Education, Other Socioeconomic Indicators, and Cognitive Function

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The authors investigated the relation of educational attainment, husband’s education, household income, and childhood socioeconomic status to cognitive function and decline among community-dwelling women aged 70–79 years. Information on exposures was self-reported, except for income (which was derived from census tract data). Between 1995 and 2000, six cognitive tests were administered to 19,319 Nurses’ Health Study participants. Second assessments began in 2001 and are ongoing; as of April 2002, information was complete for 15,594 women. The authors used logistic regression to calculate multivariate-adjusted odds of a low baseline score (bottom 10%) and substantial decline (worst 10%), and linear regression was used to estimate adjusted mean differences in score and in decline across various levels of education and socioeconomic status. On a global score combining the results of all tests, women with a graduate degree had significantly decreased odds of a low baseline score (odds ratio = 0.49, 95% confidence interval: 0.36, 0.66) and decline (odds ratio = 0.65, 95% confidence interval: 0.50, 0.86) in comparison with women with a Registered Nurse diploma. Significantly lower mean scores and less mean decline were observed among women with a bachelor’s or graduate degree than among women with a Registered Nurse diploma. Much weaker associations were evident for other socioeconomic variables. Thus, among well-educated women, educational attainment predicted cognitive function and decline, although other measures of socioeconomic status had little relation.

cognition; education; income; social class; socioeconomic factors

Abbreviations: CI, confidence interval; EBMT, East Boston Memory Test; MMSE, Mini-Mental State Examination; OR, odds ratio; SD, standard deviation; TICS, Telephone Interview for Cognitive Status.

In many studies, educational attainment at relatively younger ages has been associated with both cognitive function and cognitive decline at older ages (1–6). However, several issues remain unresolved. Some investigators have not collected adequate information for differentiating between educational attainment and associated socioeconomic variables such as income (1, 2), which is known to affect many aspects of health (7–12). Additionally, most investigations have not extensively controlled for health and behavioral characteristics that may confound the relation between education and cognitive function; for example, many potential risk factors for cognitive decline, such as diet (13), use of postmenopausal hormones (14), and history of diabetes (15–17) or cardiovascular disease (18), are related to educational status (19–24). Finally, existing studies have not included many subjects with very high educational attainment; thus, it is unclear whether effects of education may plateau at advanced levels.

To address these issues, we utilized data from the Nurses’ Health Study, a cohort study of female nurses with at least 15 years of education, in which we collected information regarding subjects’ educational attainment and other socioeconomic variables. Since the start of the Nurses’ Health Study, women have additionally provided extensive data on diet and health characteristics, allowing us to adjust for a wide array of potentially confounding factors. In the present analysis, we investigated the relation of educational attainment and other socioeconomic status indicators to baseline performance on a battery of cognitive tests among 19,319 women, as well as change in score over 2 years among

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15,594 subjects. To our knowledge, this is the largest such study conducted to date.

MATERIALS AND METHODS

The Nurses’ Health Study

The Nurses’ Health Study began in 1976, when 121,700 female registered nurses aged 30–55 years in the United States completed a mailed health questionnaire. Information is updated on biennial questionnaires, and follow-up exceeds 90 percent to date.

Population for analysis

Nurses’ Health Study participants aged 70 years or more who were free of diagnosed stroke and had answered the most recent mailed questionnaire were eligible to participate in the cognitive study. From 1995 to 2000, we contacted 22,213 women to administer a brief telephone interview assessing cognitive function; 19,510 women (88 percent) completed the interview, 7 percent refused, and we had inaccurate telephone numbers for 5 percent (i.e., of those contacted, 92 percent agreed to participate). The baseline results presented here included 19,319 subjects who answered a question about educational attainment.

Second interviews, conducted approximately 2 years after the baseline assessment, are ongoing among all participants; as of April 2002, 81 percent (n = 15,594) were complete. Participation remains high, with 5 percent loss to follow-up among women we have attempted to contact so far.

Assessment of cognitive function

The initial assessment consisted of the Telephone Interview for Cognitive Status (TICS) (25), which is modeled on the Mini-Mental State Examination (MMSE). After we had established participants’ acceptance of the telephone testing, we gradually included five additional tests to broaden the scope and accuracy of our assessment. Specifically, from 1995 to 1996, we administered the TICS alone to 862 women; from 1997 to 1999, we administered the TICS, the immediate and delayed recall portions of the East Boston Memory Test (EBMT), and a verbal fluency test to 1,732 women; and from 1999 to 2001, we added delayed recall of the TICS 10-word list at the end of our interview to the global score from an in-person interview administered by registered nurses who had been trained to conduct these interviews. A study of inter-interviewer reliability demonstrated greater than 95 percent correlation on each of our tests. Substantial data support the validity of telephone tests of cognitive function, with reported correlations of 0.85 to 0.96 for comparison of telephone and in-person administrations (27, 28).

