Social isolation, health literacy, and mortality risk: findings from the English Longitudinal Study of Ageing

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Abstract

Objective: To investigate the relationships between social isolation, health literacy, and all-cause mortality, and the modifying effect of social isolation on the latter relationship.

Methods: Data were from 7731 adults aged ≥50 years participating in Wave 2 (2004/05) of the English Longitudinal Study of Ageing. Social isolation was defined according to marital / cohabiting status and contact with children, relatives and friends, and participation in social organisations. Scores were split at the median to indicate social isolation (yes vs. no). Health literacy was assessed as comprehension of a medicine label and classified as 'high' (≥75% correct) or 'low' (<75% correct). The outcome was all-cause mortality up to February 2013. Cox proportional hazards models adjusted for sociodemographic factors, health status, health behaviours, and cognitive function.

Results: Mortality rates were 30.3% vs. 14.3% in the low vs. high health literacy groups, and 23.5% vs. 13.7% in the socially isolated vs. non-isolated groups. Low health literacy (adj. HR=1.22, 95%CI 1.02–1.45 vs. high) and social isolation (adj. HR=1.28, 95%CI 1.10–1.50) were independently associated with increased mortality risk. The multiplicative interaction term for health literacy and social isolation was not statistically significant (p=0.81).

Conclusions: Low health literacy and high social isolation are risk factors for mortality. Social isolation does not modify the relationship between health literacy and mortality. Clinicians should be aware of the health risks faced by socially isolated adults and those with low health literacy.

Key words: Health literacy; social isolation; mortality; social support

Introduction

Health literacy is increasingly recognized as an independent determinant of health-related outcomes. The construct is defined as 'the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions' (Institute of Medicine, 2004). Low health literacy has been associated with non-adherence to medication regimes (O'Conor et al., 2015; Zhang, Terry, & McHorney, 2014), low engagement in health-promoting lifestyle behaviors (von Wagner, Knight, Steptoe, & Wardle, 2007), and low uptake of preventive services (Kobayashi, Wardle, & von Wagner, 2013; Sudore, Mehta, et al., 2006). Among older adults, low health literacy has been identified as a risk factor for decline in physical function (Smith et al., 2015), hospital admission (Baker, Parker, Williams, & Clark, 1998), and all-cause mortality (Baker et al., 2007; Baker, Wolf, Feinglass, & Thompson, 2008; Bostock & Steptoe, 2012; Sudore, Yaffe, et al., 2006). One-fifth to one-third of older adults are estimated to have low health literacy in national surveys within the U.S. and the U.K. (Kutner, Greenberg, Jin, Paulsen, & White, 2007; Paasche-Orlow, Parker, Gazmararian, Nielsen-Bohlman, & Rudd, 2005; von Wagner et al., 2007), as well as in a meta-analysis of prevalence estimates across nine countries and languages (Kobayashi, Wardle, Wolf, & von Wagner, 2016a). Risk factors for having low health literacy include older age, belonging to a racial minority group, having low education, being in a low socioeconomic position, and being a linguistic minority. Health literacy could be an important target for explaining and addressing health inequalities (Kobayashi & Smith, 2016; Kobayashi et al., 2016a; Kutner et al., 2007).

Health literacy is conceptualised as an attribute of individuals, although focussing on individual capability neglects the contribution of the social environment

to health. For older adults, a particular concern is social isolation, defined as the reflection of a small network size and paucity of social contact (Berkman, Glass, Brissette, & Seeman, 2000; Steptoe, Deaton, & Stone, 2015). The intertwined age-related issues of reduced physical function, increased economic constraints, and the ill health and passing of partners and friends make social isolation increasingly likely in older age. Isolation results in a lack of emotional support, as well as a dearth of assistance with daily health matters, such as managing chronic conditions, attending medical appointments, and accessing and understanding health information (Berkman et al., 2000). Social isolation is associated with increased all-cause mortality risk in older adults (Holt-Lunstad, Smith, Baker, Harris, & Stephenson, 2015).

