental Rotation. Moeny Road Map. Local speed discrimination and Global motion detection. Critical Flicker fusion. | Money Road Map: 29%, rb=0.37; p=0.028 ; df=35, 17% | | |
| Magalhães *et al*[88] | Brazil | Cross-sectional cohort | 466 | 71.4 | 44.4/55.6 | Cognition | Cambridge Cognitive Examination (CAMCOG) | Self-report | logistic regression model for dementia: | Yes. Study showed strong association between dementia and sight-impairment | Moderate |
| 2008 | | | | | | | Dementia was diagnosed in individuals who fulfilled CAMDEX criteria for definitive, probable or possible dementia through a combination of clinical criteria, organicity indices ≥5 and CAMCoG <80. | | sight impairment OR (95% CI): 1.83 (1.15–2.91) | | |

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**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Pvalue 0.011 | | |
| Ong *et al*[89] | Singapore (SiMES) | Cross-sectional cohort | 1179 | with cognitive dysfunction: 71.2 | 21/79 | Cognition | The AMT is a 10-question test of general cognitive function | Acuity: LogMAR number chart (lighthouse international) | Age-related eye disease, model 1, model 2, model 3. | | Moderate |
| 2012 | | | | Without cognitive dysfunction: 68.0 | 67.7/33.3 | | Items assess orientation (three points), semantic knowledge (1point), episodic memory (three points), delayed recall | Cataracts were assessed from lens photographs, Glaucoma diagnosed and classified using International Society Geographical and Epidemiological Ophthalmology scheme based on gonioscopy | Cataract: 1.52 (1.02–2.27), 1.42 (0.93–2.16), 1.44 (0.94–2.22), AMD: 1.71 (0.89–3.29), 1.44 (0.71–2.91), 1.36 (0.34–5.45) | Yes. VI due to cataract (OR=2.75; 95% CI, 1.35 to 5.63) | |
| | | | | | | | (one point), picture naming (one point), and attention (one point) | | Moderate or severe DR: 2.43 (1.13–5.20), 2.26 (1.02–5.00), 5.57 (1.56–19.91) | were more likely to have cognitive dysfunction. Only moderate to severe diabetic retinopathy was independently associated with cognitive dysfunction | |
| | | | | | | | | | Glaucoma: 1.68 (0.81–3.46), 1.61 (0.75–3.45), 2.09 (0.52–8.31) | | |
| Mangione *et al*[90] | US | Cross-sectional cohort | 472 | 73 | 40/60 | Cognition | TICS questionnaire | Acuity: Snellen (results were transformed into percentages of functional central | multivariate linear regression, percent increase in ODDS of abnormal TICS score (95% CI): | | Moderate |
| 1993 | | | | | | | | vision loss following the formula outlined in the Physician's Desk Reference for Ophthalmology) | binocular vision loss(per 10% decline in vision) −9 (−23,9), percent field loss (per one category decline) 13 (-13,48) cataract (per eye) 18 (-12,58) ocular miotics 37 (-17,126) | No. An association between low TICS score and visual disorders were not seen | |
| | | | | | | | | VF: Humphrey field analyser | | | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wittich *et al*[93] | Canada (COMPASS-ND study) | Longitudinal, cohort | 109 | 72.94 | No info | Cognition | MoCA | Reading acuity (MNRead) and CS (Mars Test) | Individuals with AD had significantly lower CS than those with MCI and SCI (p=0.04, ω2=0.04;), after adjusting for age, sex and education. No differences in VA were observed p=0.46, ω2=0.004. | Yes. Declines seen in CS in individuals with AD relative to those with MCI and SCI. | Moderate |
| 2019 | | | | | | | | | | Study also observed higher rates of reduced reading acuity in the AD and MCI groups relative to those reported the general population. | |
| Brenowitz *et al*[94] | US (Health ABC Study) | Longitudinal, cohort | 1810 | 76.7 | 39.4/60/6 | Cognition | Dementia was defined as meeting one or more of the following criteria through study | Bailey-Lovie distance VA test, Pelli-Robson CS | Multivariable model for incident dementia with VA: HR=1.26 (0.90–1.77), CS: HR=1.11 (0.88–1.38) | No. Vision impairment and CS independently was not significantly associated with incident dementia | Moderate |
| 2019 | | | | | | | Year 15 (2011–2012):(a) hospitalisation with dementia as a primary or secondary diagnosis, | | | | |
| | | | | | | | (b) documented use of dementia medication, or (c) clinically meaningful Modified MMSE (3MS) | | | | |
| | | | | | | | decline from Health ABC baseline (1.5 SD, race-stratified) | | | | |
| Davies-Kershaw *et al*[95] | UK (English Longitudinal Study of Ageing) | Longitudinal cohort | 7685 | NA | 44/56 | Cognition | three methods to identify individuals with dementia: a physician diagnosis of dementia | Rate their eyesight (using glasses or corrective lenses as usual) | Cross-sectional analysis using Wave seven measures adjusted for covariates: compared with normal VA, moderate OR=2.04 (1.36–3.07) | Yes. Older adults with vision impairment have higher rates of dementia crosssectionally (all ages) and are at greater risk of incident dementia longitudinally (<70 only) | Moderate |
| 2918 | Wave 7 | | | | | | that the participant or a caregiver reported between Wave 3 (2006–7) and 7 (2014–15); | as excellent, very good, good, fair, poor, or registered blind | poor OR=4.02 (2.64–6.13) p<0.001 | | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | a score less than 3.5 on the adaptive Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE) | Combined groups into three categories for analysis (excellent or very good=normal, | Longitudinal analysis using Wave two measures individuals in the younger group ([50–68]) and with moderate (HR=1.78, 95% CI=1.04–3.04) and poor (HR=3.60, 95%CI=1.10–11.78) selfrated vision were at greater risk of developing dementia than those with normal self-rated vision | | |