We administered a delayed recall of the TICS 10-word list at the end of our interview (approximately 15 minutes later); baseline scores (n = 16,859) ranged from 0 to 10 (mean = 4.6; SD, 2.0). In the second interview, 35 percent of subjects’ scores declined, and the mean score was 4.9 (SD, 1.8).

Delayed recall of 10-word list. We administered a delayed recall of the TICS 10-word list at the end of our interview (approximately 15 minutes later); baseline scores (n = 16,859) ranged from 0 to 10 (mean = 4.6; SD, 2.0). In the second interview, 36 percent of scores declined, and the mean score was 2.7 (SD, 2.2).

East Boston Memory Test. In the EBMT (5), a short story is read to the respondent. Twelve key elements must be repeated immediately; a test of delayed recall is given 15 minutes later. Scores for the immediate recall at baseline (n = 18,591) ranged from 0 to 12; the mean was 9.4 (SD, 1.7). On the second interview (n = 15,593), 36 percent of scores declined, and the mean was 9.5 (SD, 1.8). For the delayed recall, baseline scores (n = 18,569) ranged from 0 to 12 (mean = 9.0; SD, 2.0); on the second interview (n = 15,586), 36 percent of scores declined, with a mean score of 9.1 (SD, 2.1).

Verbal fluency. In the test of verbal fluency (26), women name as many animals as they can during 1 minute. Scores ranged from 1 to 38 at baseline (n = 18,584); the mean was 16.8 (SD, 4.6). On the second interview (n = 15,593), 44 percent of scores declined, and scores ranged from 0 to 44 (mean = 16.9; SD, 4.8).

Digit span backwards. In the digit span backwards test, women repeat backwards increasingly long series of digits (12 series). The mean score was 6.7 (SD, 2.4), and scores ranged from 1 to 12 at baseline (n = 16,848). At the second interview (n = 14,964), 34 percent of scores declined; the range in scores was 0 to 12, with a mean of 6.7 (SD, 2.4).

Global score. To estimate overall performance, we calculated a global cognitive score among women who had completed all tests: 1) the TICS, 2) delayed recall of the TICS 10-word list, 3) immediate and 4) delayed recalls of the EBMT, 5) verbal fluency, and 6) the digit span backwards test (16,812 women at baseline and 13,429 for decline). We created z scores by taking the difference between the participant’s score on each test and the mean and dividing the result by the standard deviation. We added z scores to calculate a global score.

The telephone cognitive assessments were administered by registered nurses who had been trained to conduct these interviews. A study of inter-interviewer reliability demonstrated greater than 95 percent correlation on each of our tests. Substantial data support the validity of telephone tests of cognitive function, with reported correlations of 0.85 to 0.96 for comparison of telephone and in-person administrations (27, 28). In a validation study we conducted among 61 nuns from the Rush Religious Order Study (29)—women of similar age and educational status as our Nurses’ Health Study participants—we found a correlation of 0.81 when comparing the global score from our telephone-administered interview to the global score from an in-person interview consisting of 21 tests.
Assessment of socioeconomic variables

Participants provided information on educational attainment in 1992. In our analyses, we created categories according to the highest degree achieved: Registered Nurse diploma (a 3-year diploma), bachelor’s degree, or doctoral/master’s degree.

We inquired about husband’s education in 1992 among women who were married or widowed. For the analysis, we created four categories: high school or less, college degree, graduate school, and missing information (divorced or separated or no response).

In 1976, women were asked, “When you were 16 years of age, what was your father’s occupation?”. Written responses to this open-ended question were categorized into nine groups (professional, managerial, clerical, sales, craftsmen, service, laborers, farmers, and unknown/retired/deceased). We combined these groups as upper white-collar (professional, managerial), lower white-collar and skilled manual (clerical, sales, service, craftsmen), unskilled manual (laborers), farming, and other/missing (deceased, retired, unknown).

We classified subjects according to median annual household income on the basis of census tract of residence, geocoded to the 1990 US Census. We divided women’s median household income into quartiles (<$27,600, $27,600–$36,699, $36,700–$48,599, and ≥$48,600).

Statistical analysis

In baseline analyses, we used logistic regression to estimate age- and multivariate-adjusted odds ratios for low scores and corresponding 95 percent confidence intervals. For the TICS, we used a score of <31 points to define low scorers (an established cutoff (25)). For the remaining tests, we defined low score as the bottom 10th percentile and corresponding 95 percent confidence intervals.

We performed linear regression to obtain multivariate-adjusted mean differences in baseline test scores among women with different levels of education and other socioeconomic indicators and 95 percent confidence intervals.

