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published in
American Journal of Epidemiology
1999

DOI (link to publisher)
10.1093/oxfordjournals.aje.a010107

document version
Publisher's PDF, also known as Version of record

American Journal of Epidemiology

Vol. 150, No. 9
Printed in U.S.A.

Cognitive Functioning and Health as Determinants of Mortality in an Older Population

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The authors studied whether the ability of cognitive functioning to predict mortality is pervasive or specific, and they considered the role of health in the cognition-mortality association. Data were taken from a sample of 2,380 persons aged 55–85 years who took part in the Netherlands' Longitudinal Aging Study Amsterdam in 1992–1993. Five cognitive measures were distinguished: general cognitive functioning, information processing speed, fluid intelligence, learning, and proportion retained. Mortality data were obtained during an average follow-up period of 1,215 days. Cox proportional hazards regression models revealed that all cognitive functions predicted mortality independent of age, sex, education, and depressive symptoms. When health (self-rated health, medication use, physical performance, functional limitations, lung function, specific chronic diseases) was also taken into account, information processing speed, fluid intelligence, and proportion retained remained independent predictors of mortality, whereas the ability of general cognitive functioning and learning to determine mortality was lost. The authors concluded that the ability of cognitive functioning to predict mortality is pervasive to all cognitive functions that were included in the study when age, sex, education, and depressive symptoms are considered and is more specific to some functions when also controlling for health. *Am J Epidemiol* 1999;150:978–86.

aged; cognition; health; mortality; prospective studies

Cognitive impairment has been shown to be strongly associated with mortality in older persons (1–4). However, a number of issues concerning the relation between cognitive performance and mortality have not yet been resolved.

First, physical health has an impact on both cognitive performance and mortality and may therefore confound the cognition-mortality association (4). Two hypotheses deal with the role of health in the relation between cognitive functioning and mortality. The chronic disease hypothesis states that cognitive impairment is an indicator of specific chronic diseases, which eventually cause death. Diseases such as diabetes and atherosclerosis are known to affect both cognitive functioning (5) and mortality. A second hypothesis states that cognitive deterioration reflects a general breakdown due to basic biologic aging processes, resulting in decreased organ reserve capacity and failure of homeostatic systems (1, 4).

Many studies seem to confirm the early findings of Birren (6) and Riegel et al. (7) that cognitive performance predicts mortality independent of health. However, some studies did not include any health measures (8–10); others contained a single or a limited number (11) of health measures, particularly self-rated health (7), or the number of chronic diseases (2, 12). Unfortunately, few studies have included a broad range of self-reported and objective health measures. The role of health in the relation between cognition and mortality therefore has not been well controlled (1, 4).

Second, it remains to be shown whether the nature of the ability of cognitive functioning to predict mortality is pervasive (i.e., present for all cognitive functions) or is specific to one or more functions. The general breakdown hypothesis suggests that this ability is pervasive and that those cognitive functions known to be affected by physiologic functioning, such as information processing speed (1), best predict mortality.

So far, some studies have reported on the predictive ability of measures related to information processing

Received for publication April 22, 1998, and accepted for publication March 4, 1999.

Abbreviations: CES-D, Center for Epidemiologic Studies Depression Scale; CI, confidence interval; LASA, Longitudinal Aging Study Amsterdam; LSN, Living Arrangements and Social Networks of Older Adults; MMSE, Mini-Mental State Examination; OR, odds ratio.

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speed (1), verbal tasks (6, 8, 10, 12–14), and memory scores (3, 9). Moreover, the use of either single measures or composite scores (15) precludes any direct comparison of the value of separate cognitive functions in predicting mortality.

Third, many studies have used samples that were selective with respect to sex (1), education (10), health (1, 12), or degree of urbanization (8, 15–17). The use of selective samples may limit the generalizability of the conclusions drawn from the results.

The preceding information led to the following research questions:

1. Does health attenuate the ability of cognitive functioning to predict mortality?
2. Is the ability of cognitive functioning to predict mortality specific to particular cognitive functions or pervasive?

To answer these questions, we used a large national sample of older respondents well representative of all levels of physical health and cognitive performance.