| | | | | | | | or prescriptions for anticholinesterase inhibitors, N-methyl-D-aspartic acid receptor antagonists, | good or fair=moderate, poor or registered or legally blind=poor or blind) | | | |
| | | | | | | | and other relevant medication (galantamine, rivastigmine, memantine, donepezil, tacrine) to indicate dementia | Self-rated vision measure from Wave 7 (2014–15) for cross-sectional analysis and from Wave 2 (2004–05) for the longitudinal analysis | | | |
| Gui-Ying Cao | China (China Health and Retirement Longitudinal Study) | Longitudinal, cohort | 7269 | 60.2 | 56.2/43.8 | Cognition | Episodic memory (measured as the average of immediate and delayed recall scores of ten Chinese nouns), | VI was assessed by two self-reported questions, about distance VA for seeing faces on the other side of the street | Compared with older people with no VI, (1) those with DVI only were associated with poor episodic memory (β=–0.076, p<0·0001) | Yes. VI is associated with an increased risk of poor cognitive function | Moderate |
| 2018 | | | | | | | mental intactness (measured using some components of the Telephone Interview of Cognitive Status (TICS) battery), | and about near VA for reading newspapers. Individuals were assigned to one of four categories: no VI, | mental intactness (β=–0.074, p<0·0001) and global cognition ((β=–0.089, p<0·0001) | | |
| | | | | | | | and global cognition (the sum of episodic memory and mental intactness scores)—was evaluated and followed up every 2 years | distance vision impairment (DVI), near vision impairment (NVI), or both distance and near vision impairment (DNVI) | Those with NVI only were associated with poor mental intactness (β=–0.031, p=0·0001) and global cognition (β=–0.032, p=0·0224) | | |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Those with DNVI were associated with poor episodic memory (β=–0.106, p<0·0001), mental intactness (β=–0.107, p<0·0001), global cognition (β=–0.105, p<0·0001) | | |
| Ali *et al* | US (Medicare Claims data from 2014) | Cross-sectional cohort | 472871 | >65 | 34/66 | Cognition | ICD-9 diagnosis codes for dementia or cognitive impairment | ICD-9 diagnosis codes for blindness/ low vision | Among the low vision/blindness group, the prevalence of dementia or CI was 50%. | Yes. There was a significant association between low vision/blindness and dementia or AD | Moderate |
| 2019 | | | | | | | | | Blindness/low vision was also associated with a greater odds of Alzheimer's disease (AOR 1.44 95% CI: 1.415 to 1.464) | | |
| | | | | | | | | | and all-cause dementia (AOR 1.239, 95% CI: 1.223 to 1.254) | | |
| Preeti Gupta *et al* | Singapore (Singapore Epidemiology of Eye Disease (SEED) Study) | Longitudinal, cohort | 682 | 67.3 | 55.6/44.4 | Cognition | CI was assessed using the validated AMT defined as scores of | Fundus images using Canon DGI camera, graded by trained graders at University of Sydney | Those with any DR had higher odds of incident CI (OR=2.32, 95% CI 1.07 to 5.03), and those with moderate or worse DR also had a higher likelihood of | Yes, DR, particularly at the more severe stages, is associated with | Moderate |
| 2019 | | | | | | | ≤6 and≤8 for those with 0–6 and>6 years of formal education, respectively | using the modified Airlie House classification system and categorised as none (Early Treatment of Diabetic Retinopathy Study (ETDRS) level 10), | developing CI (OR=3.41, 95% CI 1.06 to 11.00, p-trend=0.021), compared with those without DR | increased risk of developing CI, independent of vision and other risk factors | |
| | | | | | | | | minimal/mild (level 20–35) and moderate or worse DR, (level 43–90) using data from the better eye | | | |
| Jost *et al* | China (The Beijing Eye Study) | Cross-sectional cohort | 3127 | 64.2 | 43.4/56.6 | Cognition | MMSE, assessed as cognitive function score (cfs). Categorised as mild (cfs 23–19), moderate (cfs 18–10) | Autorefractometry, Presenting, uncorrected and best corrected VA, | Better cognition (ie, higher CFS) was signifcantly associated with better best corrected VA (r2=0.38), | Yes | Moderate |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2018 | | | | | | | severe (cfs<9) | fundus photo, SD-OCT | smaller amount of undercorrected VA, lower prevalence of primary angle-closure glaucoma, and | | |
| | | | | | | | | | thicker subfoveal choroidal thickness | | |
| Allen *et al* | China | Longitudinal, cohort | 15576 | 74.5 | 36.2/63.8 | Cognition | ICD-10 codes or Clinical dementia rating 1 to 3 | Acuity: Snellen E chart, converted to LogMAR | Participants with incident dementia had poorer VA at baseline than those without (adjusted HR=5.88, 95% CI=4.04–8.57). | Yes, Moderate-to-severe visual impairment could be a | Moderate |
| 2020 | | | | | | | | | Incident Dementia at years 4–6 of Follow-up in Participants With Mild (HR=1.19, 95% CI 0.86 to 1.65, p=0.31) | potential predictor and possibly a risk factor for dementia | |
| | | | | | | | | | Moderate (HR=2.09, 95% CI=1.47–2.97) or Severe VI (HR=8.66, 95% CI=4.60–16.30) at baseline | | |
| Cecilia *et al* | US (Adult Changes in Thought (ACT)) | Longitudinal, cohort | 3877 | NA | 42/58 | Cognition | Cognitive Abilities Screening Instrument scores 85 underwent a standardised diagnostic evaluation, including physical and neurologic examinations and a neuropsychological test battery | ICD-9 codes for diagnosis of gluacoma, AMD, DR and cataract | The recent and established HR were 1.46 (P 5.01) and 0.87 (P 5.19) for glaucoma, | Yes, Increased AD risk was found for recent glaucoma diagnoses, | Moderate |