Social isolation might be particularly detrimental for the health of people with low health literacy, who may have greater need to rely on their social networks for instrumental and decision-making support or for behavioural cues to compensate for their lack of skills in managing health (Lee, Arozullah, & Cho, 2004). People with low health literacy may also experience shame and stigma, making help-seeking more difficult and stressful (Parikh, Parker, Nurss, Baker, & Williams, 1996). Providing the social network members have adequate levels of health literacy, being part of a supportive social relationship could promote health literacy and buffer the negative effects of low basic skills on health and facilitate access to health care and services (Edwards, Wood, Davies, & Edwards, 2012). There has been a single study examining social support as a moderator of the relationship between health literacy and health status (Lee, Arozullah, Cho, Crittenden, & Vicencio, 2009). The study found social support had a greater positive effect on self-rated health status among adults with high health literacy, although it was limited by its cross-sectional design and self-reported outcomes.

We investigated the direct effects of health literacy and social isolation on all-cause mortality over eight years in a nationally representative cohort of English adults aged ≥50 years. Crucially, we aimed to examine whether people with low health literacy are protected from increased all-cause mortality risk if they are less socially isolated.

Methods

Sample

Data were from Wave 2 (June 2004 to July 2005) of the English Longitudinal Study of Ageing (ELSA), a nationally representative cohort study of men and women aged ≥50 years (Steptoe, Breeze, Banks, & Nazroo, 2012). The ELSA was established in 2002 (Wave 1), with the initial sample (n=11392 core members) drawn from households with one or more member aged ≥50 years who responded in 1998, 1999, and 2001 to a government health survey that used random stratified sampling of all households in England. The baseline ELSA sample was representative of the general population of England aged ≥50 years, according to comparison with the national census. ELSA data are collected through in-home computer-assisted interviews with trained interviewers, alongside self-completion questionnaires. Wave 2 was used as the baseline for the present analysis, as health literacy was first assessed in this wave. The response rate in Wave 2 was 81.5% of eligible participants. Participants eligible for the present analysis had valid data for health literacy, month of interview, month of death, and who consented to mortality follow-up (n=7865). We excluded those who died within 12 months of baseline (n=134), leaving a final analytic sample of 7731 men and women. Participants gave informed consent and ethical approval was obtained from the National Research Ethics Service.

Measures

Health literacy

Health literacy was assessed using a brief reading comprehension test. Participants were shown a fictitious medicine label similar to that found on a packet of aspirin and asked four reading comprehension questions by the interviewer, e.g. "What is the maximum number of days you may take this medicine?" (Appendix 1). The measure was developed by the OECD and Statistics Canada for the Adult Literacy & Life Skills Survey to reflect the clinically-relevant health task of understanding and interpreting instructions on a medicine label (Thorn, 2009). We categorised health literacy as 'high' (≥3/4 correct answers) or 'low' (<3/4 correct answers) (Bostock & Steptoe, 2012).

Social isolation

We created an index of social isolation by assigning one point if the respondent was unmarried/not cohabiting, had less than monthly contact (including face-to-face, telephone, or written/e-mail contact) with each of the following: any of their children, other family members, and friends, and if they did not participate in social organisations such as social clubs or residents groups, religious groups or committees (Steptoe, Shankar, Demakakos, & Wardle, 2013). People without children were given a score of zero for this item. Scores ranged from 0 to 5, with higher scores indicating greater social isolation. The median split method was used to define social isolation, whereby a score of 0 or 1 reflected no social isolation, and a score of 2 or more reflected social isolation.

Mortality

We obtained data on all-cause mortality up to February 2013 from the National Health Service central data registry for all participants who consented to mortality follow-up (96.5%). The mean follow-up period was 92.6 months (7.7 years), with a range of 13 to 105 months (1.1 to 8.8 years).

Covariates

We included data on a range of covariates that are known to confound the relationship between health literacy and risk of all-cause mortality (Bostock & Steptoe, 2012). Sociodemographic covariates were age (52-59; 60-69; 70-79; ≥80 years), sex, ethnicity (white; non-white), educational attainment (no qualifications; below degree level; degree or equivalent), occupational class (routine; intermediate; managerial or professional), and net non-pension wealth (quintiles stratified at age 65 to account for changes following retirement).