MATERIALS AND METHODS

Sample and procedure

This study was based on complete data for 2,380 respondents who were included in the Longitudinal Aging Study Amsterdam (LASA) baseline. LASA is a study of the predictors and consequences of changes in physical, cognitive, emotional, and social functioning in the elderly population (18). A random sample, stratified by age and sex according to expected mortality after 5 years, was drawn from the population registries of 11 municipalities in three culturally distinct geographic areas of the Netherlands. The cohort was recruited for the Living Arrangements and Social Networks of Older Adults (LSN) Study (response rate, 3,805 persons (62.3 percent)). LSN nonresponse was associated with age ($p < 0.05$), and there was a higher rate of nonresponse among the oldest old persons due to physical or cognitive impairment (19). The LSN sample was found to be representative of the underlying population with respect to urbanization, regional distribution, and marital status (19).

The LASA baseline interview, conducted from September 1992 through September 1993 (10 months after the LSN interview), covered a broad spectrum of topics related to cognition, health, and social and psychological functioning. To minimize respondent burden, the LASA interview was completed in two sessions. The first was completed by 3,107 respondents (response rate, 81.7 percent of LSN participants). The response rate for the second session was 86.0 percent of these 3,107 respondents ($n = 2,671$).

Before LSN respondents were approached by LASA interviewers, 126 respondents (3.3 percent) had died, 44 (1.2 percent) could not be contacted, 134 (3.5 percent) were too ill or cognitively impaired to be interviewed, and 394 (10.4 percent) were unwilling to participate because of a lack of interest. Again, there was a decline in response with increasing age ($p < 0.001$). The LASA sampling procedure has been described by Smit and De Vries (20). The stratified sampling frame, with an overrepresentation of older old persons and males, guarantees the inclusion of a sufficient number of respondents in the oldest age group as well as people in poor health and with poor cognitive functioning.

Interviewers were trained during five sessions, each lasting 6 hours. Training techniques included video instruction and role playing (20). Throughout the data collection period, interviewers were monitored continuously by audiotaping their sessions and providing the interviewers with regular feedback.

Measures

Mortality. Mortality status was ascertained for all LASA respondents by using information from the municipalities as of August 1, 1996. On this date, of 2,671 LASA baseline respondents who had completed both interview sessions, 351 had died. Missing data on other variables left information on 263 deceased respondents available for our analyses (11.0 percent of 2,380 respondents with complete data).

Cox proportional hazards regression analyses took the time interval between interview and date of death or August 1, 1996, whichever occurred first, into account. This interval ranged from 55 to 1,486 days, with a mean of 1,214.9 days (standard deviation, 223.9).

Cognitive functioning. Five measures of cognitive functioning were included, all known to be sensitive to changes associated with aging: general cognitive functioning, information processing speed, fluid intelligence, learning, and proportion retained. The Mini-Mental State Examination (MMSE) (21) measures general cognitive functioning and is widely considered an indicator of cognitive impairment. Possible scores on this test range from 0 to 30; higher scores indicate better cognitive performance. The psychometric properties of the MMSE have been described by Tombaugh and McIntyre (22) and, for an aged sample of Dutch persons, by Launer et al. (23). The scores for the present sample ranged from 13 to 30, with a mean score of 27.4 (standard deviation, 2.25).

Information processing speed was measured by using the Coding Task, an adaptation of the Alphabet Coding Task 15 (24). Respondents were given a sheet of paper with an example at the top of the page, which

consisted of two rows of characters. The characters on top of each other belonged together. Underneath the sample rows, just the top character was listed. Respondents were asked to name the character that belonged underneath and to work as quickly and accurately as possible. The testing format was changed from written (24) to oral to avoid motor problems associated with hand-writing (particularly among frail persons) and problems related to the reliability of the readings by coding clerks. The characters were enlarged to 7 mm to reduce nonresponse due to poor eyesight. The average scores for the available trials were used. Correlations between the trial scores were very high (0.88–0.92). The scores for the present sample ranged from 4.33 to 50.67; the mean score was 24.34, with a standard deviation of 7.38.

Fluid intelligence, the ability to deal with essentially new problems, was measured by using Raven's Coloured Progressive Matrices (25). Respondents were presented with an incomplete design and six alternatives and were asked to choose the one that best completed the design. Every correctly solved item resulted in a score of 1. The original Raven's Coloured Progressive Matrices contain three sets (A, Ab, and B) of 12 items each. To limit respondents' burden, only sets A and B were used in the present study. An earlier study has shown that the score for the complete instrument correlates strongly (0.96) with the score for sections A and B (26). The possible range of scores extends from 0 to 24. In the present sample, the scores ranged from 2 to 24, with a mean of 18.04 and a standard deviation of 3.99.

