BMJ Open

# Health literacy and cognition during aging: a cross-sectional analysis of the LitCog Study

| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID: | bmjopen-2014-007222 |
| Article Type: | Research |
| Date Submitted by the Author: | 16-Nov-2014 |
| Complete List of Authors: | Kobayashi, Lindsay; University College London, Department of Epidemiology and Public Health<br>Smith, Samuel; Queen Mary University of London, Wolfson Institute of Preventive Medicine<br>O'Conor, Rachel; Northwestern University, Division of General Internal Medicine<br>Curtis, Laura; Northwestern University, Division of General Internal Medicine<br>Park, Denise; University of Texas at Dallas, Center for Vital Longevity<br>von Wagner, Christian; UCL, Department of Epidemiology and Public Health<br>Deary, Ian; University of Edinburgh, Department of Psychology<br>Wolf, Michael; Northwestern University, Division of General Internal Medicine; Northwestern University, Department of Learning Sciences |
| <b>Primary Subject Heading</b>: | Geriatric medicine |
| Secondary Subject Heading: | Communication |
| Keywords: | EPIDEMIOLOGY, GERIATRIC MEDICINE, PRIMARY CARE |

# Health literacy and cognition during aging: a cross-sectional analysis of the LitCog Study

Lindsay C. Kobayashi[1], Samuel G. Smith[1,2], Rachel O'Conor[3], Laura M. Curtis[3], Denise Park[4], Christian von Wagner[1], Ian J Deary[5], Michael S. Wolf[3,6]

[1]Health Behaviour Research Centre, Department of Epidemiology and Public Health, University College London, London, UK

[2]Centre for Cancer Prevention, Wolfson Institute of Preventive Medicine, Queen Mary University of London, London, UK

[3]Division of General Internal Medicine, Feinberg School of Medicine at Northwestern University, Chicago, IL, USA

[4]Center for Vital Longevity, the University of Texas at Dallas, TX, USA

[5]Centre for Cognitive Ageing and Cognitive Epidemiology, Department of Psychology, the University of Edinburgh, Edinburgh, UK

[6]Department of Learning Sciences, School of Education and Social Policy, Northwestern University, Evanston, IL, USA

Corresponding author:

Michael S. Wolf, 750 N Lake Shore Drive, 10th floor, Feinberg School of Medicine, Division of General Internal Medicine and Geriatrics, Northwestern University, Chicago, IL 60611 USA.

Email: mswolf@northwestern.edu

## ABSTRACT

**Objectives:** To investigate how three measures of health literacy correlate with age and the explanatory roles of fluid and crystallized cognitive abilities in these relationships among older adults.

**Design:** Cross-sectional baseline analysis of the 'LitCog' cohort study.

**Setting:** One academic internal medicine clinic and five federally qualified health centers in Chicago, Illinois.

**Participants:** English-speaking adults (n=828) aged 55-74 years, recruited from August 2008 through October 2011.

**Outcome measures:** Health literacy was measured by the *Test of Functional Health Literacy in Adults* (TOFHLA) and the *Newest Vital Sign* (NVS), both of which assess reading comprehension and numeracy in health contexts, and by the *Rapid Estimate of Adult Literacy in Medicine* (REALM), which assesses medical vocabulary.

**Results:** TOFHLA and NVS scores were lower at ages 70-74 years compared to all other age groups ($P$<0.05 for both tests). The inverse association between age and TOFHLA score was attenuated from β=-0.39 (95% CI: -0.55 to -0.22) to β=-0.06 (95% CI: -0.20 – 0.08) for ages 70-74 vs. 55-59 years when fluid cognitive ability was added to the model (85% attenuation). Similar results were seen with NVS scores (68% attenuation). REALM scores did not differ by age group ($P$=0.971). Crystallized cognitive ability was stable across age groups, and did not influence the relationships between age and TOFHLA or NVS performance.

**Conclusions:** Health literacy skills show differential patterns of age-related change, which may be explained by cognitive aging. Researchers should select health literacy tests appropriate for their purposes when assessing the health literacy of older adults. Clinicians should be aware of this issue to ensure that health self-management tasks for older patients have appropriate cognitive and literacy demands.

**Strengths and limitations of this study**

- The first study to simultaneously assess a range of cognitive abilities and health literacy skills in a sample of older adults
- This analysis is a cross-sectional design
- Longitudinal work is needed to establish the threshold at which cognitive aging may begin to influence various health literacy skills

## INTRODUCTION

Low health literacy is a major determinant of morbidity and mortality among older adults in the United States.[1,2] Among other outcomes, low health literacy is associated with poor chronic disease management, increased risk of hospitalization, and worse overall health status among older adults.[1-4] In the 2003 U.S. National Assessment of Adult Literacy, 13% of American adults aged 50 to 64 lacked the basic literacy skills required for health management, rising to 29% of adults aged 65 and over.[5] Despite recent investigations, the specific functional health literacy skills that may be sensitive to age-related decline and their underlying cognitive functions are relatively unknown.

Researchers in the field use several different health literacy measures, each assessing slightly different skill sets. Three commonly used measures are the *Test of Functional Health Literacy in Adults* (TOFHLA), the *Newest Vital Sign* (NVS), and the *Rapid Estimate of Adult Literacy in Medicine* (REALM). The TOFHLA is a test of reading comprehension and numeracy that uses common health materials such as a health insurance form and x-ray preparation instructions.[6] The NVS is a reading comprehension and numeracy test using a food nutrition label that requires the reader to respond to information on the label.[7] The REALM is a test of medical vocabulary, which assesses familiarity with medical words and the ability to correctly pronounce them.[8]

Performance on these health literacy tests is correlated with various cognitive abilities. The 'fluid' cognitive abilities required for active learning (e.g. reasoning, memory, phonemic and semantic fluency) are strongly correlated with TOFHLA and NVS performance, while 'crystallized' cognitive abilities (e.g. verbal ability, general knowledge) are strongly correlated with performance on all three tests.[9] Longitudinal research shows that fluid cognitive abilities tend to decline beginning in early- to mid-adulthood, while crystallized abilities are stable over time with age.[10-12] Performance on the TOFHLA and the NVS may therefore exhibit a pattern of age-related decline similar to that of fluid abilities, whereas performance on the REALM may be more stable across age groups as it likely represents crystallized abilities.

The objective of the present analysis was to investigate how health literacy, as assessed by the TOFHLA, REALM, and NVS, correlates with age, and the explanatory roles of fluid and crystallized cognitive abilities in these relationships among American adults aged 55 to 74. We hypothesized that fluid cognitive abilities would mostly explain associations between age and health literacy as measured by the TOFHLA and NVS, while crystallized abilities would more likely explain any age-related associations with the REALM.

## METHODS

### Study sample

This analysis used baseline data from the 'Literacy and Cognitive Function in Older Adults' study (hereafter referred to as 'LitCog'). LitCog was established in 2008 to investigate how cognitive ability relates to health literacy skills among older adults. It is a prospective cohort study of English-speaking adults aged 55 to 74 years, who received care at an academic general internal medicine ambulatory care clinic or at one of five federally qualified health centers in Chicago, Illinois. A full description of the recruitment procedures are published elsewhere.[9] In brief, we identified 3176 age-eligible participants through electronic health records and successfully contacted 1884 for invitations to participate, 1640 of whom were eligible. Of these, 828 participants completed the baseline interviews.

### Procedure

Participants completed two structured interviews, lasting 2 hours, conducted 7 to 10 days apart. On day one, a trained research assistant guided participants through questions on basic demographic information, comorbidities, and the three health literacy measures. On day two, patients completed a cognitive battery to measure processing speed, working memory, inductive reasoning, long-term memory, prospective memory, and verbal ability. With the exception of verbal ability, cognitive tests did not involve reading or numeracy skills. All fluid cognitive domains were assessed using multiple tests to allow a latent trait to be extracted for each. This study was approved by Northwestern University's Institutional Review Board.

**Measures**

**Health literacy.** Health literacy was assessed using the TOFHLA, REALM, and NVS.[6-8] The TOFHLA consists of a 50-item reading comprehension section that utilizes the Cloze procedure, where every fifth to seventh word in a passage is omitted and four multiple choice options for the blank are provided. The TOFHLA also includes a 17-item numeracy section. Numeracy scores are transformed to match the reading comprehension scores, and the two are summed to give a total out of 100. Scores are classified as inadequate (0-59), marginal (60-74), or adequate (75-100).

The REALM is a 66-item word-recognition test, where medical words are arranged in order of increasing difficulty and participants are instructed to read them aloud. Scores are based on the total number of words pronounced correctly, using dictionary pronunciation as assessed by the interviewer. Scores are classified as low (0-44), marginal (45-60), or adequate (61-66).

The NVS is a brief screening tool to determine risk for limited health literacy, where participants read a food nutrition label and respond to six questions about interpreting and acting on the information. Scores are classified as a high likelihood (0-1) or possibility (2-3) of limited health literacy, or adequate health literacy (4-6).