Participants reported whether they had ever had doctor-diagnosed heart disease (including angina, heart attack, congestive heart failure, and abnormal heart rhythm), diabetes, cancer, stroke, asthma, and chronic lung disease (including bronchitis or emphysema). To cover unlisted conditions, we used data on self-reported limiting longstanding illness, assessed with two questions: "*Do you have any long-standing illness, disability, or infirmity? By long-standing I mean anything that has troubled you over a period of time or that is likely to affect you over a period of time*." If they responded yes, they were asked "*Does this illness or disability limit your activities in any way?*" Affirmation of a long-standing illness and any limitation classified the participant as having a limiting long-standing illness. Functional impairment was assessed by asking participants whether they had difficulties with six

activities of daily living (such as using the toilet) because of health or physical problems. We coded 'yes' to any question as a positive response. Symptoms of depression were assessed using the eight-item Center for Epidemiological Studies depression scale, with a score of ≥4 indicating depressive symptoms (Steffick, 2000).

Participants reported their current smoking status (current vs. former/never smoker) and alcohol consumption (daily/almost daily vs. less than daily). Physical activity was assessed as the frequency of engagement in sports or activities that were vigorous/moderately energetic/mildly energetic. We dichotomised responses to distinguish between those who took part in moderate or vigorous leisure time physical activity at least once a week vs. less than once a week.

Cognitive function was assessed via a battery of commonly used interviewer-administered psychometric tests. We selected three measures to assess memory and executive function known to be sensitive to age-related decline and would be minimally influenced by reading skills: orientation in time (correctly stating the year, month, date, and day of the week, yes or no) (Folstein, Folstein, & McHugh, 1975); immediate recall (recall of 10 orally presented words) (Ofstedal, Fisher, & Herzog, 2005); and verbal fluency (number of animals listed in one minute) (Strauss, Sherman, & Spreen, 2006). The cognitive measures used within ELSA are associated with mortality (Batty, Deary, & Zaninotto, 2016).

Statistical analyses

Baseline characteristics of participants with high and low levels of health literacy were compared using t-tests for continuous variables and χ^2 tests for categorical variables. A similar approach was taken to compare sample characteristics between wave 1 and wave 2, as well as to examine the sociodemographic factors associated

with missing health literacy data. We used Cox proportional hazards regression models to estimate the hazard ratios (HRs) of all-cause mortality and 95% confidence intervals (CIs) associated with low health literacy, with high health literacy as the reference category, and mortality associated with high and low social isolation, with low isolation as the reference category. Survival time was measured in months from the date of interview to the date of death or to follow-up in February 2013. We fitted five models. Model 1 was adjusted for age and sex. We added demographic factors (ethnicity, educational attainment, occupational class, and non-pension wealth quintile) to model 2. In model 3, we added health indicators at baseline, including limiting long-standing illness, functional impairment, depressive symptoms, cancer, heart disease, stroke, diabetes, arthritis, and chronic lung disease. In model 4, we added health behaviours. In model 5, we added measures of cognitive function. We estimated the association between social isolation and mortality also using Cox proportional hazards regression, adjusting for all covariates. Finally, to investigate whether social isolation moderated the association between health literacy and mortality, we added a multiplicative interaction term for health literacy and social isolation into the model. Analyses were conducted using IBM SPSS version 22.