Memory was measured by using an adaptation of the Auditory Verbal Learning Test (27, 28). After a list of 15 words was read to respondents, they were asked to remember as many of the words as possible by naming them. The procedure was repeated twice. After approximately 20 minutes, during which time respondents completed a nonverbal task, they were again asked to name the words they remembered (delayed recall). Conducting this test resulted in scores that reflected learning (the sum of the number of words recalled after the first three trials) and the proportion of words retained (100 × the number of correct delayed recall words ÷ the maximum number of correct words recalled during any of the first three trials). The correlations between the first three trials were substantial (ranging from 0.62 to 0.79). The learning scores ranged from 1 to 39, with a mean of 18.84 and a standard deviation of 6.11. For proportion retained, the minimum score was 0.00, the maximum score was 150.00, the mean score was 64.84, and the standard deviation was 25.88.

Health. Health measures were selected because they encompass a broad range of health aspects. Moreover, the questions on self-rated health (29), functional limitations (11, 17), medication use (29), and the presence of chronic diseases (30) as well as tests of lung function (31) and physical performance (32) have been shown to be associated with mortality in older adults.

Self-rated health was measured with one question (33) that asked respondents to rate their health in general. Answers, on a 5-point scale, ranged from "excellent" to "poor." Furthermore, respondents were asked whether they currently used prescribed medications (no or yes).

Physical ability was measured with a questionnaire on functional limitations in using transportation, going up and down a staircase, and cutting one's toenails (34). Respondents were asked to indicate whether they had difficulty doing the activity, needed help, or were not able to do the activity at all. An index of functional limitations was obtained by summing the items for which respondents reported that they had difficulty or needed help.

Peak expiratory flow rate is the studied measure of lung function, indicating the maximum quantity of air exhaled (31). This rate was measured three times by using a mini-Wright peak flow meter (Armstrong Industries, North Brook, Illinois), a small handheld device that provides a crude measure of lung function. While in a standing position, respondents were asked to blow into the instrument as hard and fast as possible. The observed peak expiratory flow rate was the maximum of three measurements.

The physical performance tests included measures of mobility, balance, coordination, and strength (34). Respondents were asked to perform the following tasks: 1) put on and take off a standard cardigan, 2) close one specific button while the cardigan is on, 3) walk 3 m back and forth, and 4) get up from a kitchen chair five times with arms folded (32, 35–37). The time needed to perform each task was measured in seconds by using a stopwatch. Each subject for whom there was a time score on a performance test was given a score of 1–4 corresponding to the quartile of the distribution of time needed: the more time needed, the higher the score. Those who could not perform the test were assigned a score of 5 (32). The reliability of these four items was satisfactory, given the small number of items (Cronbach's alpha = 0.62). The four items were summed to produce a physical performance summary score. Low scores indicated good performance and high scores poor performance.

The presence of chronic diseases was determined by asking participants whether they had had any of the following diseases or disease events (38) (no or yes): chronic nonspecific lung diseases (asthma, chronic bronchitis, or pulmonary emphysema), cardiac disease (including a history of myocardial infarction), periph-

eral atherosclerosis of the abdominal aorta or the arteries of the lower limb, diabetes mellitus, cerebrovascular accident (excluding transient ischemic attacks), arthritis (rheumatoid arthritis or osteoarthritis), malignant neoplasms (cancer), and other chronic diseases. Agreement between respondents' self-reported data and the data from their general practitioners has been shown to be satisfactory to good for most diseases (38).

Other determinants. As age, sex, educational level, and depression were shown to be confounding variables in earlier studies on the relation between health and mortality and/or between cognitive impairment and mortality (11, 39–40), these variables were included in our study. Data on age and sex were derived from the municipal registries. Age was registered as chronologic age at the time of the baseline interview. Educational level was assessed by asking respondents to name the highest educational course they had completed. The original nine categories of education were recoded to three: low (incomplete or completed elementary education), middle (lower and intermediate vocational education and general intermediate training), and high (general secondary and higher vocational education, college, and university education).

The presence of depressive symptoms was assessed by using the Center for Epidemiologic Studies Depression Scale (CES-D) (41). The Dutch translation of the CES-D provided satisfactory psychometric results when used in an older Dutch sample (42). CES-D scores range from 0 to 54; 0 reflects the lowest possible level of depressive symptoms.