| 2019 | | | | | | | Dementia diagnoses using NINCDS-ARDRA criteria, Our primary outcome was either probable or possible late-onset clinical AD | | 1.20 (P 5.12) and 1.50 (P,.001) for AMD, and 1.50 (P 5 .045) and 1.50 (P 5 .03) for DR | established AMD diagnoses, and both recent and established DR | |
| Moon Jeong Lee *et al* | US (National Health and Nutrition Examination Survey (1999–2006 cycles)) | Cross-sectional cohort | 5795 | Non-VI 70.3 | 45/55 | Cognition | Memory or confusion complaints were defined as present if participants responded “yes” to the question— | VA was assessed using the built-in chart in an auto-refractor (NIDEK ARK-760; Nidek Co Ltd, Tokyo, Japan) | Individuals with VI were more likely (OR=1.3, p=0.049) to report cognitive complaints as compared with those without VI | Yes | Moderate |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019 | | | | VI 77.8 | 39/61 | | "(Are you/is survey participant) limited in any way because of difficulty | VI was defined as autorefractor corrected VA worse than 20/40 in the better-seeing eye | | | |
| | | | | | | | remembering or because (you/s/he) experience(s) periods of confusion?" | | | | |
| Ruby Yu *et al* | China | Longitudinal, cohort | 1949 | 76.1 | 23.1/76.9 | Cognition | 5-item Abbreviated Memory Inventory for Chinese (AMIC). Scored range from 0 to 5 (1 point for each item; 0—best to 5—worse). An AMIC score≥3is predictive of MCI | Questionnaire: "Do you have any difficulty seeing things?""very good" and "good" = "robust"; "fair", "not too well", "poor", and "very poor" = "poor" | Poor vision (OR 2.2 95% CI 1.8 to 2.7) at baseline was significantly associated with an increased risk of at least 3 SMCs at follow-up | Yes | Moderate |
| 2019 | | | | | | | | | | | |
| Michio Maruta *et al* | Japan | Longitudinal cohort | 2190 | 78.9 | 20.6/79.4 | Cognition | Dementia Scale labelled Level 0 to Level IV and level M based on symptoms and the | VA assessed at five levels: normal vision (there is no hindrance in daily life),' 'able to see vision testing chart at a distance of about 1 m,' | DSI associated with a higher cumulative dementia incidence compared with no sensory impairment (log-rank $\chi 2=39.92$; $p<0.001$) | Yes. | Moderate |
| 2020 | | | | | | | necessity for care. Level II and greater during the 8 year follow-up period was considered | 'able to see vision testing chart at a distance of in front,' 'very poor eyesight,' | DSI is the greatest risk factor for developing dementia among sensory impairments (HR, 1.45; 95% CI, 1.22 to 1.71; $p<0.001$) | Older adults with sensory impairments have a high incidence of dementia, with DSI presenting the greatest risk | |
| | | | | | | | "incident dementia" | and 'undecidable due to difficulty in communication. | Older adults with VI were found to be more likely to have day-night reversal symptoms when dementia occurs | | |
| Ann *et al* | UK (English Longitudinal Study of Ageing) | Longitudinal cohort | 4621 | 64.9 | 45/55 | Cognition | Working memory, Executive function. Results from the three cognitive tests available were summed, | VA: Self-report asking participants whether their eyesight was excellent, very good, good, fair, or poor using glasses or corrective lens if they normally do so | Compared with people with good vision, poor vision was asso with worse cognitive function | Yes, ageing adults with individual and combined impairments in hearing and vision had greater risks of worse cognitive performance at 6 year follow-up compared with those with good sensory function | Moderate |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | | | | | | | providing a cognitive score (range 0–80), with a lower score indicating worse cognitive function | | B=1.61, 95% CI =(0.92, 2.29)adjusted for age, sex, baseline cognition | | |
| | | | | | | | | | Compared with no sensory impairment, DSI was associated with worse cognition (B=2.30, 95% CI =(1.21, 3.39) | | |
| Stephanie Chen *et al* | US (NHATS) | Longitudinal cohort | 7075 | NA | 40/60 | Cognition | 1. Doctor told the sample person that he/she had dementia or AD, 2. A score that indicates probable dementia on the AD8 Dementia Screening Interview | Self-reported distance and near VI | Participants with self-reported visual impairment were at significantly higher risk of developing | Yes, self-reported visual impairment in the US Medicare | Moderate |
| 2019 | | | | | | | 3. Cognitive tests that evaluate the sample person's memory and orientation | | probable or possible dementia over subsequent follow-up (HR=4.4, CI: 3.9 to 5.0, p<0.001), compared with those without visual impairment | population may be associated with greater risk of cognitive decline | |
| | | | | | | | | | This association persisted after full adjustments for covariates (HR=2.1, CI: 1.8 to 2.5, p<0.001) | | |
| Ali *et al* | US (Medicare beneficiaries) | Cross-sectional cohort | 773905 | NA | NA | Cognition | ICD-9 codes and procedure code-based algorithms | ICD-9 codes and procedure code-based algorithms | Low vision was associated with greater odds of incident hip fracture (AOR 1.13, 95% CI: 1.04 to 1.22 | No. | Moderate |
| 2019 | | | | | | | | | and incident anxiety (AOR 1.11, 95% CI: 1.05 to 1.18 but not incident depression or dementia. | | |
| Tien *et al* | Singapore (SEED) | Cross-sectional cohort | 10020 | 58.9 | 49.3/50.7 | Vision | AMT, which consists of 10 questions of general cognitive function | VA ETDRS chart at 4 m converted to LogMAR | For best-corrected bilateral visual loss, cognitive impairment (OR=2.07; 95% CI=1.60–2.68) | Yes | Moderate |