Results

Sample characteristics

Of the 7731 participants in our sample, 6770 (87.6%) had high health literacy and 961 (12.4%) had low health literacy. Low health literacy was more frequent among participants who were older, who identified as non-white, and who had low educational attainment, low net wealth, and a job in a low occupational class (Table

1). Low health literacy was more frequent among participants with impaired physical function, depressive symptoms, and limiting long-standing illnesses such as heart disease, diabetes, stroke, and lung disease. Smoking, physical inactivity and less than daily alcohol intake were associated with low health literacy. Cognitive function scores were lower, on average, among the group with low health literacy scores. Using a median split to define social isolation (0-1 vs. 2 or more), 17.4% of participants were completely isolated. Social isolation was more frequent among participants who were older, male, less educated, and who had a low net wealth and a job in a low occupational class (Table 2). Social isolation was also more frequent among those with depressive symptoms, functional impairment, and a limited long-standing-illness such as heart disease, chronic lung disease and stroke. Smokers, those who were physically active less than once a week, those who drank less than daily, those who were not time orientated and who scored lower on the cognitive fluency tests were more likely to be socially isolated.

Compared with the total wave 1 core sample, our final analytical sample was significantly younger (mean [SD] age 64.0 [9.5] vs. 68.0 [11.67] years, $p<.001$). Included participants were more likely to be female (55.2% vs. 52.9%, $p=.018$), white (98.0% vs. 94.9%, $p<.001$) and married (68.2% vs. 62.7%, $p<.001$), and less likely to have no educational qualifications (37.7% vs. 53.6%, $p<.001$), work in routine occupations (42.4% vs. 52.5%, $p<.001$) or be in the lowest quintile of wealth (16.0% vs. 26.6%, $p<.001$).

There were 391 individuals who were otherwise eligible for inclusion in our sample who had missing data on health literacy. Compared to our final sample of 7731

participants, these individuals tended to be older (mean [SD] age 74.6 [12.7] vs. 66.3 [9.6] years, p<.001), and a higher proportion were unmarried (44.8% vs. 30.8%, p<.001), had no educational qualifications (66.2% vs. 37.1%, p<.001). Participants missing health literacy data were also more likely to belong to non-white ethnic groups (9.2% vs. 1.7%, p<.001), work in routine occupations (56.5% vs. 42.4%, p<.001), and be in the lowest wealth quintile group (37.5% vs. 17.8%, p<.001). The groups did not differ by sex (p=.427).

Health literacy, social isolation, and mortality

Overall, 1261/7731 (16.3%) participants died by the census date. Health literacy was significantly associated with all-cause mortality, with mortality rates of 30.3% vs. 14.3% in the low and high health literacy groups, respectively. After sequential adjustment for all of age and sex, demographic variables, baseline health status, health behaviours, and cognitive function, low health literacy remained a predictor of all-cause mortality (HR=1.22; 95% CI: 1.02–1.45; Table 3). Social isolation was also associated with an increased risk of all-cause mortality, with 23.5% of people dying by the census date in the group defined as socially isolated, compared with 13.7% in the non-isolated group. After sequential adjustment for all covariates, social isolation remained a significant predictor of all-cause mortality (HR=1.28; 95% CI 1.10–1.50) (Table 3). The multiplicative interaction term for health literacy and social isolation was not statistically significant (p=0.81).

In the fully adjusted model people who were older, male, smokers, less physically active and those with a limiting long-standing illness, heart disease, cancer or chronic lung disease had an increased risk of all-cause mortality (Supplementary

Table 1). Those who were not time orientated and had lower recall task scores also had an increased risk of all-cause mortality.

Discussion

Low health literacy and social isolation were independently associated with increased all-cause mortality risk over an 8-year period in this population-representative sample of older English adults. Adults with low health literacy were 22% more likely to die over the follow-up than those with high health literacy, and socially isolated individuals were 28% more likely to die than those who scored low in social isolation. Given older adults are at increased risk of social isolation and low health literacy, the joint effects on mortality of these two factors warrants further attention (Kobayashi et al., 2016a; Thomas, 2011).

This study is among the first to test the model proposed by Lee and colleagues (2004) in which they propose that social support could moderate the relationships between health literacy and health outcomes. A cross-sectional study (n=489) with self-reported outcomes provided some support for the hypotheses, but larger studies with stronger outcomes are needed. Our large prospective study with objective mortality outcome data constitutes the strongest test of the model to date. It is therefore important to note that while the main effects of literacy and social isolation on mortality were significant, the interaction between health literacy and social isolation on mortality did not reach statistical significance. This could represent a meaningful absence of effect whereby health literacy has a similar impact on mortality regardless of one's social isolation. However, further replication of our analyses are required.