In multivariate regression models, we included the primary variables of interest and potentially confounding variables: age at interview (2-year age groups), history of diabetes (yes/no), physician-diagnosed high blood pressure (yes/no), heart disease (yes/no), use of vitamin E supplements (yes/no), use of aspirin (<1 day/month, 1–2 days/week, ≥3 days/week), use of postmenopausal hormones (never, current, past), body mass index (weight (kg)/height (m)2) in four groups (<22, 22–24.9, 25–29.9, ≥30), smoking (current, past, never), daily alcohol consumption (0, 0–4.9, 5.0–14.9, ≥15 g), use of antidepressants (yes/no), age at menopause (<50, 50–52, ≥53 years), and mental health index (0–51, 52–100) and vitality index (0–49, 50–100) from the Medical Outcomes Short Form-36 (better known as the SF-36 (30)). In controlling for history of hypertension, diabetes, and heart disease, we constructed a cumulative variable such that a history was considered present if that disease had been diagnosed at any time prior to baseline cognitive assessment. For other covariates, the most recently updated information prior to the baseline cognitive assessment was used.

In prospective analysis in the subset of women (n = 15,594) for whom we had completed a second cognitive assessment to date, we determined change by subtracting the second test score from the baseline score. Using logistic regression analyses, we obtained odds ratios for substantial decline and 95 percent confidence intervals. We defined as “cases” those women in the worst 10 percent of the distribution of change and as “noncases” the remaining women. The following cutpoints were used: for the TICS, a decline of ≥3; for immediate recall of the TICS 10-word list, a decline of ≥3 (for delayed recall, ≥3); for immediate recall of the EBMT, ≥3 (for delayed recall, ≥3); for the verbal fluency task, ≥6 points; and for the digit span backwards test, ≥3. We also performed linear regression to examine mean declines and corresponding 95 percent confidence intervals.

Covariates included in multivariate models of change included baseline test score and time between first and second interview, as well as the variables described above.

Since we were concerned about possible floor and ceiling effects in examining change, we performed an alternate analysis grouping participants according to baseline score and, within each value, ranked the change in scores; we then normalized the ranks by dividing the difference between an individual’s rank and the mean rank by the standard deviation (3). Results using this method were virtually identical to those obtained from the analyses that simply included baseline score in the model; thus, we present only results using the baseline adjustment, since those are more easily interpretable.

RESULTS

Women whose highest educational degree was a Registered Nurse diploma (a 3-year diploma) represented 77.9 percent of our cohort; 16.4 percent had a bachelor’s degree, and 5.7 percent had a master’s or doctoral degree.

The average ages of the women were similar regardless of educational attainment (table 1). More educated women tended to have a more educated husband and a higher median household income, and they used hormone therapy and vitamin supplements slightly more often than women with less education. They were somewhat less likely to smoke cigarettes, and they reported a lower body mass index.

Analyses of baseline cognitive function

In multivariate-adjusted analyses, we found statistically significant trends of decreasing odds of a low score with an increasing level of education on four tests (TICS: p < 0.01; EBMT, immediate recall and delayed recall: p < 0.01 for both; digit span backwards: p = 0.02) and statistically significantly reduced odds of a low score on four cognitive tests (TICS: p < 0.01; TICS 10-word delayed recall: p < 0.01; verbal fluency: p < 0.01; EBMT immediate recall: p < 0.01) among women with a higher graduate degree (master’s or
doctoral degree) as compared with a Registered Nurse diploma; odds ratios ranged from 0.51 to 0.78. On the global score combining the results of all of our tests, women with a bachelor’s degree had a 17 percent decrease in the odds of a poor score (odds ratio (OR) = 0.83, 95 percent confidence interval (CI): 0.72, 0.96), and women with a graduate degree had a 51 percent decrease (OR = 0.49, 95 percent CI: 0.36, 0.66) in comparison with those with a Registered Nurse diploma after multivariate adjustment.

In contrast, on the global score, there was no difference in odds of a low score for women whose husbands had higher levels of education as compared with a high school education or less (i.e., for a husband with a graduate degree, OR = 0.99, 95 percent CI: 0.85, 1.14). We also found little difference in the odds of low cognitive function across levels of household income ($27,600–$36,699: OR = 0.90, 95 percent CI: 0.86, 1.12; $36,700–$48,599: OR = 0.99, 95 percent CI: 0.86, 1.14; ≥$48,600: OR = 0.89, 95 percent CI: 0.76, 1.03; comparison group, <$27,599). Finally, father’s occupation at age 16 was not related to odds of low cognitive function; we observed only a marginal increase in the odds of a low global score for women whose fathers were farmers as compared with upper white-collar professionals (OR = 1.19, 95 percent CI: 0.99, 1.43).