Of the cognitive functioning tasks, the MMSE and the Raven's Coloured Progressive Matrices were completed during the first interview session, whereas the Coding Task and the 15 Words Test were part of the second session. The CES-D, the physical performance tests, and the questions on self-rated health, functional limitations, and chronic diseases were included in the first session. Questions on prescribed medication use and the lung function test were included in the second interview.

Analyses

Preliminary analyses focused on the bivariate relation between independent variables and mortality. Subsequently, those variables shown to predict mortality were entered in Cox proportional hazards regression analyses.

Separate Cox proportional hazards regression models were evaluated for the effects of specific cognitive functions, adjusted for age, sex, education, and depressive symptoms (models 1). These Cox proportional hazards models were extended by adding the health measures (models 2). The analyses addressed both the question of the specificity of the ability of these cognitive functions and the role of health in predicting mortality.

As higher-order effects prevail over lower-order effects, the significance of interaction terms of cognitive functioning with age was tested in separate Cox regression analyses. To avoid multicollinearity between the first-order terms and the product terms, product terms were formed by multiplying the centered (deviation from the mean) scores of the determinants of interest.

The bivariate analyses used the median as a cutoff score of the continuous determinant variables or, as in the case of the MMSE, a cutoff that was of clinical significance. In the Cox proportional hazards analyses, education was treated as a categorical variable (reference category, middle), as the bivariate analyses showed a U-shaped relation; that is, respondents with a middle level of education had a lower rate of mortality than respondents with a high or low level of education. In the Cox proportional hazards analyses, the cognitive measures were entered as standardized scores (same mean, same standard deviation) to facilitate comparison of the ability of the cognitive functions to predict mortality on the basis of the odds ratios in the analyses.

RESULTS

Respondents who were not included because of missing data appeared to have a higher mortality rate than respondents with complete data (odds ratio (OR) = 0.39, 95 percent confidence interval (CI): 0.31, 0.48). Furthermore, respondents with complete data, in comparison with those who had incomplete data, were younger, were better educated, reported fewer depressive symptoms, and did better in terms of all included cognitive functioning and health measures, except peripheral atherosclerotic disease, arthritis, cancer, cardiac diseases, and other chronic diseases (data not shown). In all, these 2,380 respondents constituted a relatively healthy selection of the original sample, but, because of the stratified sampling frame, a sufficient number of people in the oldest age group as well as people in poor health and with poor cognitive functioning were included (table 1). Apart from age, sex, education, and depressive symptoms, a considerable number of variables were significantly related to mortality. All cognitive variables and all health variables, except arthritis and other chronic diseases, showed significant associations with mortality.

Intercorrelations between the cognitive variables ranged from 0.15 to 0.54. The correlation of memory variables with other cognitive variables was generally weaker, and general cognitive functioning, information processing speed, and fluid intelligence correlated moderately to strongly (data not shown).

TABLE 1. Percentages and numbers of persons who died, by all study variables,† among a sample of 2,380 persons who participated in the Longitudinal Aging Study Amsterdam, the Netherlands, 1992–1996

	Total no.	Persons who died	
		%	No.
Age (years)*			
55–64	836	3.7	31
65–74	783	8.9	70
75–85	761	21.3	162
Sex*			
Male	1,176	14.1	166
Female	1,204	8.1	97
Educational level*			
Low	952	13.9	132
Middle	1,084	8.6	93
High	351	11.1	39
Depressive symptoms (no.)*			
0–15	2,094	10.1	211
16–60	286	18.2	52
Self-rated health*			
Excellent/good	1,514	9.0	136
Fair/poor	866	14.7	127
Functional limitations*,‡			
1–3	874	17.3	151
0	1,506	7.4	112
Lung function*,§			
60–≤405	1,169	14.4	168
406–800	1,211	7.8	95
Medication use*			
No	857	4.9	42
Yes	1,523	14.5	221
Physical performance score**			
4–9	1,247	5.9	73
10–20	1,133	16.8	190
Chronic nonspecific lung diseases***			
No	2,122	10.6	225
Yes	258	14.7	38
Cardiac disease*			
No	1,922	9.4	180
Yes	458	18.1	83
Atherosclerosis*			
No	2,156	9.7	210
Yes	224	23.7	53
Diabetes*			
No	2,215	9.8	218
Yes	165	27.3	45
Cerebrovascular accident**			
No	2,279	10.7	243
Yes	101	19.8	20
Arthritis			
No	1,538	10.7	164
Yes	842	11.8	99
Cancer**			
No	2,172	10.5	227
Yes	208	17.3	36
Other diseases			
No	1,610	11.5	185
Yes	770	10.1	78
General cognitive functioning*,¶			
<24	151	23.2	35
24–30	2,229	10.2	228
Information processing speed*			
0–24.50	1,180	16.4	194
24.51–50.70	1,200	5.8	69
Fluid intelligence*			
2–18	1,219	14.9	182
19–24	1,161	7.0	81
Learning*			
1–18	1,163	15.7	183
19–39	1,217	6.6	80
Proportion retained*			
0–≤65.90	1,142	14.2	162
65.91–150	1,238	8.2	101