The absence of a direct association between health literacy and social isolation contrasts with qualitative data on the topic. The Health Literacy Pathway Model argues that health literacy skills are distributed throughout a social network, which in turn promotes self-management of chronic conditions, communication with medical professionals and health decision-making (Edwards et al., 2012; Edwards, Wood, Davies, & Edwards, 2015). Our data do not support these hypotheses and no attenuation of the relationship between health literacy and mortality was observed when adjusting for social isolation. However this was not the primary aim of our analyses and alternative approaches using social network analysis may provide further insight (Carrington, 2005).

Our results are of further importance in developing the evidence base for the independent roles of health literacy and social isolation on mortality risk in older adults (Baker et al., 2007, 2008; Bostock & Steptoe, 2012; Holt-Lunstad et al., 2015; Lee et al., 2009; Sudore, Yaffe, et al., 2006). Previous studies of health literacy and mortality risk in older adults have had follow up periods of five to six years (Baker et al., 2007, 2008; Bostock & Steptoe, 2012; Sudore, Yaffe, et al., 2006). A previous analysis of ELSA found health literacy was associated with mortality over a 5 year period (Bostock & Steptoe, 2012). The current data extend this observation by demonstrating that this relationship persists for at least eight years.

Our findings contribute to understanding the role of cognition in the relationship between health literacy and adverse health behaviours and outcomes. Previous work indicates these relationships are largely due to poor underlying cognitive function (Baker et al., 2008; Mõttus et al., 2014; O'Conor et al., 2015; Wolf et al., 2012). However, we showed only small attenuation of the relationship between health literacy and mortality when including cognitive function within the model.

Formal mediation analyses are needed however, as cognition and health literacy were recorded within the same data collection wave.

There are many potential explanations for these different observations. The ELSA is a larger dataset by comparison with the LitCog (Wolf et al., 2012), ABLE (O'Conor et al., 2015) and the Lothian Birth Cohort 1936 samples (Mõttus et al., 2014), and therefore our estimates for these relationships may have been more accurate. ELSA also used different measures of health literacy and cognitive function to these datasets. For example, LitCog contains measures of reasoning, prospective memory, verbal ability and processing speed which were not adjusted for in our analyses. Some of these assessments involved literacy skills, and therefore the correlation with health literacy assessments would be expected to be stronger. More speculatively, health literacy could be more strongly related to behaviours that are more proximal to mortality than morbidity. However, this requires investigation and replication in other datasets.

Importantly, social isolation is a risk factor for increased cognitive decline during ageing (Bassuk, Glass, & Berkman, 1999), which in turn may have a negative effect on health literacy (Kobayashi, Wardle, Wolf, & von Wagner, 2015; Kobayashi et al., 2016a). Therefore, health literacy might decline more rapidly over time among those older adults who are socially isolated, magnifying the health risks associated with each factor. Investigating how the relationship between social isolation and health literacy changes over time could be an important next step in future research.

Social network membership is undoubtedly beneficial to health (Berkman & Syme, 1979; Ford, Loucks, & Berkman, 2006; Fratiglioni, Paillard-Borg, & Winblad, 2004; Loucks et al., 2006; Shankar, McMunn, Banks, & Steptoe, 2011; Steptoe et al., 2013), and our results suggest it is of similar importance for groups with different

health literacy levels (Lee et al., 2004). Social isolation reflects a range of adverse factors that could lead to increased mortality risk (Berkman et al., 2000). Adults who are socially isolated are denied the resources conferred by membership in a social network, including positive support for one's ability and motivation to access health services and engage in health-promoting behaviours (Berkman et al., 2000; Rosenstock, Strecher, & Becker, 1988). Social influence, also lacking in situations of isolation, may either enable or constrain positive health behaviours (Berkman et al., 2000). People often take social cues from those who are close to them, adhering to the behavioural norms of their network (Emmons, Barbeau, Gutheil, Stryker, & Stoddard, 2007; Sorensen et al., 2007). For example, positive health behaviour changes are more likely to be initiated and maintained by those with a partner who engages in healthy behaviours (Jackson, Steptoe, & Wardle, 2015). Identifying further explanations for the relationship between social isolation and mortality could contribute to the development of interventions at the individual and societal level.