### TABLE 1. Characteristics of Nurses’ Health Study participants according to educational attainment, 1995–2000

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Master’s or doctoral degree</th>
<th>Bachelor’s degree</th>
<th>Registered Nurse diploma</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. (%)</td>
<td>1,098 (5.7)</td>
<td>3,172 (16.4)</td>
<td>15,049 (77.9)</td>
</tr>
<tr>
<td>Age (years) at interview</td>
<td>74.1</td>
<td>74.1</td>
<td>74.3</td>
</tr>
<tr>
<td>Husband’s education (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school graduate</td>
<td>31.8</td>
<td>29.5</td>
<td>44.2</td>
</tr>
<tr>
<td>Bachelor’s degree</td>
<td>25.1</td>
<td>25.0</td>
<td>20.7</td>
</tr>
<tr>
<td>Graduate degree</td>
<td>31.8</td>
<td>23.0</td>
<td>13.2</td>
</tr>
<tr>
<td>Father’s occupation at age 16 (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper white-collar</td>
<td>30.5</td>
<td>31.6</td>
<td>19.9</td>
</tr>
<tr>
<td>Lower white-collar and skilled manual labor</td>
<td>45.3</td>
<td>45.7</td>
<td>54.6</td>
</tr>
<tr>
<td>Unskilled manual labor</td>
<td>3.7</td>
<td>2.4</td>
<td>3.3</td>
</tr>
<tr>
<td>Farmer</td>
<td>8.3</td>
<td>9.7</td>
<td>11.4</td>
</tr>
<tr>
<td>Other</td>
<td>12.2</td>
<td>10.6</td>
<td>10.8</td>
</tr>
<tr>
<td>Median annual household income (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest quartile (&lt;$27,600)</td>
<td>19.9</td>
<td>19.8</td>
<td>26.3</td>
</tr>
<tr>
<td>Highest quartile ($≥$48,600)</td>
<td>37.5</td>
<td>32.7</td>
<td>22.6</td>
</tr>
<tr>
<td>Mental Health Index score &lt;52 (%)</td>
<td>1.6</td>
<td>2.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Energy Fatigue Index score &lt;50 (%)</td>
<td>18.9</td>
<td>26.6</td>
<td>27.1</td>
</tr>
<tr>
<td>Use of antidepressants (%)</td>
<td>4.1</td>
<td>5.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Cigarette smoking* (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>7.1</td>
<td>9.3</td>
<td>10.1</td>
</tr>
<tr>
<td>Past smoker</td>
<td>43.6</td>
<td>42.8</td>
<td>44.4</td>
</tr>
<tr>
<td>Never smoker</td>
<td>48.5</td>
<td>47.4</td>
<td>45.1</td>
</tr>
<tr>
<td>Mean daily alcohol consumption (g)</td>
<td>5.6</td>
<td>5.6</td>
<td>4.7</td>
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<tr>
<td>Body mass index† ≥30 (%)</td>
<td>16.9</td>
<td>18.7</td>
<td>20.0</td>
</tr>
<tr>
<td>Physician-diagnosed high blood pressure (%)</td>
<td>53.1</td>
<td>53.6</td>
<td>56.2</td>
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<tr>
<td>Diabetes mellitus (%)</td>
<td>8.8</td>
<td>9.4</td>
<td>10.6</td>
</tr>
<tr>
<td>Heart disease (%)</td>
<td>3.4</td>
<td>4.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Current postmenopausal hormone use (%)</td>
<td>34.2</td>
<td>33.0</td>
<td>29.0</td>
</tr>
<tr>
<td>Vitamin E use (%)</td>
<td>45.4</td>
<td>42.2</td>
<td>40.4</td>
</tr>
<tr>
<td>Age (years) at menopause</td>
<td>48.2</td>
<td>49.0</td>
<td>48.4</td>
</tr>
<tr>
<td>Use of aspirin ≥3 times per week (%)</td>
<td>38.4</td>
<td>34.9</td>
<td>35.4</td>
</tr>
</tbody>
</table>

* Percentages for current, past, and never smokers do not add up to 100% because of missing data (0.8% for a master’s or doctoral degree, 0.5% for a bachelor’s degree, and 0.4% for a Registered Nurse diploma).
† Weight (kg)/height (m)^2.
Findings from analyses examining the baseline cognitive test results as continuous data were almost identical to logistic regression results.

Analyses of cognitive decline

After multivariate adjustment, we found statistically significant trends of decreasing odds of cognitive decline with increasing level of education on all six tests (TICS: \( p < 0.01 \); TICS 10-word delayed recall: \( p = 0.03 \); verbal fluency: \( p < 0.01 \); EBTM immediate and delayed recall: \( p < 0.01 \) for both; digit span backwards: \( p = 0.02 \)). On the global score, women with a graduate degree had a 35 percent decrease in odds of substantial decline (OR = 0.65, 95 percent CI: 0.50, 0.86) compared with women with a Registered Nurse diploma, and women with a bachelor’s degree had 20 percent lower odds (OR = 0.80, 95 percent CI: 0.68–0.94) in multivariate-adjusted analyses (table 2).