Scores on all three tests will be herein referred to as adequate, as defined above, or as limited (<75 on the TOFHLA, <61 on the REALM, and <4 on the NVS), and will also be analyzed continuously as standardized scores.

**Cognitive abilities.** Six cognitive domains were assessed through a set of 16 cognitive tests and latent variables were derived for each domain. In brief, the cognitive domains were processing speed, working memory, inductive reasoning, long-term memory, prospective memory, and verbal ability; the specific tests cited here have been described in detail previously.[9] The former five domains were considered to represent fluid cognitive ability as they are associated with active information processing, whereas the latter domain represented crystallized cognitive ability as it is associated with general background knowledge.

**Participant characteristics.** Participant characteristics relevant to this analysis were assessed in the study interview: age (55-59; 60-64; 65-69; 70-74), gender (male; female), race (black; white; other), educational attainment (high school or less; some college or technical school; college graduate; graduate degree), annual income (<\$10,000; \$10,000-\$24,999; \$25,000-\$49,999; ≥\$50,000), employment status (no work; part-time; full-time), marital status (married; unmarried), and presence of chronic conditions: arthritis, asthma, bronchitis or emphysema, cancer, coronary heart disease, depression, diabetes, heart failure, and hypertension.

**Statistical analysis**

Socio-demographics and health conditions of study participants were described, along with the overall proportions with limited health literacy. Raw health literacy scores on each test were transformed into standardized z-scores and compared across age groups using one-way analysis of variance (ANOVA) and Scheffé's multiple comparison test. Univariate imputation sampling methods were used to estimate any missing values (n=98) on cognitive measures, and domain-specific cognitive ability scores were calculated using a latent trait analysis.[9] Latent items were calculated for each domain (working memory, inductive reasoning, long-term memory, prospective memory, and verbal ability), and summary scores for general cognitive abilities (fluid and crystallized) were calculated by estimating a single factor score for each using maximum likelihood estimation. Mean scores for each of six cognitive domains and overall fluid and crystallized abilities were transformed into standardized z-scores and compared across age groups using one-way ANOVA and Scheffé's multiple comparison test.

Standardized health literacy and cognitive ability scores were plotted by age group to generate a visualization of trends with age. Multiple linear regression modelling was used to estimate the associations between age and standardized score on each of the TOFHLA, NVS, and REALM. All *a priori*-identified covariates were included in modelling, with standardized fluid and crystallized cognitive ability scores added in a stepwise fashion to determine their separate and combined mediating effects on the relationship between age and health literacy. Health literacy data were missing for 14 participants (<2%) and data on one or more cognitive variable were missing and non-imputable for 40 participants (<5%), giving an effective sample size of 774. Statistical tests were two-sided and conducted at the 95% confidence level. Analyses were conducted using StataSE 13.1 (StataCorp, College Station, TX).

## RESULTS

Participant characteristics are shown in Table 1. Two-thirds (68.4%) of the sample were women and approximately half were white (50.6%). Educational attainment was fairly evenly distributed among the sample (26.4% had high school or less; 21.7% had some college or technical school; 20.5% were college graduates; 31.0% had graduate degrees). Over half had an annual income of at least $50,000 USD (53.6%), and 12.0% had an annual income less than $10,000 USD. Nearly two-thirds of the sample was not working (64.6%). Just under half were married (44.9%). Participants had, on average, 1.9 (SD=1.4) chronic health conditions. According to the TOFHLA, 29.1% of participants had limited health literacy, according to the NVS, 51.6%, and to the REALM, 24.2% (Table 1).

Mean standardized scores on the TOFHLA and the NVS differed across age groups ($P$=0.003 and $P$=0.0004, respectively; Figure 1). Scheffé's *post-hoc* test showed that TOFHLA and NVS scores were lower at ages 70-74 than at all younger age groups ($P$<0.05 for all). By contrast, REALM scores did not differ by age ($P$=0.971). Mean standardized scores for all fluid abilities differed across age groups ($P$<0.05 for all; Figure 1). Scheffé's *post-hoc* test showed that scores for all fluid abilities were lower at ages 70-74 than at all younger age groups ($P$<0.05 for all). By contrast, crystallized (verbal) ability did not differ by age ($P$=0.240; Figure 1).

In multivariable linear regression modelling, standardized TOFHLA and NVS scores were significantly lower in the 70-74 versus in the 55-59 years age group (β=-0.39; 95% CI: -0.55 to -0.22 for the TOFHLA and β=-0.38; 95% CI: -0.53 to -0.22 for the NVS; Table 2). In contrast, REALM scores were not associated with age. When fluid ability was added to the models, it attenuated the association between age and standardized TOFHLA score by 84.6% (attenuated β=-0.06; 95% CI: -0.20 to 0.08 for the 70-74 vs. 55-59 age group), and attenuated the association between age and standardized NVS score by 68.4% (attenuated β=-0.12; 95% CI: -0.26 to 0.02 for the 70-74 vs. 55-59 age group). Crystallized ability had no mediating effect on the associations between age and standardized TOFHLA and NVS scores (Table 2). The addition of fluid and crystallized abilities together somewhat lessened the attenuation observed with fluid ability only (from 84.6% to 53.8% attenuation for the TOHFLA, and from 68.4% to 52.6% attenuation for the NVS; Table 1). This may be due to the correlation between the two constructs (Spearman's rho = 0.76; $P<0.0001$).

## DISCUSSION

Among a sample of English-speaking older American adults, performance on the TOFHLA and the NVS appeared to be lowest in the oldest age group (70-74 years), with a threshold rather than a graded trend across age groups. Performance on tests of fluid cognitive abilities demonstrated a more graded decline with increasing age, with the poorest abilities seen in the oldest age group such as with the TOFHLA and the NVS. As with performance on the REALM, crystallized verbal ability remained constant with age. As fluid abilities nearly fully attenuated the association between both the TOFHLA and the NVS with age, it can be postulated that these two constructs have significant overlap with regard to their roles during aging. In support of our hypotheses, neither crystallized cognitive ability nor performance on the REALM had a relationship with age.

This study supports the findings of a recent systematic review showing that cross-sectional studies using the TOFHLA or NVS to measure health literacy more frequently observe an inverse association with age than those using the REALM.[13] Two studies of chronic disease patients using similar cognitive measures to ours are comparable to our study; the first found that a set of fluid abilities and visual and auditory function completely explained the inverse association between age and TOFHLA-assessed health literacy,[14] while the second study found that educational differences explained age differences in STOFHLA score.[15] Other previous research on this topic has focused on cognitive dysfunction or impairment, rather than a broader range of functional ability such as that captured by the measures in our study.[16-19] In a previous study, cognitive dysfunction explained the association between increasing age and poorer performance on the TOFHLA and NVS among older adults.[19] The exception was for the REALM, where the highest scores were observed among the oldest adults who screened negative for cognitive dysfunction, consistent with the preservation of crystallized cognitive ability with age.[19] Our study adds the knowledge that subtle individual differences in fluid cognitive ability largely influence the literacy skills required to self-manage health among older adults.

As a cross-sectional investigation, we are limited to the extent we can infer a temporal relationship between increasing age and declining health literacy. Health literacy differences between older and younger adults in our study may alternatively be explained by cohort effects, such as by potentially differential educational experiences between generations. As the LitCog study continues, future investigations will consider prospective analyses. Our findings are applicable to English speaking American adults, and are based on a predominantly female sample. We analyzed a comprehensive set of fluid cognitive abilities, but only one measure of crystallized ability. Distributions for each health literacy measure are known to be positively skewed, resulting in ceiling effects. Both the limited crystallized ability measurement and the differing treatment of cognitive and health literacy data may have impacted our findings to a degree, in particular with respect to the threshold and graded trends noted in certain analyses.

Although our study and others indicate that the health literacy skills reliant on fluid cognitive ability are sensitive to age-related decline, longitudinal evidence is needed to elucidate the point at which age-related cognitive decline begins to affect health literacy and, in turn, self-management of health. Whether health literacy decline can be prevented through cognitive-based interventions would be valuable knowledge for the improvement of health autonomy and quality of life for older adults. Strategies may differ significantly depending on whether health literacy concerns are more related to a lack of knowledge and experience in a contextualized health care setting, or whether they are related to a lack of the active learning skills that would allow one to access and use new health information. The former scenario would reflect an individual's life experiences and long health care use patterns, while the latter scenario could be acquired as a result of a new diagnosis or mild cognitive impairment.

In conclusion, our study indicates that the fluid health literacy skills assessed by the TOFHLA and NVS decline with older age among English-speaking American adults. In contrast, the crystallized health literacy skills assessed by the REALM appear to be stable with age among older adults. Researchers should be mindful of these issues when selecting tests to measure the health literacy of older patients. Clinicians should be aware that health self-management tasks involving comprehension of new information may be increasingly difficult for older patients because of cognitive and literacy burdens. However, performance on health tasks involving the recall of long-term stored knowledge and vocabulary may be relatively unaffected by age. Overall, these results add practical knowledge to help refine the construct of health literacy and its relation to cognitive changes during aging.