This study had limitations. Our analytical sample were younger, and more likely to be female, white, married, and have educational qualifications and less likely to work in routine occupations or have low wealth. These differences are consistent with retention in other longitudinal studies (Mendes de Leon, 2007). The socio-demographic groups who were less likely to provide data on health literacy are similar to the groups who scored poorly on the assessment. It is therefore likely that we underestimate the prevalence of low health literacy within the sample.

This analysis could not establish causality, as the data were observational. It may be that people with low health literacy or who were socially isolated at baseline had worse health, and were more likely to die for this reason. We accounted for this possibility by excluding those participants who passed away within 12 months of the

baseline study interview and adjusting for a range of chronic conditions and self-rated health. People with low health literacy may also be less accurate at reporting their own chronic diseases or rating their own general health than those with adequate health literacy, which could affect the results if there was a consistent tendency to under- or overestimate their health conditions.

Our social isolation measure has been previously used and is associated with important health outcomes (Steptoe et al., 2013), but it has not been validated. Similarly, our measure of chronic conditions was not validated. Replication of our results in other cohorts with validated instruments is needed. We opted to define social isolation by a median split, partly because of skewed data. This may have compromised statistical power. Cut-points are likely to vary from sample to sample. The median level of social isolation captures the norm within a sample, and therefore our measure perhaps reflects relative rather than absolute isolation. Future research is needed to identify the optimal threshold for defining isolation.

Strengths of this study include its representativeness of a wide segment of the older English population. Rich data on sociodemographic and health-related factors were collected through in-person interviews, and we had an approximately eight-year follow-up period for all-cause mortality. The analyses were adjusted for a range of different factors known to affect the outcome, including socio-demographic, physical and cognitive measures.

These results demonstrate that older adults are simultaneously at risk of being socially isolated and lacking health literacy skills. The effects on mortality of these two factors underscore the importance of further investigation. There was no support for the hypothesis that lower levels of social isolation would protect an individual from the harmful effects of low health literacy. This effect requires replication in

similarly large cohorts where objective mortality data are available. Researchers and clinicians should be aware of the health risks faced by older adults at risk of social isolation and low health literacy.

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Table 1. Participant characteristics at baseline by health literacy score. Values are numbers (percentages) unless stated otherwise

Participant characteristic	Health literacy		p-value
	High (n=6770; 87.6%)	Low (n=961; 12.4%)	
Demographics			
Age (years) (*n* = 7731)			
52-59	2223 (32.8)	170 (17.7)	<.001
60-69	2322 (34.3)	279 (29.0)	-
70-79	1606 (23.7)	309 (32.2)	-
≥80	619 (9.1)	203 (21.1)	-
Sex (*n* = 7731)			
Male	3007 (44.4)	453 (47.1)	.112
Female	3763 (55.6)	508 (52.9)	-
Ethnicity (*n* = 7728)			
White	6675 (98.6)	919 (95.6)	<.001
Non-white	92 (1.4)	42 (4.4)	-
Educational attainment (*n* = 7729)			
None	2259 (33.4)	608 (63.3)	<.001
Up to degree level	3568 (52.7)	331 (34.5)	-
Degree or equivalent	942 (13.9)	21 (2.2)	-
Occupational class (*n* = 7624)			
Routine	2669 (39.9)	564 (60.3)	<.001
Intermediate	1631 (24.4)	212 (22.6)	-