However, we found little relation between husband’s education and women’s cognitive decline (table 3). For example, on the global score, comparing women whose husbands had an advanced graduate degree with those whose husbands had a high school education or less, the odds ratio was 1.15 (95 percent CI: 0.97, 1.38). Results were similar on the individual tests. We also found no distinction in the odds of decline on the global score across levels of household income (i.e., comparing the top quartile of income with the bottom quartile, OR = 1.04, 95 percent CI: 0.89, 1.22).

Finally, we observed a modest increase in the odds of decline on the global score for women whose fathers were farmers as compared with upper white-collar workers (OR = 1.25, 95 percent CI: 1.01, 1.55).

Results of analyses examining the cognitive tests as continuous data were comparable; we found statistically significantly less mean decline on five tests for women with advanced graduate degrees (TICS, verbal fluency, EBTM immediate and delayed recall, and digit span backwards: \( p < 0.01 \) for all) and statistically significant trends of decreasing mean decline with increasing education (TICS, verbal fluency, EBTM immediate and delayed recall, and digit span backwards: \( p < 0.01 \) for all) after multivariate adjustment. For example, on the global score, mean decline was lower for women with a bachelor’s degree (linear regression estimate of mean difference = –0.20, 95 percent CI: –0.34, –0.06) and women with an advanced graduate degree (difference = –0.39, 95 percent CI: –0.62, –0.17) than for women with a Registered Nurse diploma. Although these absolute differences may seem small, in our generally healthy women, the differences translate into substantial effects. Based on calculations within our subjects, the observed difference in decline on the global score between women with a bachelor’s degree and women with a Registered Nurse diploma was equivalent to the difference between subjects who were almost 2 years apart in age, and having a master’s or doctoral degree was equivalent to being 3 years younger.

There were few relations between other socioeconomic status markers and women’s cognitive decline. For example, on the global score, mean declines were similar for women whose husbands had a higher level of education and women whose husbands had a high school education or less (linear regression estimate of mean difference = –0.09, 95 percent CI: –0.25, 0.07). We found little difference in mean cognitive decline for household income (i.e., comparing the top income level with the bottom income level, the mean difference was –0.11 (95 percent CI: –0.26, 0.04)). Finally, father’s occupation at age 16 had no association with mean decline (i.e., comparing an upper white-collar father with a laborer, the linear regression estimate of mean difference was 0.003 (95 percent CI: –0.30, 0.31)).

**DISCUSSION**

We observed strong, consistent relations between educational attainment and both cognitive function and cognitive decline on several cognitive tests among community-dwelling women aged 70–79 years. All of these women had received at least 3 years of education after high school and were registered nurses. We found substantially weaker effects for other socioeconomic status markers.

Several aspects of this study are unique in comparison with previous investigations. First, to our knowledge, this is the only study that has examined the effects of education and socioeconomic status among highly educated, professional women. Second, we were able to carefully control for confounding by a wide array of health and behavioral covariates. Finally, our large sample size allowed us to estimate effects with great precision.

Since exposure information was self-reported or census-derived, there may have been misclassification. In particular, census-derived information on household income and information on father’s occupation at age 16 may have been randomly misclassified, which may partly explain those generally null results. However, participant’s and husband’s education were probably well-reported; thus, we expect that there was little bias toward the null for these estimates. In these subjects, who all had the same occupation, husband’s education is an extremely strong determinant of socioeconomic status. Therefore, despite the possibility of some misclassification, we believe our finding that subject’s education was highly related to cognitive function and decline while husband’s education was not indicates that education is more important in cognition than is socioeconomic status.

Another limitation may have been the somewhat short follow-up period for measuring cognitive decline, possibly leading us to underestimate true relations with decline. However, the average 2-year interval between interviews was sufficient to identify relations with education, as well as with established risk factors for cognitive decline; for example, on the global score, we found a linear 19 percent elevation in the odds of decline with each 2-year increase in age (OR = 1.19, 95 percent CI: 1.08, 1.31).

Other large studies of cognitive function have generally reported inverse associations between educational attainment and cognitive function. In one cross-sectional study, Gallacher et al. (4) administered cognitive tests to 1,870 men aged 55–69 years in the Caerphilly Study. There was a significant trend of increasing scores with increasing educa-
tion (from none to a college degree) after adjustment for age, mood, and social class; the adjusted mean difference in score between college graduates and men with no educational qualification was 1.6 for the MMSE and 5.9 for the Cambridge Cognitive Examination (4). Another recent cross-sectional study by Cagney and Lauderdale (6) examined 6,577 men and women aged 70 years or older; they found that education had a strong impact on cognition after adjustment for wealth and income.