Table continues

* $p < 0.001$; ** $p < 0.01$; *** $p < 0.05$.
† All continuous variables have been recoded as low and high scores on the basis of the median; general cognitive functioning was recoded on the basis of a clinically relevant cutoff point.
‡ No. of items performed with difficulty.
§ Peak expiratory flow rate.
¶ Mini-Mental State Examination score.

Intercorrelations among the continuous health variables (self-rated health, performance tests) were low to moderate, ranging from 0.18 to 0.48 (data not shown). The presence of specific chronic diseases was not strongly associated with the presence of other chronic diseases (data not shown). As intercorrelations were not extremely high, the independent variables might have been thought to reflect empirically distinct concepts; therefore, collinearity was not considered a major problem in the analyses.

In separate Cox regression analyses, the included interaction terms of cognitive functioning with age did not appear to be significant predictors of mortality. Therefore, the results presented here focused on the total sample.

Table 2, models 1, reflects the results of separate analyses of the ability of general cognitive functioning,

information processing speed, fluid intelligence, learning, and proportion retained to predict mortality. Each cognitive function predicted mortality when controlling for age, sex, education, and depressive symptoms. Information processing speed appeared to be the strongest cognitive determinant of mortality (OR = 0.69, 95 percent CI: 0.59, 0.81) and general cognitive functioning the weakest (OR = 0.88, 95 percent CI: 0.78, 0.98).

The impact of health factors on the relation between the cognitive functions and mortality is shown in table 2, models 2. The ability of information processing speed (OR = 0.80, 95 percent CI: 0.67, 0.94), fluid intelligence (OR = 0.86, 95 percent CI: 0.75, 0.99), and proportion retained (OR = 0.87, 95 percent CI: 0.77, 0.97) to predict mortality remained significant after control for health factors. General cognitive functioning and learning did not predict mortality when health was taken into account.

DISCUSSION

The present study focused on the prediction of mortality based on distinct cognitive functions and on the role of health in this relation in a large population sample aged 55–85 years. In bivariate analyses and after control for age, sex, education, and depressive symptoms, all cognitive measures were associated with mortality. In this sense, the ability of cognitive functions to determine mortality is pervasive. This ability remained intact for all cognitive functions except general cognitive functioning and learning when health factors were taken into account and therefore may be said to be more specific. The ability to predict mortality did not differ substantially for the cognitive components distinguished in cognitive aging research (43), which were included in our study: information processing speed, fluid intelligence, and memory.

The reliability of the self-reported health measures and their sensitivity to cognitive functioning might have limited our conclusions. For this reason, objective health measures (performance tasks and lung function) were included. Furthermore, measurement of self-reported medication use was very thorough, and the interviewer actually inspected the medication. In previous research, the role of cognitive functioning in the discrepancy between self-report and performance-based tests has been shown to be minor (44). In our study, the association between the performance task scores and self-rated health did not differ substantially for respondents with high versus low MMSE scores (data not shown). Therefore, the self-reported health measures do not appear to have been sensitive to cognitive impairment. Finally, agreement between respondents' self-reported data and the data from their general practitioners was shown to be satisfactory for most chronic diseases, which underlines the reliability of the self-report question on chronic diseases (38).