Managerial	2388 (35.7)	160 (17.1)	-
Wealth quintile (*n* = 6863)			
1 (poorest)	962 (16.0)	260 (31.2)	<.001
2	1145 (19.0)	196 (23.5)	-
3	1251 (20.7)	166 (19.9)	-
4	1294 (21.5)	132 (15.8)	-
5 (richest)	1377 (22.8)	80 (9.6)	-
Baseline health status			
Limiting long-standing illness (*n* = 7729)			
Present	2210 (32.7)	461 (48.0)	<.001
Absent	4558 (67.3)	500 (52.0)	-
Functional impairment (*n* = 7730)			
Present	1200 (17.7)	301 (31.3)	<.001
Absent	5569 (82.3)	660 (68.7)	-
Depressive symptoms (*n* = 7678)			
Present	895 (13.3)	231 (24.3)	<.001
Absent	5834 (86.7)	718 (75.7)	-
Heart disease (*n* = 7731)			
Present	758 (11.2)	178 (18.5)	<.001
Absent	6012 (88.8)	783 (81.5)	-
Diabetes (*n* = 7731)			
Present	516 (7.6)	120 (12.5)	<.001
Absent	6254 (92.4)	841 (87.5)	-
Stroke (*n* = 7731)			

Present	259 (3.8)	75 (7.8)	<.001
Absent	6511 (96.2)	886 (92.2)	-
Cancer (*n* = 7731)			
Present	422 (6.2)	56 (5.8)	.625
Absent	6348 (93.8)	905 (94.2)	-
Asthma (*n* = 7731)			
Present	851 (12.6)	142 (14.8)	.056
Absent	5919 (87.4)	819 (85.2)	-
Chronic lung disease (*n* = 7731)			
Present	461 (6.8)	105 (10.9)	<.001
Absent	6309 (93.2)	856 (89.1)	-
Health behaviours			
Smoking (*n* = 7718)			
Current smoker	988 (14.6)	176 (18.3)	.003
Non-smoker	5769 (85.4)	785 (81.7)	-
Physical activity (*n* = 7731)			
Once a week or more	4459 (65.9)	455 (47.3)	<.001
Less than once a week	2311 (34.1)	506 (52.7)	-
Alcohol intake (*n* = 6832)			
Daily	1458 (24.1)	120 (15.5)	<.001
Less than daily	4602 (75.9)	652 (84.5)	-
Cognitive function			
Time orientation (*n* = 7731)			
Yes	5527 (81.6)	672 (69.9)	<.001
No	1243 (18.4)	289 (30.1)	-

Recall (mean, SD) (*n* = 7730)	5.87 (1.67)	4.66 (1.71)	<.001
Fluency (mean, SD) (*n* = 7730)	20.61 (6.24)	16.54 (5.85)	<.001
Social isolation			
Social isolation (*n* = 7135)			
Not isolated	3792 (60.2)	483 (57.6)	.152
Isolated	2505 (39.8)	355 (42.4)	-

Note: Numbers may not sum to the total sample number, as some items were not answered by all participants.

Table 2. Participant characteristics at baseline by social isolation.

Participant characteristic	Social isolation		p-value
	Not isolated (n=5892; 82.6%)	Isolated (n = 1243; 17.4%)	
Age (years)			
52-59	1856 (31.5)	356 (28.6)	<.001
60-69	2086 (35.4)	373 (30.0)	-
70-79	1438 (24.4)	325 (26.1)	-
≥80	512 (8.7)	189 (15.2)	-
Sex			
Male	2619 (44.5)	583 (46.9)	.114
Female	3273 (55.5)	660 (53.1)	-
Ethnicity			
White	5811 (98.7)	1229 (98.9)	.403
Non-white	79 (1.3)	13 (1.0)	-
Educational attainment			
None	2005 (34.0)	566 (45.5)	<.001
Up to degree level	3093 (52.5)	568 (45.7)	-
Degree or equivalent	792 (13.4)	109 (8.8)	-
Occupational class			
Routine	2339 (40.2)	606 (49.6)	<.001
Intermediate	1419 (24.4)	288 (23.6)	-
Managerial	2060 (40.2)	328 (26.8)	-
Wealth quintile			
1 (poorest)	734 (13.9)	341 (30.4)	<.001
2	978 (18.5)	253 (22.5)	-