In a prospective study of 3,266 community-dwelling subjects over age 65 years, Evans et al. (3) administered cognitive tests twice over a 3-year interval and found that each year of education predicted significantly less decline, after adjustment for age, birthplace, language of interview,

<table>
<thead>
<tr>
<th>Cognitive test</th>
<th>Registered Nurse diploma</th>
<th>Bachelor's degree</th>
<th>Master's or doctoral degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>TICS*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. in top 10% of decline</td>
<td>1,246</td>
<td>228</td>
<td>65</td>
</tr>
<tr>
<td>Age-adjusted</td>
<td>1.0</td>
<td>0.78</td>
<td>0.67, 0.91</td>
</tr>
<tr>
<td>Multivariate-adjusted†</td>
<td>1.0</td>
<td>0.81</td>
<td>0.69, 0.94</td>
</tr>
<tr>
<td>TICS 10-word list—immediate recall</td>
<td>816</td>
<td>184</td>
<td>47</td>
</tr>
<tr>
<td>Age-adjusted</td>
<td>1.0</td>
<td>0.90</td>
<td>0.75, 1.08</td>
</tr>
<tr>
<td>Multivariate-adjusted†</td>
<td>1.0</td>
<td>0.92</td>
<td>0.76, 1.11</td>
</tr>
<tr>
<td>TICS 10-word list—delayed recall</td>
<td>638</td>
<td>156</td>
<td>59</td>
</tr>
<tr>
<td>Age-adjusted</td>
<td>1.0</td>
<td>1.05</td>
<td>0.86, 1.29</td>
</tr>
<tr>
<td>Multivariate-adjusted†</td>
<td>1.0</td>
<td>1.03</td>
<td>0.83, 1.27</td>
</tr>
<tr>
<td>Test of verbal fluency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. in top 10% of decline</td>
<td>1,276</td>
<td>304</td>
<td>113</td>
</tr>
<tr>
<td>Age-adjusted</td>
<td>1.0</td>
<td>0.96</td>
<td>0.83, 1.31</td>
</tr>
<tr>
<td>Multivariate-adjusted†</td>
<td>1.0</td>
<td>0.98</td>
<td>0.84, 1.13</td>
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<tr>
<td>EBMT*—immediate recall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. in top 10% of decline</td>
<td>1,323</td>
<td>271</td>
<td>86</td>
</tr>
<tr>
<td>Age-adjusted</td>
<td>1.0</td>
<td>0.90</td>
<td>0.78, 1.04</td>
</tr>
<tr>
<td>Multivariate-adjusted†</td>
<td>1.0</td>
<td>0.89</td>
<td>0.77, 1.04</td>
</tr>
<tr>
<td>EBMT—delayed recall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. in top 10% of decline</td>
<td>1,233</td>
<td>234</td>
<td>76</td>
</tr>
<tr>
<td>Age-adjusted</td>
<td>1.0</td>
<td>0.86</td>
<td>0.74, 1.00</td>
</tr>
<tr>
<td>Multivariate-adjusted†</td>
<td>1.0</td>
<td>0.85</td>
<td>0.73, 0.99</td>
</tr>
<tr>
<td>Digit span backwards test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. in top 10% of decline</td>
<td>1,338</td>
<td>304</td>
<td>94</td>
</tr>
<tr>
<td>Age-adjusted</td>
<td>1.0</td>
<td>0.98</td>
<td>0.84, 1.13</td>
</tr>
<tr>
<td>Multivariate-adjusted†</td>
<td>1.0</td>
<td>0.99</td>
<td>0.85, 1.16</td>
</tr>
<tr>
<td>Global score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. in top 10% of decline</td>
<td>1,068</td>
<td>211</td>
<td>64</td>
</tr>
<tr>
<td>Age-adjusted</td>
<td>1.0</td>
<td>0.80</td>
<td>0.68, 0.94</td>
</tr>
<tr>
<td>Multivariate-adjusted†</td>
<td>1.0</td>
<td>0.80</td>
<td>0.68, 0.94</td>
</tr>
</tbody>
</table>

* OR, odds ratio; CI, confidence interval; TICS, Telephone Interview for Cognitive Status; EBMT, East Boston Memory Test.
† Multivariate-adjusted analyses were adjusted for age at interview, husband’s education, father’s occupation at age 16, census-derived median household income (according to census tract), mental health index, vitality index, use of antidepressants, cigarette smoking, body mass index, high blood pressure, diabetes, heart disease, current use of postmenopausal hormones, vitamin E intake, age at menopause, use of aspirin, and time between the two interviews. In controlling for history of hypertension, diabetes, and heart disease, we constructed a cumulative variable such that a history was considered present if that disease had been diagnosed at any time prior to baseline cognitive assessment. For other covariates, the most recently updated information obtained prior to the baseline cognitive assessment was used.
However, this population was substantially less educated than ours (75 percent of subjects had less than a high school education) (3). Another study of change in MMSE over 1 year by Farmer et al. (1) included 14,833 subjects aged 18 years or more. Each 8-year increment in education was related to a 70 percent lower risk of decline on the MMSE (relative risk = 0.3, 95 percent CI: 0.2, 0.4) after adjustment for age, sex, ethnicity, residential status, income, baseline score, and substance abuse. However, there was little control for confounders, and most participants had a high school education or less (1). Finally, in a study of 1,488 men and women, the association between education and cognitive decline was also found to be significant. The table below shows the odds ratios for cognitive decline (Telephone Interview for Cognitive Status score and global cognitive score) according to husband’s education, father’s occupation at age 16, and income among participants in the Nurses’ Health Study, 1995–April 2002.