## ACKNOWLEDGEMENTS

**Contributors:** DP, IJD, and MSW were responsible for the study concept and design. RO, LCM, and MSW were responsible for the acquisition of data. LCK conducted the statistical analysis and wrote the first draft of the manuscript. All authors contributed to the interpretation

of data, critical revision of the manuscript for important intellectual content, and have approved of the final manuscript for publication and agree to be accountable for all aspects of the work.

**Funding:** The LitCog study is supported by a grant from the National Institute on Aging (R01 AG030611; PI: Wolf).

**Competing interests:** None.

**Data sharing statement:** No additional data are available.

## REFERENCES

1. Serper M, Patzer RE, Curtis LM, Smith SG, O'Conor R, Baker DW, et al. Health literacy, cognitive ability, and functional health status among older adults. *Health Serv Res* 2014;49:1249-67.
2. Baker DW, Wolf MS, Feinglass J, Thompson JA, Gazmararian JA, Huang J. Health literacy and mortality among elderly persons. *Ann Intern Med* 2007;167:1503–9.
3. Kobayashi LC, Wardle J, von Wagner C. (2014). Limited health literacy is a barrier to colorectal cancer screening in England: Evidence from the English Longitudinal Study of Ageing. *Prev Med* 2014;61:100–5.
4. Berkman ND, Sheridan SL, Donahue KE, Halpern DJ, Crotty K. (2011). Low Health literacy and health outcomes: an updated systematic review. *Ann Intern Med* 2011:155:97–107.
5. Kutner M, Greenberg E, Jin Y, Paulsen C. The Health Literacy of America's Adults: Results From the 2003 National Assessment of Adult Literacy. Washington DC: National Center for Education Statistics; 2006 Sept. Report No.: 2006-483. Sponsored by the Department of Education.

6. Parker R, Baker D, Williams M, Nurss J. The test of functional health literacy in adults: a new instrument for measuring patients' literacy skills. *J Gen Intern Med* 1995;10:537–41.

7. Weiss B, Mays M, Martz W, Castro K, DeWalt D, Pignone M, et al. Quick assessment of literacy in primary care: the Newest Vital Sign. *Ann Fam Med* 2005;3:514–22.

8. Davis T, Long S, Jackson R, Mayeaux E, George R, Murphy P, et al. (1993). Rapid assessment of adult literacy in medicine: a shortened screening instrument. *Fam Med* 1993;25:391-5.

9. Wolf MS, Curtis LM, Wilson EAH, Revelle W, Waite KR, Smith SG, et al (2012). Literacy, cognitive function, and health: results of the LitCog study. *J Gen Intern Med* 2012;27:1300-7.

10. O'Carroll, R. The assessment of premorbid ability: a critical review. *Neurocase* 1995:1;83–99.

11. Salthouse TA. When does age-related cognitive decline begin? *Neurobiol Aging* 2009;30:507–14.

12. Singh-Manoux A, Kivimaki M, Glymour M, Elbaz A, Berr C, Ebmeier K. Timing of onset of cognitive decline: results from Whitehall II prospective cohort study. *BMJ* 2012;344:d7622.

13. Kobayashi LC, Wardle J, Wolf MS, von Wagner C. Aging and functional health literacy: a systematic review and meta-analysis. *J Gerontol B Psychol Sci Soc Sci* 2014 (in press).

14. Levinthal BR, Morrow DG, Tu W, Wu J, Murray MD. Cognition and health literacy in patients with hypertension. *J Gen Intern Med* 2008;23:1172–6.

15. Morrow D, Clark D, Tu W, Wu J, Weiner M, Steinley D, et al. Correlates of health literacy in patients with chronic heart failure. *Gerontologist* 2006;46:669–76.

16. Armistead-Jehle P, Cifu DX, Wetzel R, Carne W, Klanchar LA. Health literacy among patients diagnosed with movement disorders: a pilot study. *PM R* 2010;2:43–7.

17. Chew LD, Bradley KA, Flum DR, Cornia PB, Koepsell TD. The impact of low health literacy on surgical practice. *Am J Surg* 2004;188:250–3.

18. Gazmararian JA, Baker DW, Williams M V, Parker RM, Scott TL, Green DC, et al. Health literacy among Medicare enrollees in a managed care organization. *JAMA* 1999;281:545–51.

19. Kaphingst KA, Goodman MS, Macmillan WD, Carpenter CR, Griffey RT. Effect of cognitive dysfunction on the relationship between age and health literacy. *Pat Educ Couns* 2014;95:218–25.

| Table 1. Participant Characteristics, the LitCog Study (n=774) | |
|---|---|
| Characteristic | N (%) |
| Age | |
| 55-59 | 239 (30.9%) |
| 60-64 | 250 (32.3%) |
| 65-69 | 154 (19.9%) |
| 70-74 | 131 (16.9%) |
| Gender | |
| Male | 245 (31.7%) |
| Female | 529 (68.4%) |
| Race | |
| Black | 326 (42.4%) |
| White | 389 (50.6%) |
| Other | 54 (7.0%) |
| Education | |
| High school or less | 207 (26.7%) |
| Some college or technical school | 168 (21.7%) |
| College graduate | 159 (20.5%) |
| Graduate degree | 240 (31.0%) |
| Income | |
| < $10,000 | 87 (12.0%) |
| $10,000 - $24,999 | 138 (19.1%) |
| $25,000 - $49,999 | 112 (15.4%) |
| ≥$50,000 | 390 (53.6%) |
| Employment status | |
| Full-time | 158 (20.5%) |
| Part-time | 114 (14.9%) |
| Not working | 497 (64.6%) |
| Marital status | |
| Married | 346 (44.9%) |
| Not married | 425 (55.1%) |
| Chronic conditions | |
| Arthritis | 357 (46.8%) |
| Asthma | 144 (18.8%) |
| Bronchitis or emphysema | 98 (12.9%) |
| Cancer | 56 (7.2%) |
| Coronary heart disease | 39 (5.2%) |
| Depression | 152 (19.8%) |
| Diabetes | 119 (15.5%) |
| Heart failure | 36 (4.7%) |
| Hypertension | 458 (59.3%) |
| Mean number of conditions (SD) | 1.9 (1.4) |
| Limited health literacy | |
| TOFHLA | 225 (29.1%) |
| NVS | 339 (51.6%) |
| REALM | 187 (24.2%) |

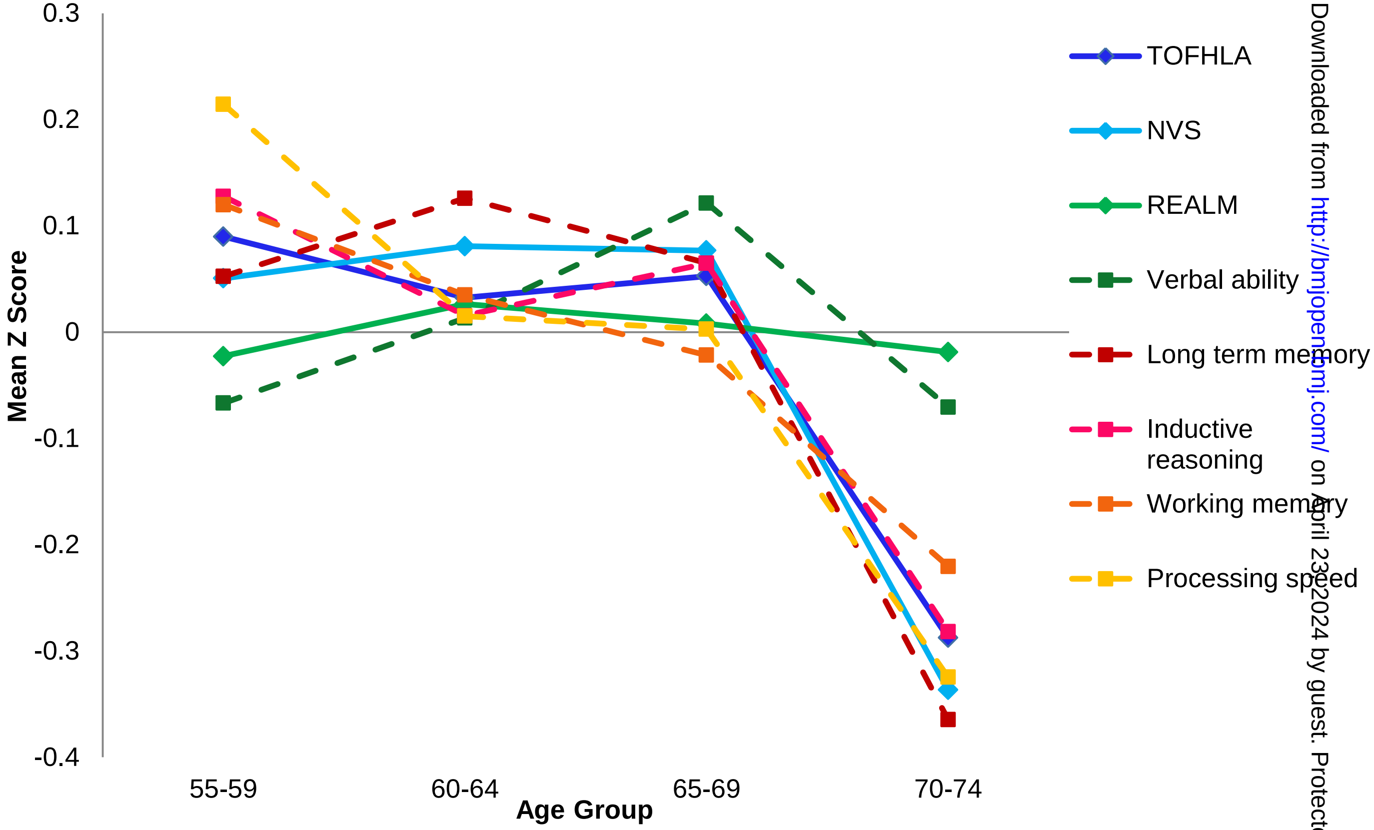
Table 2. Linear regression results for the association between age and health literacy, the LitCog Cohort, 2008-10 (n=774)