Continued

**Table 4** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019 | | | | | | | | | was a significantly associated risk factor. CI was also significantly associated with higher risk of presenting bilateral VI or blindness (OR=2.15; 95% CI=1.75–2.63) | | |
| Bonnielin Swenor *et al*[122] | US (Health ABC study) | Longitudinal cohort | 2444 | 74 | 47.8/52.2 | Cognition | DSST and 3 MS. Incident cognitive impairment was defined as | VA: Bailey-love chart, CS: Pelli-Robson chart | VA impairment HR=1.55, 95% CI 1.12, 2.14 vs No VA impairment, CS impairment HR=1.33 | Yes, VA, CS, and stereo acuity are | Moderate |
| 2019 | | | | | | | a 3 MS score<80 or a decline in 3MS>5 points following Year 3 | | 95% CI 1.13, 1.55 vs No CS impairment | risk factors for cognitive decline | |

ACE-R, Addenbrooke's Cognitive Examination-Revised; AMD, age-related macular degeneration; CS, contrast sensitivity; DSI, dual sensory impairment; MMSE, Mini-Mental State Examination; MoCA, Montreal-Cognitive Assessment; MPOD, macular pigment optical density; NHATS, National Health and Aging Trends Study; VA, visual acuity; VF, visual field.

concluded that VI was associated with both an increased risk and an increased clinical severity of AD. Although Frost *et al*[38] found a strong association between early age-related macular degeneration and AD, their study was cross-sectional, and the sample size was too low to derive an inference. Both these studies received 'moderate' rating in QA. Davies-Kershaw *et al*[95] in their longitudinal analysis using the ELSA wave 2 and wave 7 data found that individuals in the younger group (50–69 years) and with moderate and poor self-rated vision were at greater risk of developing dementia than those with normal self-rated vision. Hamedani *et al*[99] used Medicare claims data from 2014 consisting of 472 871 participants and concluded that blindness/low vision was associated with a greater odd of Alzheimer's disease and all-cause dementia. Both these studies also received 'moderate' rating in QA. Soto-Perez-de-Celis *et al62* in their cross-sectional study case–control study found that DSI was significantly associated with possible CI. However, the study received an overall 'weak' rating in QA.

Of the 91 studies that found an association between VI and cognitive function, 35 were longitudinal, 46 were cross-sectional and 10 were case–control studies. Of the 13 studies that found no association between VI and cognitive function, 6 were longitudinal, 5 were cross-sectional and 2 were case–control studies. Ihle *et al*[60] performed a cross-sectional analysis using a sample of 2812 participants from Switzerland. They objectively measured cognition and vision and concluded that their data did not support an increased relation of cognitive and sensory abilities in old age. This study received a 'weak' rating in QA. Hong *et al*[82] used data from Blue Mountain Eye Study, a longitudinal study from Australia that studied associations between VI and a decline in MMSE scores over a duration of 10 years. The study concluded that VI was not associated with cognitive decline over 5 years or 10 years. Although the study included a large number of participants overall (n=2334), only 152 individuals with VI were included in this analysis, suggesting that there may have been survival bias. Brenowitz *et al*[94] in their longitudinal study using the Health ABC data concluded that VA and CS independently were not significantly associated with incident dementia. However, Swenor *et al*[122] used data from the same study and found that impaired VA, CS and stereo acuity had a greater risk of incident cognitive impairment. This could be due to the different outcome measures assessed, that is, dementia[94] vs cognitive impairment.[122] These three studies received a 'moderate' rating in QA. Michalowsky *et al*,[117] who received a 'strong' rating in their case–control study concluded that VI was not significantly associated with dementia, a combination of both visual and hearing impairments was significantly associated with the risk of dementia.

There was considerable heterogeneity in the measurement and reporting of cognitive function. Studies measured cognitive function using a variety of instruments with the most common being MMSE. The MMSE is a paper-based test with a maximum score of 30, with lower

**Table 5** Studies with a 'weak' rating

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bayer[20] | Germany | Case control | 228 | With AD+Glau 72.9 | 10%/19% | Glaucoma | Diagnosis of Alzheimer's Disease according to the NINADS-ADRDA classification | Acuity - Snellen | 25.9% occurrence rate of probable glaucoma among AD | Yes- Significantly higher occurrence rate of glaucoma | Weak |
| 2002 | | | AD 112 | With AD+no Glau 71.4 | 28%/55% | | | VF - Humphrey Field Analyser | 5.2% occurrence rate of probable glaucoma among healthy controls | among AD patients | |
| | | | Control 116 | W/o AD+No glau 68.1 | 38%/72% | | | Optic disc evaluation | | | |
| | | | | W/o AD+Glau 70.1 | 2%/4% | | | | | | |
| Cigolle[24] | US (1995–2010 of HRS) | Longitudinal cohort, Adults>65y | 8847 | No info | No info | Cognition | Performance based measure (Telephone interview) to determine cognitive function (0–27) | No info | Vison and hearing predicted cognitive decline (p<0.001) | Cognitive function declines in an acclerating fashion, with older age | Weak |
| 2013 | Abstract Only | | | | | | | | | and visual impairment predicting decline over time | |
| Feeney[34] | Ireland (The Irish Longitudinal study on Ageing) | Cross-sectional study | 4281 | No info | No info | Cognition | MMSE, MoCA, CTT, CRT, SART, Prospective memory, picture memory, word recall and visual reasoning | heterochromatic flicker photometry (HFP) - a non-invasive method of | Linear, Negative binomial and logistic regression. MPOD men=0.20, SD=0.15. | MPOD is significantly associated with cognitive function | Weak |
| 2013 | Abstract only | | | | | | | gauging the density of Macular Pigment | One SD inc in MPOD assoc with few errors on MoCA: b=−0.03 p<0.01 & MMSE: b=−0.05 p=<0.05 | among older adults. | |
| | | | | | | | | | Faster time to complete CTT2: b=−0.02 p<0.01, faster CRT: b=−0.06 p<0.01, better word recall:b=0.07 p<0.05 | | |
| | | | | | | | | | Fewer SRT omission errors: b=−0.04 p<0.05, success on prospective memory task: b=0.14 p<0.01 | | |
| Jefferis[45] | UK | Cross-sectional study | 112 | 80.7 | NA | Cognition | Revised Addenbrook's Cognitive Examination (ACE-R) | Acuity: LogMar chart, Cataract density graded using LOC III system | ACE-R scores were split into those items requiring vision and those items not requiring vision, both subscores | Better general cognition (ACE-R total score) was associated with | Weak |