**TABLE 3.** Odds ratios for cognitive decline (Telephone Interview for Cognitive Status score and global cognitive score) according to husband’s education, father’s occupation at age 16, and income among participants in the Nurses’ Health Study, 1995–April 2002

<table>
<thead>
<tr>
<th>Socioeconomic status measure</th>
<th>No. in the worst 10%</th>
<th>Age-adjusted OR*</th>
<th>95% CI*</th>
<th>Multivariate-adjusted OR†</th>
<th>95% CI†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Telephone Interview for Cognitive Status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Husband’s education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>647</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>College degree</td>
<td>325</td>
<td>0.90</td>
<td>0.78, 1.04</td>
<td>0.95</td>
<td>0.82, 1.10</td>
</tr>
<tr>
<td>Graduate degree</td>
<td>218</td>
<td>0.83</td>
<td>0.70, 0.98</td>
<td>0.91</td>
<td>0.77, 1.08</td>
</tr>
<tr>
<td>Annual income‡</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;$27,599</td>
<td>383</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$27,600–$36,699</td>
<td>399</td>
<td>1.04</td>
<td>0.89, 1.21</td>
<td>1.04</td>
<td></td>
</tr>
<tr>
<td>$36,700–$48,599</td>
<td>384</td>
<td>0.97</td>
<td>0.83, 1.13</td>
<td>1.01</td>
<td>0.86, 1.18</td>
</tr>
<tr>
<td>≥$48,600</td>
<td>373</td>
<td>0.95</td>
<td>0.81, 1.10</td>
<td>1.04</td>
<td>0.89, 1.22</td>
</tr>
<tr>
<td>Father’s occupation at age 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper white-collar</td>
<td>325</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower white-collar</td>
<td>803</td>
<td>1.10</td>
<td>0.96, 1.26</td>
<td>1.05</td>
<td>0.92, 1.21</td>
</tr>
<tr>
<td>Blue-collar</td>
<td>52</td>
<td>1.22</td>
<td>0.89, 1.68</td>
<td>1.15</td>
<td>0.84, 1.59</td>
</tr>
<tr>
<td>Farmer</td>
<td>187</td>
<td>1.22</td>
<td>1.01, 1.48</td>
<td>1.19</td>
<td>0.97, 1.45</td>
</tr>
<tr>
<td>Other</td>
<td>172</td>
<td>1.14</td>
<td>0.94, 1.39</td>
<td>1.10</td>
<td>0.90, 1.35</td>
</tr>
<tr>
<td><strong>Global cognitive score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Husband’s education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>544</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>College degree</td>
<td>294</td>
<td>0.98</td>
<td>0.84, 1.14</td>
<td>1.04</td>
<td>0.89, 1.22</td>
</tr>
<tr>
<td>Graduate degree</td>
<td>221</td>
<td>1.02</td>
<td>0.86, 1.21</td>
<td>1.15</td>
<td>0.97, 1.38</td>
</tr>
<tr>
<td>Annual income‡</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;$27,599</td>
<td>316</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$27,600–$36,699</td>
<td>341</td>
<td>1.03</td>
<td>0.87, 1.21</td>
<td>1.03</td>
<td>0.87, 1.22</td>
</tr>
<tr>
<td>$36,700–$48,599</td>
<td>353</td>
<td>1.01</td>
<td>0.86, 1.19</td>
<td>1.03</td>
<td>0.87, 1.22</td>
</tr>
<tr>
<td>≥$48,600</td>
<td>316</td>
<td>0.90</td>
<td>0.76, 1.07</td>
<td>0.95</td>
<td>0.80, 1.13</td>
</tr>
<tr>
<td>Father’s occupation at age 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper white-collar</td>
<td>305</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower white-collar</td>
<td>687</td>
<td>0.98</td>
<td>0.85, 1.14</td>
<td>0.95</td>
<td>0.82, 1.11</td>
</tr>
<tr>
<td>Blue-collar</td>
<td>47</td>
<td>1.26</td>
<td>0.90, 1.77</td>
<td>1.22</td>
<td>0.87, 1.71</td>
</tr>
<tr>
<td>Farmer</td>
<td>165</td>
<td>1.27</td>
<td>1.03, 1.56</td>
<td>1.25</td>
<td>1.01, 1.55</td>
</tr>
<tr>
<td>Other</td>
<td>139</td>
<td>0.96</td>
<td>0.77, 1.20</td>
<td>0.93</td>
<td>0.75, 1.16</td>
</tr>
</tbody>
</table>