| | Model 1 Age only | | Model 2 Age + FA | | Model 3 Age + CA | | Model 4 Age + FA + CA | |
|---|---|---|---|---|---|---|---|---|
| TOFHLA score | Coef. | 95% CI | Coef. | 95% CI | Coef. | 95% CI | Coef. | 95% CI |
| Age | | | | | | | | |
| 55-59 | - | - | - | - | - | - | - | - |
| 60-64 | -0.13 | (-0.27, 0.00) | -0.01 | (-0.12, 0.10) | -0.13 | (-0.24, -0.02) | -0.06 | (-0.16, 0.05) |
| 65-69 | -0.15 | (-0.31, 0.00) | 0.00 | (-0.13, 0.13) | -0.17 | (-0.29, -0.04) | -0.07 | (-0.19, 0.05) |
| 70-74 | -0.39 | (-0.55, -0.22) | -0.06 | (-0.20, 0.08) | -0.37 | (-0.51, -0.24) | -0.18 | (-0.21, -0.05) |
| Fluid ability | - | - | 0.64 | (0.57, 0,71) | - | - | 0.39 | (0.32, 0.47) |
| Crystallized ability | - | - | - | - | 0.71 | (0.64, 0.78) | 0.47 | (0.39, 0.55) |
| Adjusted $R^2$ | 0.43 | | 0.61 | | 0.62 | | 0.67 | |
| NVS score | | | | | | | | |
| Age | | | | | | | | |
| 55-59 | - | - | - | - | - | - | - | - |
| 60-64 | -0.04 | (-0.16, 0.09) | 0.06 | (-0.06, .017) | -0.04 | (-0.15, 0.08) | 0.04 | (-0.08, 0.15) |
| 65-69 | -0.10 | (-0.25, 0.04) | 0.01 | (-0.12, 0.15) | -0.11 | (-0.25, 0.02) | -0.02 | (-0.15, 0.11) |
| 70-74 | -0.38 | (-0.53, -0.22) | -0.12 | (-0.26, 0.02) | -0.37 | (-0.51, -0.23) | -0.18 | (-0.32, -0.04) |
| Fluid ability | - | - | 0.50 | (0.43, 0.56) | - | - | 0.38 | (0.30, 0.46) |
| Crystallized ability | - | - | - | - | 0.45 | (0.37, 0.52) | 0.41 | (0.25, 0.57) |
| Adjusted $R^2$ | 0.50 | | 0.61 | | 0.58 | | 0.62 | |
| REALM score | | | | | | | | |
| Age | | | | | | | | |
| 55-59 | - | - | - | - | - | - | - | - |
| 60-64 | -0.04 | (-0.18, 0.10) | 0.03 | (-0.11, 0.16) | -0.04 | (-0.15, 0.07) | -0.06 | (-0.17, 0.06) |
| 65-69 | -0.09 | (-0.26, 0.07) | -0.01 | (-0.17, 0.15) | -0.11 | (-0.24, 0.03) | -0.13 | (-0.26, 0.002) |
| 70-74 | -0.04 | (-0.21, 0.13) | 0.14 | (-0.03, 0.31) | -0.02 | (-0.16, 0.11) | -0.07 | (-0.22, 0.07) |
| Fluid ability | - | - | 0.34 | (0.26, 0.43) | - | - | -0.10 | (-0.18, -0.12) |
| Crystallized ability | - | - | - | - | 0.79 | (0.71, 0.86) | 0.85 | (0.76, 0.94) |
| Adjusted $R^2$ | 0.36 | | 0.42 | | 0.59 | | 0.60 | |

Note: All models adjusted for sex, race/ethnicity, education, marital status, and number of chronic conditions

Note: HL = health literacy; FA = fluid ability; CA = crystallized ability

Note: All health literacy and cognitive ability scores are standardized


0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Mean Z Score
55-59
60-64
65-69
70-74
Age Group
TOFHLA
NVS
REALM
Verbal ability
Long term memory
Inductive reasoning
Working memory
Processing speed

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

| | Item No | Recommendation | Completed on Page Number: |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | 1 |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | 2-3 |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | 3-4 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | 4 |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | 4-5 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | 4 |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants. | 4 |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 5-6 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | 5-6 |
| Bias | 9 | Describe any efforts to address potential sources of bias | 7 |
| Study size | 10 | Explain how the study size was arrived at | 5,7 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | 6-7 |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | 6-7 |
| | | (*b*) Describe any methods used to examine subgroups and interactions | Not applicable |
| | | (*c*) Explain how missing data were addressed | 6-7 |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy | N/A |
| | | (*e*) Describe any sensitivity analyses | N/A |
| **Results** | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | 5,7 |
| | | (b) Give reasons for non-participation at each stage | 4 (also described in detail in another paper, which is cited) |
| | | (c) Consider use of a flow diagram | Not done as the flow is simple to describe narratively. |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, | 7 |

| | | | |
|---|---|---|---|
| | | clinical, social) and information on exposures and potential confounders | |
| | | (b) Indicate number of participants with missing data for each variable of interest | 5 |
| Outcome data | 15* | Report numbers of outcome events or summary measures | 7 |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | 7-8 |
| | | (*b*) Report category boundaries when continuous variables were categorized | 6 |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | Not applicable |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | N/A |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | 8 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | 9 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | 10 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | 9 |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | 11 |

*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

# The role of cognitive function in the relationship between age and health literacy: a cross-sectional analysis of older adults in Chicago, USA


| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID: | bmjopen-2014-007222.R1 |
| Article Type: | Research |
| Date Submitted by the Author: | 19-Feb-2015 |



| | |
|---|---|
| Complete List of Authors: | Kobayashi, Lindsay; University College London, Department of Epidemiology and Public Health<br>Smith, Samuel; Queen Mary University of London, Wolfson Institute of Preventive Medicine<br>O'Conor, Rachel; Northwestern University, Division of General Internal Medicine<br>Curtis, Laura; Northwestern University, Division of General Internal Medicine<br>Park, Denise; University of Texas at Dallas, Center for Vital Longevity<br>von Wagner, Christian; UCL, Department of Epidemiology and Public Health<br>Deary, Ian; University of Edinburgh, Department of Psychology<br>Wolf, Michael; Northwestern University, Division of General Internal Medicine; Northwestern University, Department of Learning Sciences |



| | |
|---|---|
| <b>Primary Subject Heading</b>: | Geriatric medicine |
| Secondary Subject Heading: | Communication |
| Keywords: | EPIDEMIOLOGY, GERIATRIC MEDICINE, PRIMARY CARE |
| | |

# The role of cognitive function in the relationship between age and health literacy: a cross-sectional analysis of older adults in Chicago, USA

Lindsay C. Kobayashi[1], Samuel G. Smith[1,2], Rachel O'Conor[3], Laura M. Curtis[3], Denise Park[4], Christian von Wagner[1], Ian J Deary[5], Michael S. Wolf[3,6]

[1]Health Behaviour Research Centre, Department of Epidemiology and Public Health, University College London, London, UK

[2]Centre for Cancer Prevention, Wolfson Institute of Preventive Medicine, Queen Mary University of London, London, UK

[3]Division of General Internal Medicine, Feinberg School of Medicine at Northwestern University, Chicago, IL, USA

[4]Center for Vital Longevity, the University of Texas at Dallas, TX, USA

[5]Centre for Cognitive Ageing and Cognitive Epidemiology, Department of Psychology, the University of Edinburgh, Edinburgh, UK

[6]Department of Learning Sciences, School of Education and Social Policy, Northwestern University, Evanston, IL, USA

Corresponding author:

Michael S. Wolf, 750 N Lake Shore Drive, 10th floor, Feinberg School of Medicine, Division of General Internal Medicine and Geriatrics, Northwestern University, Chicago, IL 60611 USA.

Email: mswolf@northwestern.edu

## ABSTRACT

**Objectives:** To investigate how three measures of health literacy correlate with age and the explanatory roles of fluid and crystallized cognitive abilities in these relationships among older adults.