The results of the present study are to some extent in accordance with those of previous investigations. The results concerning memory have been mixed. Some studies have reported weak abilities to predict mortality (45), whereas others have described memory as a strong predictor (3, 9). Contrary to our findings, several studies have reported the MMSE to be a good predictor of mortality (11, 17, 46). These studies did not include such a broad range of health measures as our study did, which may explain the discrepancy in results. Earlier studies also found information processing speed to be a good determinant of mortality (1). Furthermore, the predictive ability of other specific aspects of cognitive functioning independent of health variables has been noted before, albeit not with such a broad range of self-reported and objective health measures in a large population sample as were included in our study.

In explaining our results, we reflected on the chronic disease hypothesis, the general breakdown hypothesis, and some alternatives. In the present study, some chronic diseases were found to predict mortality. However, our results did not confirm the chronic disease hypothesis, as cognitive functions appeared to be predictors of mortality independent of the most common chronic diseases. Our finding that information processing speed, considered a basic component of cognitive functioning, was such a strong determinant of mortality affirms the general breakdown hypothesis (1, 4). This hypothesis could not be affirmed completely because not all cognitive functions retained their ability to predict mortality when health was considered.

In any case, the ability of information processing speed, fluid intelligence, and proportion retained to predict mortality independent of health measures suggests that the association between cognitive functions and mortality reflects processes different from those underlying the relation between health and mortality. The fact that general cognitive functioning, as measured by using the MMSE, did not predict mortality when health was taken into account suggests that the relation between cognition and mortality might not be attributable to cognitive impairment, as occurs with dementia. Low MMSE scores may also be due to other factors, such as lifelong subnormal cognitive functioning or emotional disorder. Final conclusions about dementia as a predictor of mortality are therefore feasible only in studies that include dementia diagnoses. An alternative explanation is that limited cognitive functioning may increase health hazards as a result of decreased behavioral adaptations, such as failure to

TABLE 2. *Multivariate determinants of mortality among a sample of 2,380 persons who participated in the Longitudinal Aging Study Amsterdam, the Netherlands, 1992-1996,†**

	General cognitive functioning		Information processing speed		Fluid Intelligence		Learning		Proportion retained	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
					Models 1‡					
Cognitive ability (standardized; low = poor, high = good)	**0.88**	**0.78, 0.98**	**0.69**	**0.59, 0.81**	**0.80**	**0.70, 0.91**	**0.86**	**0.74, 0.99**	**0.87**	**0.78, 0.98**
Age (55–85 years)	**1.08**	**1.06, 1.10**	**1.07**	**1.05, 1.09**	**1.08**	**1.06, 1.10**	**1.08**	**1.06, 1.10**	**1.08**	**1.06, 1.10**
Sex (male = 1, female = 2)	**0.49**	**0.37, 0.64**	**0.52**	**0.40, 0.68**	**0.49**	**0.37, 0.64**	**0.51**	**0.39, 0.67**	**0.50**	**0.38, 0.65**
Educational level§ low	1.05	0.71, 1.54	0.82	0.55, 1.22	0.95	0.64, 1.41	1.09	0.75, 1.59	1.13	0.78, 1.64
Educational level§ high	0.79	0.54, 1.16	0.70	0.47, 1.03	0.74	0.50, 1.09	0.81	0.55, 1.18	0.83	0.57, 1.21
Depressive symptoms (0 = low, 54 = high)	**1.03**	**1.02, 1.05**	**1.03**	**1.02, 1.05**	**1.03**	**1.02, 1.05**	**1.03**	**1.02, 1.05**	**1.04**	**1.02, 1.05**
					Models 2¶					
Cognitive ability (standardized; *low = poor, high = good*)	0.90	0.81, 1.01	**0.80**	**0.67, 0.94**	**0.86**	**0.75, 0.99**	0.92	0.79, 1.06	**0.87**	**0.77, 0.97**
Age (55–85 years)	**1.05**	**1.03, 1.07**	**1.04**	**1.02, 1.06**	**1.05**	**1.03, 1.07**	**1.05**	**1.03, 1.07**	**1.05**	**1.03, 1.07**
Sex (male = 1, female = 2)	**0.42**	**0.31, 0.56**	**0.44**	**0.32, 0.60**	**0.42**	**0.31, 0.58**	**0.43**	**0.32, 0.59**	**0.43**	**0.32, 0.58**
Educational level§ low	0.90	0.61, 1.34	0.82	0.55, 1.22	0.87	0.60, 1.30	0.95	0.65, 1.39	0.96	0.66, 1.40
Educational level§ high	0.75	0.51, 1.10	0.72	0.48, 1.05	0.73	0.50, 1.08	0.77	0.52, 1.13	0.77	0.53, 1.13
Depressive symptoms (0 = low, 54 = high)	1.01	1.00, 1.03	1.01	1.00, 1.03	1.01	1.00, 1.03	1.02	0.99, 1.03	1.01	1.00, 1.03
Self-rated health (1 = excellent, 5 = poor)	1.02	0.87, 1.19	1.02	0.87, 1.19	1.02	0.88, 1.19	1.02	0.87, 1.18	1.01	0.87, 1.18
Functional limitations (many-no items with difficulty)	0.90	0.78, 1.04	0.91	0.79, 1.05	0.91	0.79, 1.05	0.91	0.79, 1.05	0.90	0.78, 1.03
Lung function (60 = poor, 800 = good)	**1.00#**	**0.99, 0.99**	**0.99**	**0.99, 0.99**	**0.99**	**0.99, 0.99**	**0.99**	**0.99, 0.99**	**0.99**	**0.99, 0.99**
Medication use (no-yes)	**1.71**	**1.19, 2.44**	**1.66**	**1.16, 2.38**	**1.68**	**1.17, 2.41**	**1.70**	**1.19, 2.44**	**1.68**	**1.17, 2.41**
Physical performance (4 = fast, 20 = slow)	**1.05**	**1.01, 1.10**	1.05	1.00, 1.10	**1.06**	**1.01, 1.10**	**1.06**	**1.01, 1.11**	**1.05**	**1.01, 1.10**
Chronic nonspecific lung diseases (no-yes)	0.75	0.51, 1.09	0.77	0.53, 1.13	0.77	0.52, 1.12	0.75	0.52, 1.10	0.77	0.52, 1.12
Cardiac disease (no-yes)	1.12	0.84, 1.49	1.13	0.85, 1.51	1.11	0.83, 1.48	1.13	0.85, 1.51	1.12	0.84, 1.49
Atherosclerosis (no-yes)	1.35	0.98, 1.87	1.33	0.96, 1.84	1.36	0.98, 1.88	1.33	0.96, 1.84	1.35	0.98, 1.87