Continued

**Table 5** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | Abstract Only | | | | | | | | were significantly and similarly associated with VA (p=0.008 and p=0.001 respectively). | better vision (p=0.001) | |
| Maharani *et al*[49] | Survey of Health, Ageing and Retirement in Europe 2002–2014 | Cross-sectional study | 24 116 | NA | NA | Cognition | Using a summary cognitive score from the questions on episodic memory, verbal fluency, and numeracy. | Self-reported hearing and visual quality. Sensory function recoded into 2: | Older adults with single SI: b=−0.064 (-0.072 to -0.056), with DSI: b=-0.229 (-0.247 to −0.211) | Older adults with single and dual SI showed significantly lower | Weak |
| 2017 | Conference abstract | | | | | | | Excellent,v good & good into Good sens fn and fair & poor into Poor sens | | cognitive function compared with those without SI | |
| Miyata[50] | Japan (Fujiwara-Kyo study) | Cross-sectional study | 668 | 76.3 | NA | Cognition | MMSE | Cataract surgery history- obtained using a self-reported questionnaire | CI for Cataract surgery group OR: 0.82 (0.68, 0.99) p=0.042 when compared with no cataract sx group | Cat Sx group significantly lower odds for CI than the no Cat Sx group | Weak |
| 2016 | Conference abstract | | | | | | | | | | |
| Nael[51] | France (Three-City Study) | Longitudinal cohort study | 7722 | Range: 65 & older | NA | Cogniton | Incident dementia over the 12 year follow-up was actively screened for (diagnosis code) | Dist VF:loss self-reported, as inability/ difficulty recognising a face@ 4 m. | Cox regression models: Near VI: HR=1.30 (1.05, 1.61), Dist VF loss: HR=1.47 (1.02, 2.11) compared with those | Both near VI and distant VF loss were associated with an increased | Weak |
| 2017 | Short oral presentation | | | | | | | Near VI:presenting binoc VA <20/30 @ reading distance of 33 cm. | without visual loss | risk of dementia | |
| Setti[53] | Ireland (The Irish Longitudinal Study on Ageing (TILDA)) | Cross-sectional study | 5021 | NA | NA | Cognition | MMSE and MoCA | Vision measured subjectively and objectively (no other info) | Poor hearing and immediate recall of orally presented words: b=−0.46, poor hearing and delayed recall b=−0.60 | Vision was a significant predictor of visually presented tasks | Weak |
| 2013 | Abstract only | | | | | | | | Poor hearing and category fluency b=−1.96, poor hearing & memory (OR 0.23)& absent-mindedness (OR2.18). | but also of category fluency. | |

Continued

**Table 5** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Zheng [56] | US (The Salisbury Eye Evaluation Study) | Longitudinal cohort | 2520 | Range 65–84 | | Vision | MMSE | Acuity: ETDRS chart | VA and MMSE score worsened over time (VA (Log MAR) intercept=0.004, slope=0.022 for VA; MMSE intercept=27.3, slope=-.59; all p<0.001) | Both presenting VA and MMSE score worsened over time | Weak |
| 2017 | Conference abstract | | | | | | | | The intercept of VA trajectory is statistically significantly associated with the intercept of MMSE trajectory (r=-.267, SE=0.029, p<0.001) | | |
| | | | | | | | | | suggesting that worse baseline VA is associated with worse baseline MMSE score. | | |
| Ihle *et al*[60] | Switzerland (LIVES study) | Cross-sectional cohort | 2812 | 77.9 | 52.7/47.3 | Cognition | Processing speed- Was assessed by the Trail Making Test part A, Cognitive flexibility- Was assessed by the Trail Making Test part B | Self-report on a 3-point Likert-type scale whether their | Stability in (inter) relations of the other cognitive and the sensory abilities across the age tranches in old age were not moderated by general cognitive ability, educational level, nor general health status (all ps>0.225) | No.Present data do not support the view of a generally increased relation of cognitive and sensory abilities in old age. | Weak |
| 2015 | | | | range 65–101 | | | Verbal abilities- Was assessed by administering the Mill Hill vocabulary scale | current eyesight allowed them to read a newspaper by choosing one of the following | | | |
| | | | | | | | | 0 D 'no'; 1 D 'yes, but with difficulties'; or 2 D 'yes, without difficulties.' | | | |
| Soto-Perez-de-Celis *et al*[62] | US | Cross-sectional case control | 750 | 72 | 56/44 | Cognition | Score of 11 in the Blessed Orientation-Memory-Concentration test. | Self-reported visual impairment based on their rating of their eyesight | OR for VI and: IADL Dependence: 1.9 (1.2–3.2)<0.01, Poor Physical Function: 1.9 (1.1–3.3) .03, Possible CI: 1.9 | VI was associated with IADL dependence, poor physical function and | Weak |
| 2018 | | | | Range 65–94 | | | | (with glasses) as “excellent,” “good,” “fair,” “poor”, “totally blind” | (0.7–4.8) 0.20, Depression: 2.5 (1.4–4.3)<0.01, Anxiety: 1.4 (0.8–2.4) .19. OR for DSI and: IADL dep 2.8 (1.5–5.3)<0.01 | depression. Dual SI was assicated with IADL dependence, anxiety, depression and CI | |
| | | | | | | | | | Poor Physical Function: 1.7 (0.9–3.4) .10, Possible CI: 3.2 (1.3 to 8.1) .01, Depression: 2.5 (1.3–4.8)<0.01, Anxiety: 2.3 (1.2–4.2) .01 | | |