**Design:** Cross-sectional baseline analysis of the 'LitCog' cohort study.

**Setting:** One academic internal medicine clinic and five federally qualified health centers in Chicago,, USA.

**Participants:** English-speaking adults (n=828) aged 55-74 years, recruited from August 2008 through October 2011.

**Outcome measures:** Health literacy was measured by the *Test of Functional Health Literacy in Adults* (TOFHLA) and the *Newest Vital Sign* (NVS), both of which assess reading comprehension and numeracy in health contexts, and by the *Rapid Estimate of Adult Literacy in Medicine* (REALM), which assesses medical vocabulary. Fluid cognitive ability was assessed through the cognitive domains of processing speed, inductive reasoning, and working, prospective, and long-term memories, and crystallized cognitive ability through the verbal ability domain.

**Results:** TOFHLA and NVS scores were lower at ages 70-74 years compared to all other age groups ($P$<0.05 for both tests). The inverse association between age and TOFHLA score was attenuated from β=-0.39 (95% CI: -0.55 to -0.22) to β=-0.06 (95% CI: -0.20 – 0.08) for ages 70-74 vs. 55-59 years when fluid cognitive ability was added to the model (85% attenuation). Similar results were seen with NVS scores (68% attenuation). REALM scores did not differ by age group ($P$=0.971). Crystallized cognitive ability was stable across age groups, and did not influence the relationships between age and TOFHLA or NVS performance.

**Conclusions:** Health literacy skills show differential patterns of age-related change, which may be explained by cognitive aging. Researchers should select health literacy tests appropriate for their purposes when assessing the health literacy of older adults. Clinicians should be aware of

this issue to ensure that health self-management tasks for older patients have appropriate cognitive and literacy demands.

**Strengths and limitations of this study**

- This study simultaneously assesses a range of cognitive abilities and health literacy skills in a sample of older adults
- This analysis is a cross-sectional design
- Longitudinal work is needed to establish the threshold at which cognitive aging may begin to influence various health literacy skills

## INTRODUCTION

Low health literacy is a major determinant of morbidity and mortality among older adults in the United States.[1,2] Among other outcomes, low health literacy is associated with poor chronic disease management, increased risk of hospitalization, and worse overall health status among older adults.[1-4] In the 2003 U.S. National Assessment of Adult Literacy, 13% of American adults aged 50 to 64 lacked the basic literacy skills required for health management, rising to 29% of adults aged 65 and over.[5] Despite recent investigations, the specific functional health literacy skills that may be sensitive to age-related decline and their underlying cognitive functions are relatively unknown.

Researchers in the field use several different health literacy measures, each assessing slightly different skill sets. Three commonly used measures are the *Test of Functional Health Literacy in Adults* (TOFHLA) or its shortened version (S-TOFHLA), the *Newest Vital Sign* (NVS), and the *Rapid Estimate of Adult Literacy in Medicine* (REALM). The TOFHLA is a test of reading comprehension and numeracy that uses common health materials such as a health insurance form and x-ray preparation instructions.[6] The NVS is a reading comprehension and numeracy test using a food nutrition label that requires the reader to respond to information on the label.[7] The REALM is a test of medical vocabulary, which assesses familiarity with medical words and the ability to correctly pronounce them.[8]

Performance on these health literacy tests is correlated with various 'fluid' and 'crystallized' cognitive abilities. Fluid cognitive abilities are those required for active learning and information processing (e.g. reasoning, memory, processing speed), and are strongly correlated with performance on the TOFHLA, NVS, and similar tests.[9-11] Crystallized cognitive abilities represent long-term memory or general knowledge (e.g. verbal ability or vocabulary), and are strongly correlated with performance on all three of the TOFHLA, REALM, and NVS.[9] Longitudinal research shows that fluid cognitive abilities tend to decline beginning in early- to mid-adulthood, while crystallized abilities are stable over time with age.[12-14]

The relationship between the constructs of cognitive ability and health literacy appears to be stable across the life-course: in a cohort of Scottish children born in 1936, childhood cognitive ability (age 11) was associated with late-life (age ~72) performance on each of the S-TOFHLA, NVS, and REALM.[15,16] In this cohort, relative cognitive change between ages 11 and 70 predicted late-life S-TOFHLA and NVS scores but not REALM scores.[16] Performance on the TOFHLA and the NVS may therefore exhibit a pattern of age-related decline similar to that of fluid abilities, whereas performance on the REALM may be more stable across age groups due to its relation with crystallized abilities.

The objective of the present analysis was to investigate how health literacy, as assessed by the TOFHLA, REALM, and NVS, correlates with age, and the explanatory roles of fluid and crystallized cognitive abilities in these relationships among American adults aged 55 to 74. We hypothesized that fluid cognitive abilities would mostly explain associations between age and health literacy as measured by the TOFHLA and NVS, while crystallized abilities would more likely explain any age-related associations with the REALM.

## METHODS

### Study sample

This analysis used baseline data from the 'Literacy and Cognitive Function in Older Adults' study (hereafter referred to as 'LitCog'). LitCog was established in 2008 to investigate how cognitive ability relates to health literacy skills among older adults. It is a prospective cohort study of English-speaking adults aged 55 to 74 years, who received care at an academic general internal medicine ambulatory care clinic or at one of five federally qualified health centers in Chicago, Illinois, USA. Electronic health records were used to identify 3176 eligible adults who had had at least two clinic visits within the past 18 months. Of these, 1904 were randomly selected for inclusion in the study. They were notified of the study by mail and were able to opt out at this stage. After screening by telephone, 244 adults were excluded due to cognitive or hearing impairment, limited English proficiency, or lack of affiliation with a clinic physician (i.e. less than two recorded visits in the previous two years). A total of 794 adults refused, 20 had scheduling conflicts, 14 were deceased, and 4 were duplicate records. The final sample included 828 participants who completed the baseline interview, for a cooperation rate of 51%.

**Procedure**

Participants completed two structured interviews, lasting 2 hours, conducted 7 to 10 days apart. On day one, a trained research assistant guided participants through questions on basic demographic information, comorbidities, and the three health literacy measures. On day two, patients completed a cognitive battery to measure processing speed, working memory, inductive reasoning, long-term memory, prospective memory, and verbal ability. With the exception of verbal ability, cognitive tests did not involve reading or numeracy skills. All fluid cognitive domains were assessed using multiple tests to allow a latent trait to be extracted for each. This study was approved by Northwestern University's Institutional Review Board.

**Measures**

**Health literacy.** Health literacy was assessed using the TOFHLA, REALM, and NVS.[6-8] The TOFHLA consists of a 50-item reading comprehension section that utilizes the Cloze procedure, where every fifth to seventh word in a passage is omitted and four multiple choice options for the blank are provided. The TOFHLA also includes a 17-item numeracy section. Numeracy scores are transformed to match the reading comprehension scores, and the two are summed to give a total out of 100. Scores are classified as inadequate (0-59), marginal (60-74), or adequate (75-100).

The REALM is a 66-item word-recognition test, where medical words are arranged in order of increasing difficulty and participants are instructed to read them aloud. Scores are based on the total number of words pronounced correctly, using dictionary pronunciation as assessed by the interviewer. Scores are classified as low (0-44), marginal (45-60), or adequate (61-66).

The NVS is a brief screening tool to determine risk for limited health literacy, where participants read a food nutrition label and respond to six questions about interpreting and acting on the information. Scores are classified as a high likelihood (0-1) or possibility (2-3) of limited health literacy, or adequate health literacy (4-6).

Scores on all three tests will be herein referred to as adequate, as defined above, or as limited (<75 on the TOFHLA, <61 on the REALM, and <4 on the NVS), and will also be analyzed continuously as standardized scores.

**Cognitive abilities.** Six cognitive domains were assessed through a set of 16 cognitive tests and latent variables were derived for each domain. In brief, the cognitive domains were processing speed, working memory, inductive reasoning, long-term memory, prospective memory, and verbal ability; the specific tests cited here have been described in detail previously.[9] The former five domains were considered to represent fluid cognitive ability as they are associated with active information processing, whereas the latter domain represented crystallized cognitive ability as it is associated with general background knowledge.

**Participant characteristics.** Participant characteristics relevant to this analysis were assessed in the study interview: age (55-59; 60-64; 65-69; 70-74), gender (male; female), race (black; white; other), educational attainment (high school or less; some college or technical school; college graduate; graduate degree), annual income (<$10,000; $10,000-$24,999; $25,000-$49,999; ≥$50,000), employment status (no work; part-time; full-time), marital status (married; unmarried), and presence of chronic conditions: arthritis, asthma, bronchitis or emphysema, cancer, coronary heart disease, depression, diabetes, heart failure, and hypertension.