* OR, odds ratio; CI, confidence interval.
† Multivariate-adjusted analyses were controlled for age at interview, education, husband’s education, father’s occupation at age 16, census-derived median household income (according to census tract), mental health index, vitality index, use of antidepressants, cigarette smoking, body mass index, high blood pressure, diabetes, heart disease, current use of postmenopausal hormones, vitamin E intake, age at menopause, use of aspirin, and time between the two interviews. In controlling for history of hypertension, diabetes, and heart disease, we constructed a cumulative variable such that a history was considered present if that disease had been diagnosed at any time prior to baseline cognitive assessment. For other covariates, the most recently updated information prior to the baseline cognitive assessment was used. Each indicator in this table was adjusted for others listed in the table, subjects’ own education, and other confounders listed in table 1.
‡ Income information was based on the median household income of the subject’s census tract.
women aged 18 years or more with 11.5-years of follow-up, Lyketsos et al. (2) found that having more than 8 years of formal education was associated with significantly less decline on the MMSE after adjustment for age and race; unlike us, they found no further protection against decline with increasing levels of education after 8 years. However, participants may have been too young for such a decline to be detected; over half of the subjects were less than 41 years of age, and just 53 were over age 70 years.

A cross-sectional study of Finnish men \( (n = 496) \) aged 58–64 years investigated parent’s education and occupation and cognitive function as measured on five tests, including the MMSE (31). After adjustment for subject’s education, only mother’s education (less than primary school vs. more) was significantly predictive of sons’ cognition; for example, the mean MMSE score for subjects whose mothers did not complete primary school was 26.6, and for the others it was 27.2 \( (p = 0.01) \). Similarly to our study, there was no relation between father’s occupation and participant’s cognitive function.

In studies of adult socioeconomic status, Gallacher et al. (4) used the Caerphilly Study to examine cross-sectionally the association between occupation/social class and cognitive function in 1,870 men aged 55–69 years. Social class was strongly related to each test in univariate analysis; after adjustment for age, mood, and education, social class effects universally declined (30–45 percent), principally because of adjustment for education. The adjusted mean difference between the highest and lowest social classes was 1.9 units for the MMSE and 5.3 units for the Cambridge Cognitive Examination; it is possible that adjustment for additional confounders would have eliminated these observed associations. Evans et al. (3) demonstrated that increases in occupational prestige score and income predicted significantly less cognitive decline on a test of immediate memory after adjustment for sex, age, education, birthplace, and language of interview. However, neither occupation nor income was related to decline in their general test of cognitive function \( (3) \), which is similar to our results.

There are several possible mechanisms supporting our finding that less education is related to cognitive decline. First, education may exert direct effects on brain structure early in life by increasing synapse number or vascularization and creating cognitive reserves \( (32) \); this has been called the “reserve capacity” hypothesis. Second, education in early life may have effects in later life if persons with more education continue searching for mental stimulation (the “use it or lose it” hypothesis), which may lead to beneficial neurochemical or structural alterations in the brain \( (32) \). Indeed, one study found that among men and women aged 65 years or older, cognitive function was positively related to composite measures of recent mental stimulation (activities such as playing games and puzzles, etc.) \( (33) \).

In addition, education may simply represent better health or other behavioral choices that in turn lead to maintenance of cognitive function \( (32) \). Our study may contribute to the elimination of this hypothesis, since we found strong effects of education after carefully adjusting for numerous health and behavioral characteristics in a population of registered nurses, who are relatively homogeneous in terms of their health habits and access to health care.

Finally, higher levels of education may improve an individual’s ability to perform on tests of cognitive function or to hide mild cognitive deficits \( (32) \). Again, in our group of educated professionals, it does not seem likely that this could completely explain the substantial differences in performance that we observed between women with a 3-year Registered Nurse diploma and those with a master’s or doctoral degree. Thus, overall, our data would suggest that the education effect is most likely explained by the “cognitive reserve” hypothesis or the “use it or lose it” hypothesis.

In conclusion, this appears to have been the first study of educational attainment and cognitive decline in community-dwelling, older women, all of whom are well-educated. We found strongly decreased odds of cognitive decline among women with higher levels of education; we found little association with other markers of socioeconomic status. Further exploration of these findings, through research specifically investigating whether continued mental stimulation in old age may protect against cognitive decline, seems warranted for establishing productive public health recommendations.

Acknowledgments

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References

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