Continued

**Table 5** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Maharani *et al*[77] | HRS, ELSA, SHARE | Cross-sectional cohort | 13 123 hours | 67.8/32.2 | 41.8/58.2 | Cognition | Episodic memory: In all surveys, the interviewer reads a list of 10 common nouns to the respondent | In HRS and ELSA, self-reported vision quality was collected in all seven waves using the question: 'Is your eyesight (using glasses or corrective lens as usual) excellent (1), very good (2), good (3), fair (4) or poor (5)?'. | HRS: Single impairment β −0.15 (0.02)* | Yes. Those with sensory impairment are at a greater risk of developing cognitive impairment | Weak |
| 2018 | | | 11 417 ELSA | 64.8/35.2 | 45.6/54.4 | | then asks the respondent to recall as many words as possible from the list in any order twice: immediately after the respondent heard the complete list (immediate recall) and at the end of the cognitive function module | In SHARE, we used the two self-reported measures of visual function | Dual impairment β −0.25 (0.04)* | and may show a faster trajectory of cognitive decline that those without sensory impairment | |
| | | | 21 265 SHARE | 64.8/35.2 | 45.5/54.5 | | (delayed recall). | that are present in all waves: distance eyesight and reading eyesight. | ELSA: Single impairment β−0.14 (0.02)* | | |
| | | | | | | | | | Dual impairment β −0.35 (0.05)* | | |
| | | | | | | | | | SHARE: Single impairment β −0.26 (0.01)* | | |
| | | | | | | | | | Dual impairment β −0.68 (0.03)* | | |
| Jefferis *et al*[83] | UK (Newcastle 85+study) | Cross-sectional cohort | 839 | no info | no info | Cognition | sMMSE | Data collection of general practice records on whether the participant was | Median (inter-quartile range) sMMSE scores were 25 (22-29) for SI and 28 (25-29) for non-SI participants (p=0.006). | It is important to consider the possibility of vision impairment in older | Weak |
| 2012 | | | | | | | | registered as blind (severly sight impaired) or partially sighted (sight impaired), or neither (by a consultant ophthalmologist) | SI participants had lower subscale scores on tasks requiring vision (p<0.001 for each) but also for some subscale | people when carrying out the MMSE and to consider using the MMblind. | |

Continued

**Table 5** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | scores not obviously requiring vision: orientation (p=0.018) and repetition (p=0.030). | Beyond this however, visual impairment may be a marker for cognitive impairment. | |
| MacDonald SWS *et al*[84] | Canada | Longitudinal, cohort | 408 | NIC 75.44 | NIC 35.5/64.5 | Cognition | Episodic memory-The word recall task (Hultsch, Hertzog, & Dixon, 1990) was used to assess episodic memory | Acuity: Vision-Binocular-corrected distance VA was measured at three metres using the Snellen chart. | Age-related change in sensory function. | Decline in VA was also a notable predictor | Weak |
| 2018 | | | | SA-MCI :76.71 | SA-MCI: 40.5/59.5 | | Inductive reasoning-The Letter Series test (Thurstone, 1962) was used to assess inductive reasoning. | Snellen acuity fractions ranged from 0.20 to 1. | Variables, Intercept γ00, Slope γ10, SE Slope, p | of being classified as SA-MCI or MA-MCI | |
| | | | | MA-MCI: 75.68 | MA-MCI: 48.2/51.8 | | Perceptual speed-The WAIS-R Digit Symbol Substitution task (Wechsler, 1958) was used to assess perceptual processing speed | | Olfaction: 7.05,–0.043, 0.008,<0.001 | | |
| | | | | | | | Verbal fluency-The Controlled Associations test from the ETS kit of factor-referenced cognitive tests (Ekstrom, French, Harman, & Dermen, 1976) was used to assess verbal fluency. | | Distance Vision: 0.946,–0.004, 0.001,<0.001 | | |
| | | | | | | | Vocabulary-A recognition vocabulary test, combining three 18-item multiple-choice tests from the ETS kit of factor-referenced cognitive tests (Ekstrom et al., 1976), was used to assess vocabulary | | Audition: 32.84, 0.796, 0.059,<0.001, γ00=Average sensory function centred at the grand mean of age (74.17 years; SD=9.20); γ10=slope reflecting the average rate of linear change per additional year of age | | |
| Miyata *et al*[87] | Japan (HEIJO-KYO Cohort) | Cross-sectional cohort | 945 | 71.7 | 46.8/53.2 | Cognition | MMSE | Acuity: using the Landolt ring chart. A better value of LogMAR was used for analysis. | Logistic Regression Analysis for the Association Between Ocular Status and Cognitive Impairment | Yes. ORs for cognitive impairment were significantly lower in the pseudophakic group than in the phakic group | Weak |
| 2015 | | | | | | | | Questionnaire asking participants about pseudophakia/phakia | Age-adjusted, Multivariate OR for cognitive impairment: Model 1, Model 2, Model 3 | | |
| | | | | | | | | Confirmed by ophthalmologist using slit-lamp | Phakia (no previous cataract surgery): 1.00 (ref), 1.00 (ref), 1.00 (ref), 1.00 (ref), | | |
| | | | | | | | | | Pseudophakia (previous cataract surgery): 0.66 (0.45, 0.98), 0.66 (0.44, 0.98), 0.64 (0.43, 0.95), 0.64 (0.43, 0.96) | | |
| | | | | | | | | | p: 0.038, 0.039, 0.026, 0.031 | | |