**Statistical analysis**

Socio-demographics and health conditions of study participants were described, along with the overall proportions with limited health literacy. Raw health literacy scores on each test were transformed into standardized z-scores and compared across age groups using one-way analysis of variance (ANOVA) and Scheffé's multiple comparison test. Univariate imputation sampling methods were used to estimate any missing values (n=98) on cognitive measures, and domain-specific cognitive ability scores were calculated using a latent trait analysis.[9] One aim of the LitCog study is to investigate the latent cognitive domains that may underlie health literacy skills, hence, latent items were calculated for each cognitive domain (processing speed, working memory, inductive reasoning, long-term memory, prospective memory, and verbal ability).[9] Maximum likelihood estimation was used to estimate single factor summary scores for general cognitive abilities (fluid and crystallized).[9] Mean scores for each of six cognitive domains and overall fluid and crystallized abilities were transformed into standardized z-scores and compared across age groups using one-way ANOVA and Scheffé's multiple comparison test.

Standardized health literacy and cognitive ability scores were plotted by age group to generate a visualization of trends with age. Multiple linear regression modelling was used to estimate the associations between age and standardized score on each of the TOFHLA, NVS, and REALM. All *a priori*-identified covariates were included in modelling, with standardized fluid and crystallized cognitive ability scores added in a stepwise fashion to determine their separate and combined mediating effects on the relationship between age and health literacy. A *post-hoc* analysis was performed to assess the individual contributions of each of processing speed, working memory, inductive reasoning, prospective memory, and long-term memory to the overall mediating effect of fluid cognitive ability on the age-TOFHLA and age-NVS relationships. Health literacy data were missing for 14 participants (<2%) and data on one or more cognitive variable were missing and non-imputable for 40 participants (<5%), giving an effective sample size of 774. Statistical tests were two-sided and conducted at the 95% confidence level. Analyses were conducted using StataSE 13.1 (StataCorp, College Station, TX).

## RESULTS

Participant characteristics are shown in Table 1. Two-thirds (68.4%) of the sample were women and approximately half were white (50.6%). Educational attainment was fairly evenly distributed among the sample (26.4% had high school or less; 21.7% had some college or technical school; 20.5% were college graduates; 31.0% had graduate degrees). Over half had an annual income of at least $50,000 USD (53.6%), and 12.0% had an annual income less than $10,000 USD. Nearly two-thirds of the sample was not working (64.6%). Just under half were married (44.9%). Participants had, on average, 1.9 (SD=1.4) chronic health conditions. According to the TOFHLA, 29.1% of participants had limited health literacy, according to the NVS, 51.6%, and to the REALM, 24.2% (Table 1).

Mean standardized scores on the TOFHLA and the NVS differed across age groups (*P*=0.003 and *P*=0.0004, respectively; Figure). Scheffé's *post-hoc* test showed that TOFHLA and NVS scores were lower at ages 70-74 than at all younger age groups (*P*<0.05 for all). By contrast, REALM scores did not differ by age (*P*=0.971). Mean standardized scores for all fluid abilities differed across age groups (*P*<0.05 for all; Figure). Scheffé's *post-hoc* test showed that scores for all fluid abilities were lower at ages 70-74 than at all younger age groups (*P*<0.05 for all). By contrast, crystallized (verbal) ability did not differ by age (*P*=0.240; Figure).

In multivariable linear regression modelling, standardized TOFHLA and NVS scores were significantly lower in the 70-74 versus in the 55-59 years age group (β=-0.39; 95% CI: -0.55 to -0.22 for the TOFHLA and β=-0.38; 95% CI: -0.53 to -0.22 for the NVS; Table 2). In contrast, REALM scores were not associated with age. When fluid ability was added to the models, it attenuated the association between age and standardized TOFHLA score by 84.6% (attenuated β=-0.06; 95% CI: -0.20 to 0.08 for the 70-74 vs. 55-59 age group), and attenuated the association between age and standardized NVS score by 68.4% (attenuated β=-0.12; 95% CI: -0.26 to 0.02 for the 70-74 vs. 55-59 age group). Crystallized ability had no mediating effect on the associations between age and standardized TOFHLA and NVS scores (Table 2). The addition of fluid and crystallized abilities together somewhat lessened the attenuation observed with fluid ability only (from 84.6% to 53.8% attenuation for the TOHFLA, and from 68.4% to 52.6% attenuation for the NVS; Table 1). This may be due to the correlation between the two constructs (Spearman's rho = 0.76; *P*<0.0001).

Each of processing speed, working memory, inductive reasoning, prospective memory, and long-term memory mediated the age-TOFHLA performance relationship to some degree (Table 3). However, it appeared that that processing speed was the strongest mediator and that prospective and long-term memory minimally contributed to mediation (Table 3). Together, the contributions of these cognitive abilities led to the overall degree of mediation shown by the 'fluid cognitive ability' construct in Table 2. With respect to the NVS, the individual cognitive abilities did not explain age differences in performance to the same degree as observed with the TOFHLA (Table 3). However, the incremental contributions of the individual abilities to the overall mediating effect of 'fluid cognitive ability' mostly explained the age-NVS performance relationship, as shown in Table 2.

## DISCUSSION

Among a sample of English-speaking older American adults, performance on the TOFHLA and the NVS appeared to be lowest in the oldest age group (70-74 years), with a threshold rather than a graded trend across age groups. Performance on tests of fluid cognitive abilities demonstrated a more graded decline with increasing age, with the poorest abilities seen in the oldest age group such as with the TOFHLA and the NVS. As with performance on the REALM, crystallized verbal ability remained constant with age. As fluid abilities nearly fully attenuated the association between both the TOFHLA and the NVS with age, it can be postulated that these two constructs have significant overlap with regard to their roles during aging. In support of our hypotheses, neither crystallized cognitive ability nor performance on the REALM had a relationship with age.

This study supports the findings of a recent systematic review showing that performance on the REALM is more stable with increasing age than is performance on the TOFHLA and NVS.[17] Two studies of chronic disease patients using similar cognitive measures to ours are comparable to our study; the first found that a set of fluid abilities and visual and auditory function completely explained the inverse association between age and TOFHLA-assessed health literacy,[18] while the second study found that educational differences explained age differences in STOFHLA score.[19] Other research on this topic has focused on cognitive impairment, rather than a broader range of functional ability such as that captured by the measures in our study.[20-23] In a previous study, cognitive dysfunction explained the association between increasing age and poorer performance on the TOFHLA and NVS among older adults, while performance on the REALM was best among the oldest adults who screened negative for cognitive dysfunction.[23] Our study adds the knowledge that subtle individual differences in fluid cognitive ability largely influence age-related differences in the literacy skills required to self-manage health among older adults.

Consistent with evidence showing that speed of visual discrimination, an aspect of processing speed, is an important marker of cognitive ageing,[24-26] we found that processing speed was the fluid cognitive ability that individually held the most responsibility for mediating the relationship between age and TOFHLA performance. In LitCog, processing speed was assessed through visual tests of digit and simple line comparisons, and symbol-digit matching.[9] A similar test of processing speed used in the English Longitudinal Study of Ageing was also shown to mediate the relationship between age and health literacy as assessed by a reading comprehension test.[27] In the present study, prospective and long-term memory minimally explained age differences in TOFHLA or NVS performance, consistent with previous LitCog research showing that scores on these memory tests are less strongly correlated with TOFHLA and NVS performance than scores on tests of processing speed or inductive reasoning.[9] These findings provide valuable early insight into the specific fluid abilities that influence performance on health literacy tests and are worth further longitudinal investigation.

As a cross-sectional investigation, we are limited to the extent we can infer a temporal relationship between increasing age and declining health literacy. Health literacy differences between older and younger adults in our study may alternatively be explained by cohort effects, such as by potentially differential educational experiences between generations. As the LitCog study continues, future investigations will consider prospective analyses. Our findings are applicable to English speaking American adults, and are based on a predominantly female sample. We analyzed a comprehensive set of fluid cognitive abilities, but only one measure of crystallized ability. Distributions for each health literacy measure are known to be positively skewed, resulting in ceiling effects. Both the limited crystallized ability measurement and the differing treatment of cognitive and health literacy data may have impacted our findings to a degree, in particular with respect to the threshold and graded trends noted in certain analyses.

Although our study and others indicate that the health literacy skills reliant on fluid cognitive ability are sensitive to age-related decline, longitudinal evidence is needed to elucidate the point at which age-related cognitive decline begins to affect health literacy and, in turn, self-management of health. Whether health literacy decline can be prevented through cognitive-based interventions would be valuable knowledge for the improvement of health autonomy and quality of life for older adults. In particular, improvement of mental processing speed may aid in performance on tests of fluid health literacy skills. Strategies may differ significantly depending on whether health literacy concerns are related to a lack of knowledge and experience in a contextualized health care setting, or whether they are related to a lack of the active learning skills that would allow one to access and use new health information. The former scenario would reflect an individual's life experiences and long health care use patterns, while the latter scenario could be acquired as a result of a new diagnosis or mild cognitive impairment.