3	1144 (21.6)	204 (18.2)	-
4	1209 (22.8)	162 (14.4)	-
5 (richest)	1230 (23.2)	162 (14.4)	-
Baseline health status			
Limiting long-standing illness			
Present	1923 (32.6)	506 (40.7)	<.001
Absent	3967 (67.4)	737 (59.3)	-
Functional impairment			
Present	1055 (17.9)	297 (23.9)	<.001
Absent	4836 (82.1)	946 (76.1)	-
Depressive symptoms			
Present	715 (12.2)	268 (21.8)	<.001
Absent	5146 (87.8)	961 (78.2)	-
Heart disease			
Present	680 (11.5)	169 (13.6)	.042
Absent	5212 (88.5)	1074 (86.4)	-
Diabetes			
Present	471 (8.0)	107 (8.6)	.471
Absent	5421 (92.0)	1136 (91.4)	-
Stroke			
Present	218 (3.7)	74 (6.0)	<.001
Absent	5674 (96.3)	1169 (94.0)	-
Cancer			
Present	368 (6.2)	76 (6.1)	.862
Absent	5892 (93.8)	1167 (93.9)	-
Asthma			

Present	747 (12.7)	168 (13.5)	.422
Absent	5145 (87.3)	1075 (86.5)	-
Chronic lung disease			
Present	382 (6.5)	137 (11.0)	<.001
Absent	5510 (93.5)	1106 (89.0)	-
Health behaviours			
Smoking			
Current smoker	755 (12.8)	283 (22.8)	<.001
Non-smoker	5126 (87.2)	959 (77.2)	-
Physical activity			
Once a week or more	3894 (66.1)	696 (56.0)	<.001
Less than once a week	1998 (33.9)	547 (44.0)	-
Alcohol intake			
Daily	1334 (22.6)	244 (19.6)	.020
Less than daily	4308 (73.1)	946 (76.1)	-
Cognitive function			
Time orientation			
Yes	4802 (81.5)	975 (78.4)	.012
No	1090 (18.5)	268 (21.6)	-
Recall (mean, SD)	5.82 (1.68)	5.52 (1.75)	<.001
Fluency (mean, SD)	20.49 (6.26)	19.38 (6.27)	<.001

Note: Numbers may not sum to the total sample number, as some items were not answered by all participants. Valid percentages are presented for ease of interpretation. Values are numbers (percentages) unless stated otherwise

Table 3. Direct associations between low health literacy, social isolation, and all-cause mortality

Models	Hazard ratios (95% CI)[a]	
	Low health literacy	Social isolation
Model 1: adjusted for age and sex	1.56 (1.36, 1.78)	1.50 (1.32, 1.72)
Model 2: model 1 + demographics[b]	1.40 (1.21, 1.63)	1.39 (1.20, 1.61)
Model 3: model 2 + baseline health status[c]	1.33 (1.14, 1.55)	1.34 (1.16, 1.56)
Model 4: model 3 + health behaviours[d]	1.29 (1.08, 1.53)	1.28 (1.09, 1.49)
Model 5: model 4 + cognitive function[e]	1.22 (1.02, 1.45)	1.28 (1.10, 1.50)
Model 6a: model 5 + social isolation	1.22 (1.03, 1.46)	-
Model 6b: model 5 + health literacy	-	1.29 (1.10, 1.51)

Note: Models 1-5 are testing the role of health literacy and social isolation on mortality separately.

[a]Obtained from multivariable Cox proportional hazards regression models with high health literacy / low social isolation as the reference category.

[b]Included ethnicity, educational attainment, occupational class, wealth quintile.

[c]Included limiting long-standing illness, functional impairment, depressive symptoms, and self-reported doctor-diagnosed disease: heart disease, diabetes, cancer, stroke, asthma, and chronic lung disease.

[d]Included current smoking, moderate/vigorous exercise once or more weekly, and daily or almost daily alcohol consumption.

[e]Included time orientation, recall of word list, fluency on an animal naming task.