Continued

**Table 5** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mine *et al*[91] | Japan (Fujiwara-kyo Study) | Cross-sectional cohort | 2818 | 76.3 | 52.7/47.3 | Cognition | MMSE; analysed the MMSE excluding the following vision-related five items: ''naming two objects,'' ''following a 3-step command,'' ''reading and following instruction,'' ''writing a sentence,'' and ''visual reconstruction'' and the maximum score for this was 22 points. | Acuity: Landolt ring chart at 5 m (converted to logMAR)(mild visual impairments (>0.2 logMAR)) | Associations between VA and Cognitive Impairment (multivariate regression model): | Yes. Subjects with mild visual impairments had 2.4 times higher odds of | Weak |
| 2016 | | | | | | | | | OR (CI) for different BCVA in the better eye (logMAR) groups: | having cognitive impairment than those without visual impairment | |
| | | | | | | | | | ≤0: 1.0 (reference), 0–0.1: 1.8 (1.2–2.7) p 0.007<br>0.1–0.2: 1.7 (0.8–3.5) p 0.187<br>>0.2: 3.3 (2.1–5.4) p 0.005 | | |
| Steffi G. Riedel-Heller[92] | Germany (LEILA 75+and AgeCoDe) | Longitudinal, cohort | 3199 | 79.3 | 34.7/65.3 | Cognition | No data | Self-report at baseline | Vision impairment (HR 1.19, 95% CI 1.01 to 1.42, p=0.043) and the combination of both (HR 1.47, 95% CI 1.18 to 1.83, p=0.001) | Yes. Vision impairment is independently associated with incident dementia. Looking at the combination we could show that individuals suffering from both are at highest risk for developing dementia | Weak |
| 2019 | | | | | | | | | on dementia incidence adjusted for baseline gender, age, education, marital status, depression, diabetes and cardiovascular risks (smoking, hypertension) | | |
| Asri Maharani[109] | US (HRS) | Longitudinal cohort | 19 618 | 57.8 | 44.6/55.4 | Cognition | Telephone Interview for Cognitive Status (TICS): include episodic memory, serial of 7 subtraction, and counting backward tests | Self report: “Is your eyesight (using glasses or corrective lens as usual) excellent (1), very good (2), good (3), fair (4) or poor (5)?” | VI and risk of possible CIND HR 1.351 (1.267, 1.441) p<0.001 when compared with no VI. VI and risk of probable | Yes. Self-assessed sensory impairment is independently associated with cognitive decline and incident possible CIND and probable dementia | Weak |
| 2019 | Waves 3 (1996) to 12 (2014) | | | | | | categorised those scoring 0 to 6 points on the 27-point TICS scale as having probable dementia | Further categorised sensory impairment in the simultaneous model into no impairment, | dementia HR 1.255 (1.074, 1.466) p=0.004 when compared with no VI | | |

Continued

**Table 5** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | seven to 11 as having possible CIND, and 12 to 27 as having normal cognitive function | single (vision or hearing) sensory impairment, and DSI (impairment in both senses). | | | |
| | | | | | | | | | | | |
| Phillip Hwang *et al*[112] | US (GEM study) | Longitudinal cohort | 2827 | NA | NA | Cognition | Incident dementia over 7 years of follow-up was based on a clinical diagnosis of dementia using DSM-IV criteria | Self-report | For all-cause dementia, the adjusted HR was 1.27 (95% CI: 1.02, 1.59) for single sensory visual or hearing impairment, | Yes, Dual visual and hearing impairment was strongly associated with increased risk of all-cause dementia and AD | Weak |
| 2019 | | | | | | | Alzheimer's disease was determined using NINCDS-ADRDA criteria | | and 1.70 (95% CI: 1.18, 2.45) for dual visual and hearing impairment, compared with no sensory impairment | | |
| Virginie Naël[113] | France (The Three-City-Alienor Cohort) | Longitudinal cohort | 7460 | NA | NA | Cognition | four cognitive domains (global cognition (MMSE and MMSE-blind), verbal fluency (IST), | At baseline, near VI was measured using the Parinaud scale | Participants with near VI and distance VF loss had lower baseline performances in verbal fluency, | Yes but only baseline. Participants with | Weak |
| 2019 | | | | | | | executive function (TMT) and visuospatial abilities (BVRT)) were assessed up to 6 times over 12 years of follow-up | at a standardised reading distance of 33 cm and distance VF loss was | global cognition, executive function and visuospatial abilities. Regarding changes over time, | visual loss had lower baseline performances in several cognitive tests | |
| | | | | | | | | self-reported, defined as inability or difficulty in recognising a familiar face at 4 m | MMSE where participants with mild near VI exhibited a faster cognitive decline (b=−0.02, p=0.04) | | |
| M.Q.Li[116] | China | Cross-sectional cohort | 10 116 | NA | NA | Vision | AD8 questionnaire | No info | Risk factor for cognitive impairment: VA loss 1.383 (1.188, 1.610) | Yes, The old people who suffered from a variety of chronic diseases including, poor eyesight were prone to cognitive impairment | Weak |
| 2019 | | | | | | | | | | | |
| Melanie Varin[118] | US | Cross-sectional cohort | 365 | AMD:83.1 | 32.4/67.6 | Cognition | six cognitive tests orally: the 1 min verbal fluency test (letter and category versions) | Binocular VA was measured using the ETDRS chart at 2 m | People with glaucoma showed lower scores on three cognitive tests than the group with normal vision: | Yes | Weak |