In conclusion, our study indicates that the fluid health literacy skills assessed by the TOFHLA and NVS decline with older age among English-speaking American adults. In contrast, the crystallized health literacy skills assessed by the REALM appear to be stable with age among older adults. Researchers should be mindful of these issues when selecting tests to measure the health literacy of older patients. The ways in which these health literacy tests are constructed result in an operationalization of health literacy that closely maps onto cognitive abilities that are sensitive to change with age. Clinicians should be aware that health self-management tasks involving comprehension of new information may be increasingly difficult for older patients because of cognitive and literacy burdens. However, performance on health tasks involving the recall of long-term stored knowledge and vocabulary may be relatively unaffected by age. Overall, these results add practical knowledge to help refine the construct of health literacy and its relation to cognitive changes during aging.

## ACKNOWLEDGEMENTS

**Contributors:** DP, IJD, and MSW were responsible for the study concept and design. RO, LCM, and MSW were responsible for the acquisition of data. LCK conducted the statistical analysis and wrote the first draft of the manuscript. All authors contributed to the interpretation of data, critical revision of the manuscript for important intellectual content, and have approved of the final manuscript for publication and agree to be accountable for all aspects of the work.

**Funding:** The LitCog study is supported by a grant from the National Institute on Aging (R01 AG030611; PI: Wolf).

**Competing interests:** None.

**Data sharing statement:** No additional data are available.

## REFERENCES


1. Serper M, Patzer RE, Curtis LM, Smith SG, O'Conor R, Baker DW, et al. Health literacy, cognitive ability, and functional health status among older adults. *Health Serv Res* 2014;49:1249-67.
2. Baker DW, Wolf MS, Feinglass J, Thompson JA, Gazmararian JA, Huang J. Health literacy and mortality among elderly persons. *Ann Intern Med* 2007;167:1503–9.
3. Kobayashi LC, Wardle J, von Wagner C. (2014). Limited health literacy is a barrier to colorectal cancer screening in England: Evidence from the English Longitudinal Study of Ageing. *Prev Med* 2014;61:100–5.
4. Berkman ND, Sheridan SL, Donahue KE, Halpern DJ, Crotty K. (2011). Low Health literacy and health outcomes: an updated systematic review. *Ann Intern Med* 2011:155:97–107.
5. Kutner M, Greenberg E, Jin Y, Paulsen C. The Health Literacy of America's Adults: Results From the 2003 National Assessment of Adult Literacy. Washington DC: National Center for Education Statistics; 2006 Sept. Report No.: 2006-483. Sponsored by the Department of Education.
6. Parker R, Baker D, Williams M, Nurss J. The test of functional health literacy in adults: a new instrument for measuring patients' literacy skills. *J Gen Intern Med* 1995;10:537–41.
7. Weiss B, Mays M, Martz W, Castro K, DeWalt D, Pignone M, et al. Quick assessment of literacy in primary care: the Newest Vital Sign. *Ann Fam Med* 2005;3:514–22.
8. Davis T, Long S, Jackson R, Mayeaux E, George R, Murphy P, et al. (1993). Rapid assessment of adult literacy in medicine: a shortened screening instrument. *Fam Med* 1993;25:391-5.

9. Wolf MS, Curtis LM, Wilson EAH, Revelle W, Waite KR, Smith SG, et al (2012). Literacy, cognitive function, and health: results of the LitCog study. *J Gen Intern Med* 2012;27:1300-7.

10. Boyle PA, Yu L, Wilson RS, Segawa E, Buchman AS, Bennett DA. Cognitive decline impairs financial and health literacy among community-based older persons without dementia. *Psychol Aging* 2013;28:614-24

11. Bennett JS, Boyle PA, James BD, Bennett DA. Correlates of health and financial literacy in older adults without dementia. *BMC Geriatrics* 2012;12:30.

12. O'Carroll, R. The assessment of premorbid ability: a critical review. *Neurocase* 1995;1:83–99.

13. Salthouse TA. When does age-related cognitive decline begin? *Neurobiol Aging* 2009;30:507–14.

14. Singh-Manoux A, Kivimaki M, Glymour M, Elbaz A, Berr C, Ebmeier K. Timing of onset of cognitive decline: results from Whitehall II prospective cohort study. *BMJ* 2012;344:d7622.

15. Mõttus R, Johnson W, Murray C, Wolf MS, Starr JM, Deary IJ. Towards understanding the links between health literacy and physical health. *Health Psychol* 2014;33:164-73.

16. Murray C, Johnson W, Wolf MS, Deary IJ. The association between cognitive ability across the lifespan and health literacy in old age: The Lothian Birth Cohort 1936. *Intelligence* 2011;39:178-87.

17. Kobayashi LC, Wardle J, Wolf MS, von Wagner C. Aging and functional health literacy: a systematic review and meta-analysis. *J Gerontol B Psychol Sci Soc Sci* 2015 pii: gbu161 [Epub ahead of print].

18. Levinthal BR, Morrow DG, Tu W, Wu J, Murray MD. Cognition and health literacy in patients with hypertension. *J Gen Intern Med* 2008;23:1172–6.

19. Morrow D, Clark D, Tu W, Wu J, Weiner M, Steinley D, et al. Correlates of health literacy in patients with chronic heart failure. *Gerontologist* 2006;46:669–76.

20. Armistead-Jehle P, Cifu DX, Wetzel R, Carne W, Klanchar LA. Health literacy among patients diagnosed with movement disorders: a pilot study. *PM R* 2010;2:43–7.

21. Chew LD, Bradley KA, Flum DR, Cornia PB, Koepsell TD. The impact of low health literacy on surgical practice. *Am J Surg* 2004;188:250–3.

22. Gazmararian JA, Baker DW, Williams M V, Parker RM, Scott TL, Green DC, et al. Health literacy among Medicare enrollees in a managed care organization. *JAMA* 1999;281:545–51.

23. Kaphingst KA, Goodman MS, Macmillan WD, Carpenter CR, Griffey RT. Effect of cognitive dysfunction on the relationship between age and health literacy. *Pat Educ Couns* 2014;95:218–25.

24. Salthouse TA. The processing-speed theory of adult age differences in cognition. *Psychol Rev* 1996;103:403-28.

25. Deary IJ, Johnson W, Starr JM. Are processing speed tasks biomarkers of aging? *Psychol Aging* 2010;25:219-28.

26. Ritchie SJ, Tucker-Drob EM, Deary IJ. A strong link between speed of visual discrimination and cognitive ageing. *Curr Biol* 2014;24:R681-3.

27. Kobayashi LC, Wardle J, Wolf MS, von Wagner C. Cognitive function and health literacy decline in a cohort of aging English adults. *J Gen Intern Med* 2015 doi: 10.1007/s11606-015-3206-9 [Epub ahead of print].

| Table 1. Participant Characteristics, the LitCog Study (n=774) | |
|---|---|
| Characteristic | N (%) |
| Age | |
| 55-59 | 239 (30.9%) |
| 60-64 | 250 (32.3%) |
| 65-69 | 154 (19.9%) |
| 70-74 | 131 (16.9%) |
| Gender | |
| Male | 245 (31.7%) |
| Female | 529 (68.4%) |
| Race | |
| Black | 326 (42.4%) |
| White | 389 (50.6%) |
| Other | 54 (7.0%) |
| Education | |
| High school or less | 207 (26.7%) |
| Some college or technical school | 168 (21.7%) |
| College graduate | 159 (20.5%) |
| Graduate degree | 240 (31.0%) |
| Income | |
| < $10,000 | 87 (12.0%) |
| $10,000 - $24,999 | 138 (19.1%) |
| $25,000 - $49,999 | 112 (15.4%) |
| ≥$50,000 | 390 (53.6%) |
| Employment status | |
| Full-time | 158 (20.5%) |
| Part-time | 114 (14.9%) |
| Not working | 497 (64.6%) |
| Marital status | |
| Married | 346 (44.9%) |
| Not married | 425 (55.1%) |
| Chronic conditions | |
| Arthritis | 357 (46.8%) |
| Asthma | 144 (18.8%) |
| Bronchitis or emphysema | 98 (12.9%) |
| Cancer | 56 (7.2%) |
| Coronary heart disease | 39 (5.2%) |
| Depression | 152 (19.8%) |
| Diabetes | 119 (15.5%) |
| Heart failure | 36 (4.7%) |
| Hypertension | 458 (59.3%) |
| Mean number of conditions (SD) | 1.9 (1.4) |
| Limited health literacy | |
| TOFHLA | 225 (29.1%) |
| NVS | 339 (51.6%) |
| REALM | 187 (24.2%) |