Diabetes (no-yes)	**1.93**	**1.38, 2.70**	**1.87**	**1.33, 2.62**	**1.88**	**1.34, 2.63**	**1.93**	**1.38, 2.70**	**1.99**	**1.42, 2.79**
Cerebrovascular accident (no-yes)	0.74	0.46, 1.19	0.74	0.46, 1.19	0.74	0.46, 1.19	0.76	0.47, 1.22	0.77	0.48, 1.23
Cancer (no-yes)	1.33	0.92, 1.93	1.35	0.93, 1.95	1.31	0.91, 1.91	1.31	0.91, 1.91	1.30	0.90, 1.89

* Cox proportional hazards regression analyses were used.
† Significant odds ratios (OR) and 95% confidence intervals (CI) are in bold type.
‡ Adjusted for age, sex, education, and depressive symptoms.
§ Reference, middle level.
¶ Adjusted for age, sex, education, depressive symptoms, and health factors.
# Because of rounding, the odds ratio does not fall within the confidence limits.

take medication or to call for a physician's help (47, 48). The present study did not include any measures of such behavioral adaptations, leaving this hypothesis untested.

Although we can report on a large sample of respondents that covered a wide age range, with a good representation of all levels of physical health and cognitive functioning, nonresponse was selective, which left a relatively healthy sample. However, the fact that we found significant effects in such a sample suggests that the strengths of the associations might have been underestimated.

The relatively short duration of follow-up may be a limitation of this study, although it has been suggested (8) that most of the significant determinants of mortality can be established during a follow-up period of as short as 5 years. Indeed, in 3 years and 3 months, a considerable number of independent predictors of mortality were found in our study.

Longitudinal studies may enable conclusions to be drawn about the ability of changes in cognitive functioning to determine mortality after controlling for changes in health and about the underlying processes involved. From our data we conclude that general biologic breakdown is the most likely hypothesis explaining the predictive ability of specific cognitive functions independent of health factors.

ACKNOWLEDGMENTS

This study was based on data collected in the context of the Longitudinal Aging Study Amsterdam, funded largely by the Netherlands Ministry of Health, Welfare, and Sports.

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