Continued

**Table 5** Continued

| Author and title | Country (Study name if applicable) | Study design | No of participants | Mean age (M/F) | Gender (M/F) | Outcome variable | CI: type of measurement/ evaluation | VI: Type of measurement/ evaluation | Point estimates and analysis performed | Summary of association | Quality of study |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019 | | | | Glaucoma:78.1 | 43.7/56.3 | | the digit span test (forward and backward versions), and the logical memory test (immediate and 30 min delayed recall) | VF measured using HFA, CS measured using the Pelli Robson chart at 1 m | the digit span forward and backward tests (b=−0.8, 95% CI −1.5 to −0.2 and b=−0.7, 95% CI −1.3 to −0.1, respectively) | People with glaucoma showed lower scores on cognitive tests | |
| Peiyuan Qiu[120] 2019 | China (Chinese Longitudinal Healthy Longevity Survey) | Longitudinal cohort | 3859 | 74.5 | 48.7/51.3 | Cognition | Chinese MMSE (C-MMSE) | Self-report | NA | Yes, visual impairment was a risk factor for cognitive decline | Weak |

AMD, age-related macular degeneration; CS, contrast sensitivity; DSI, dual sensory impairment; ELSA, English Longitudinal Study of Aging; HRS, Health and Retirement Study; MMSE, Mini-Mental State Examination; MoCA, Montreal-Cognitive Assessment; MPOD, macular pigment optical density; sMMSE, standardised MMSE; VA, visual acuity; VF, visual field.

scores indicating more severe cognitive impairment. A score of 24 is often used as a threshold to define 'normal' cognitive function.[123] The MMSE has been found to be a valid and reliable tool as assesses by many studies.[123 124] Several studies used self-report, diagnosis codes and data from existing records to define cognitive status. Similarly, visual function was also assessed by various methods including self-report. While VA was assessed most commonly, there was significant variation in the charts and tools used to assess it. The parameters used to define cognitive decline and VI may have impacted results across and within studies.

Our systematic review has found that there is a strong consensus in the literature that VI is associated with cognitive decline, cognitive impairment or dementia. Two hypotheses may help explain this association. The first one is that a common pathological process (eg, vascular disease) might be responsible for both the sensory and cognitive impairment in older adults. The second one is that by increasing cognitive load, sensory impairments such as VI might cause cognitive impairment.[125] Literature also suggests that vision rehabilitation in the form of cataract surgery slows the rate of cognitive decline, and therefore, early vision interventions could potentially reduce risk of dementia.[126]

Our review evaluated bias for all of the 110 included studies. The majority of studies included in our review were cross-sectional, and according to EPHPP guidelines, cross-sectional studies can only receive a low or moderate rating in the bias assessment. Cross-sectional studies are also prone to selection bias, thus yielding estimates that may not reflect true associations in the target population. Studies receiving a strong rating were all longitudinal. However, the tool penalises longitudinal studies that lose >40% of participants due to dropouts/withdrawals. This may, perhaps unfairly, affect longer longitudinal studies to a greater extent since they collect data over many years and can have more drop-outs due to deaths since they are conducted among older adults.

This review has several important implications. First, it highlights the need for standardised methods to assess and define both visual and cognitive function that will aid future research on these emerging public health issues. Second, it brings into focus the consistent association of VI with cognitive impairment in older adults and the need to better understand the mechanisms underlying this relationship. Third, as the longitudinal results support the sensory consequence theory, and suggest that VI may be a risk factor for cognitive decline, this points to a need for formulating preventive measures and vision rehabilitation models, such as prescription glasses, cataract surgery, low vision rehabilitation, etc, that could have the potential to improve overall health and well-being of older adults.

## Limitations

Given the large number of studies included in this review and the heterogeneity of measures used to assess

the outcome, it was not possible to compare and meta-analyse results across studies. Although 35 longitudinal studies found a positive association between VI and cognitive decline, we cannot establish temporality between this relationship due to the heterogeneous nature of the studies. The studies included diverse populations, with different disease processes, and variation in definitions of both cognitive and VI. There is also potential bias associated with studies that used different protocols for cognitive and sensory measurements. The MMSE, which was the most commonly used assessment method for testing cognition is sensory dependent and therefore one can argue that the results may be confounded with VI.[127] Further studies should examine the impact of using vision independent cognitive tests on the vision–cognition relationship. Our review examined all cause VI and dementia, and further study is needed to examine the vision–cognition relationship by dementia subtype and by different vision pathology. However, despite the heterogeneity in studies and assessment methods, we synthesised the evidence qualitatively and by taking into account study quality assessed using a validated tool. While our search strategy was robust, it may have been limited by the exclusion of studies that were not published in English.

## CONCLUSION

The number of older adults with VI and dementia is increasing globally, and therefore, the elucidation of the relationship between vision and cognition is of particular public health importance. This systematic review found that the positive association of VI with cognitive decline, cognitive impairment or dementia is largely consistent across studies using different measures of vision and cognition, as well as between countries and cohorts. This overall agreement in the literature suggests that poor visual and cognitive function are associated, and that additional research is now needed to move beyond documenting these associations. The focus of this area of research should now turn to identifying the factors and strategies that mediate the vision–cognition relationship and identifying potential interventions, such as vision rehabilitation models and strategies tailored to people with VI, that may mitigate the cognitive implications of VI.

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