Table 2. Linear regression results for the association between age and health literacy, the LitCog Cohort, 2008-10 (n=774)

| | Model 1 Age only | | Model 2 Age + FA | | Model 3 Age + CA | | Model 4 Age + FA + CA | |
|---|---|---|---|---|---|---|---|---|
| TOFHLA score | Coef. | 95% CI | Coef. | 95% CI | Coef. | 95% CI | Coef. | 95% CI |
| Age | | | | | | | | |
| 55-59 | - | - | - | - | - | - | - | - |
| 60-64 | -0.13 | (-0.27, 0.00) | -0.01 | (-0.12, 0.10) | -0.13 | (-0.24, -0.02) | -0.06 | (-0.16, 0.05) |
| 65-69 | -0.15 | (-0.31, 0.00) | 0.00 | (-0.13, 0.13) | -0.17 | (-0.29, -0.04) | -0.07 | (-0.19, 0.05) |
| 70-74 | -0.39 | (-0.55, -0.22) | -0.06 | (-0.20, 0.08) | -0.37 | (-0.51, -0.24) | -0.18 | (-0.21, -0.05) |
| Fluid ability | - | - | 0.64 | (0.57, 0,71) | - | - | 0.39 | (0.32, 0.47) |
| Crystallized ability | - | - | - | - | 0.71 | (0.64, 0.78) | 0.47 | (0.39, 0.55) |
| Adjusted $R^2$ | 0.43 | | 0.61 | | 0.62 | | 0.67 | |
| NVS score | | | | | | | | |
| Age | | | | | | | | |
| 55-59 | - | - | - | - | - | - | - | - |
| 60-64 | -0.04 | (-0.16, 0.09) | 0.06 | (-0.06, .017) | -0.04 | (-0.15, 0.08) | 0.04 | (-0.08, 0.15) |
| 65-69 | -0.10 | (-0.25, 0.04) | 0.01 | (-0.12, 0.15) | -0.11 | (-0.25, 0.02) | -0.02 | (-0.15, 0.11) |
| 70-74 | -0.38 | (-0.53, -0.22) | -0.12 | (-0.26, 0.02) | -0.37 | (-0.51, -0.23) | -0.18 | (-0.32, -0.04) |
| Fluid ability | - | - | 0.50 | (0.43, 0.56) | - | - | 0.38 | (0.30, 0.46) |
| Crystallized ability | - | - | - | - | 0.45 | (0.37, 0.52) | 0.41 | (0.25, 0.57) |
| Adjusted $R^2$ | 0.50 | | 0.61 | | 0.58 | | 0.62 | |
| REALM score | | | | | | | | |
| Age | | | | | | | | |
| 55-59 | - | - | - | - | - | - | - | - |
| 60-64 | -0.04 | (-0.18, 0.10) | 0.03 | (-0.11, 0.16) | -0.04 | (-0.15, 0.07) | -0.06 | (-0.17, 0.06) |
| 65-69 | -0.09 | (-0.26, 0.07) | -0.01 | (-0.17, 0.15) | -0.11 | (-0.24, 0.03) | -0.13 | (-0.26, 0.002) |
| 70-74 | -0.04 | (-0.21, 0.13) | 0.14 | (-0.03, 0.31) | -0.02 | (-0.16, 0.11) | -0.07 | (-0.22, 0.07) |
| Fluid ability | - | - | 0.34 | (0.26, 0.43) | - | - | -0.10 | (-0.18, -0.12) |
| Crystallized ability | - | - | - | - | 0.79 | (0.71, 0.86) | 0.85 | (0.76, 0.94) |
| Adjusted $R^2$ | 0.36 | | 0.42 | | 0.59 | | 0.60 | |

Note: All models adjusted for sex, race/ethnicity, education, marital status, and number of chronic conditions

Note: HL = health literacy; FA = fluid ability; CA = crystallized ability

Note: All health literacy and cognitive ability scores are standardized

Table 3. The individual contributions of each of the fluid cognitive abilities to the relationship between age and health literacy, the LitCog Cohort, 2008-10 (n=774)

| | Model 1<br>Age only | Model 2<br>Age<br>+ processing speed | Model 3<br>Age<br>+ working memory | Model 4<br>Age<br>+ inductive reasoning | Model 5<br>Age<br>+ prospective memory | Model 6<br>Age<br>+ long-term memory |
|---|---|---|---|---|---|---|
| TOFHLA score | β (95% CI) | β (95% CI) | β (95% CI) | β (95% CI) | β (95% CI) | β (95% CI) |
| Age | | | | | | |
| 55-59 | - | - | - | - | - | - |
| 60-64 | -0.13 (-0.27, 0.00) | 0.01 (-0.11, 0.12) | -0.06 (-0.18, 0.06) | -0.04 (-0.16, 0.08) | -0.13 (-0.26, 0.003) | -0.14 (-0.27, -0.01) |
| 65-69 | -0.15 (-0.31, 0.00) | 0.01 (-0.12, 0.14) | -0.04 (-0.18. 0.10) | -0.06 (-0.20, 0.07) | -0.14 (-0.29, 0.01) | -0.14 (-0.29, 0.01) |
| 70-74 | -0.39 (-0.55, -0.22) | -0.06 (-0.20, 0.08) | -0.22 (-0.36, 0.07) | -0.17 (-0.31, -0.02) | -0.35 (-0.51, -0.19) | -0.29 (-0.45, -0.13) |
| Adjusted $R^2$ | 0.43 | 0.60 | 0.54 | 0.56 | 0.45 | 0.46 |
| NVS score | | | | | | |
| Age | | | | | | |
| 55-59 | - | - | - | - | - | - |
| 60-64 | -0.04 (-0.16, 0.09) | 0.04 (-0.08, 0.16) | 0.01 (-0.11, 0.13) | 0.04 (-0.07, 0.16) | -0.03 (-0.16, 0.09) | -0.05 (-0.17, 0.08) |
| 65-69 | -0.11 (-0.25, 0.04) | -0.01 (-0.15, 0.13) | -0.03 (0.16, 0.11) | -0.03 (-0.16, 0.10) | -0.09 (-0.23, 0.05) | -0.10 (-0.24, 0.05) |
| 70-74 | -0.38 (-0.53, -0.22) | -0.21 (-0.36, 0.06) | -0.26 (-0.40, -0.11) | -0.19 (-0.33, -0.05) | -0.34 (-0.49, -0.19) | -0.28 (-0.43, -0.13) |
| Adjusted $R^2$ | 0.50 | 0.55 | 0.55 | 0.59 | 0.52 | 0.53 |

Note: All models adjusted for sex, race/ethnicity, education, marital status, and number of chronic conditions

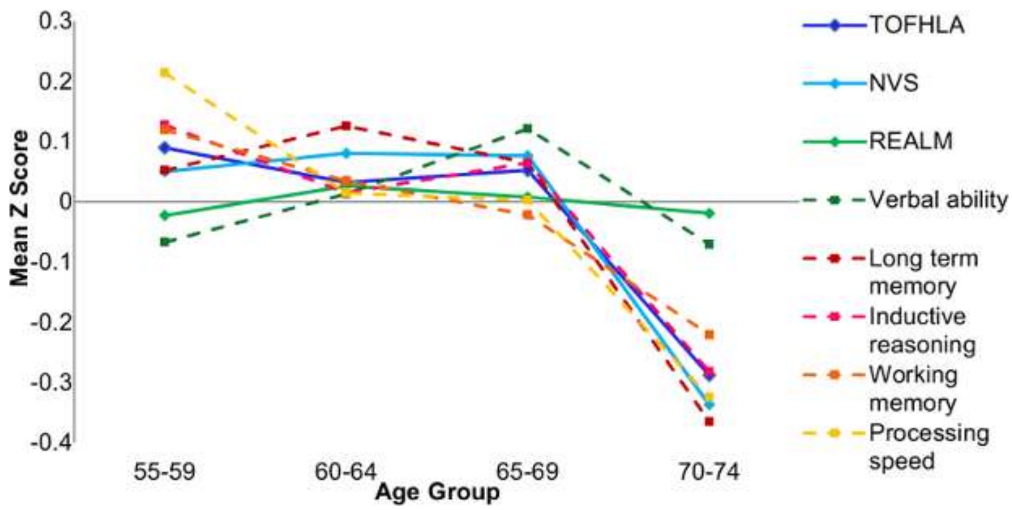



Figure. Health literacy and cognitive abilities by 5-year age group, the LitCog study (n=774)
52x25mm (300 x 300 DPI)

**STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies***

| Section/Topic | Item # | Recommendation | Reported on page # |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | 1 |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | 2 |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | 4-5 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | 5 |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | 5-6 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | 5-6 |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants | 5-6 |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 6-7 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | 6-8 |
| Bias | 9 | Describe any efforts to address potential sources of bias | 8 |
| Study size | 10 | Explain how the study size was arrived at | 6 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | 7-9 |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | 8-9 |
| | | (*b*) Describe any methods used to examine subgroups and interactions | N/A |
| | | (*c*) Explain how missing data were addressed | 8-9 |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy | N/A |
| | | (*e*) Describe any sensitivity analyses | 9 (post-hoc analysis) |
| **Results** | | | |

| | | | |
|---|---|---|---|
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | 6, 9 |
| | | (b) Give reasons for non-participation at each stage | 6 |
| | | (c) Consider use of a flow diagram | Not done as study flow is simple to describe in the text |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | 8-9 |
| | | (b) Indicate number of participants with missing data for each variable of interest | 9 |
| Outcome data | 15* | Report numbers of outcome events or summary measures | 9 |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | 9, 10, Table 1 |
| | | (*b*) Report category boundaries when continuous variables were categorized | 7, 9 |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | N/A |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | 10-11 |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | 11 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | 13 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | 11-14 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | 10, 13 |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | 14 |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.