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Original Research Article

The Impact of Later-Life Learning on Trajectories of Cognitive Function Among U.S. Older Adults

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Abstract

Background and Objectives: Low education in early life is a major risk factor for dementia. However, little is known about how education in later life is related to cognitive function in older adults. We assessed whether later-life learning was associated with better cognitive function over time and whether the associations differed by sex, race/ethnicity, and prior education.

Research Design and Methods: We used data from the 2008–2018 Health and Retirement Study, including participants aged 65+ without baseline dementia and followed for up to 6 years. Global cognition was measured using a summary score. Later-life learning was measured at every wave at least once a month or more, not in the last month, or never.

Results: Of 12 099 participants, 10.2% attended an educational or training course "at least once a month or more," 45.5% reported "not in the last month," and 43.3% reported "never" at each wave of the study. Results from adjusted mixed-effects models showed that engaging in any later-life learning, either at least once a month (0.56 points higher, 95% confidence interval [CI] = 0.40–0.73) or not in the last month (0.55 points higher, 95% CI = 0.45–0.65) was associated with better cognitive function compared to never engaging in these activities. The association remained consistent as people aged. The benefits of later-life learning on cognitive function were greater in women than in men—at least once a month versus never was 0.30 points greater in women than men (95% CI = –0.03 to 0.63, $p = .0760$); not in the last month versus never was 0.24 points greater in women than men (95% CI = 0.04–0.43, $p = .016$). There were no significant differences by race/ethnicity or prior education.

Discussion and Implications: Later-life learning was associated with better cognitive function over time. These findings underscore the importance of continued learning among older adults.

Keywords: Alzheimer's disease and related dementias, Healthy aging, Later-life learning, Longitudinal study, Public health prevention

Translational Significance: Among the attributable fraction of all risk factors, low education in earlier life is estimated to account for up to 20% of dementia risk. As early-life education is not modifiable among older adults, this paper focused on the association between later-life learning and trajectories of cognitive function. Thus, this paper is significant because it provides real-world evidence that suggests engagement in later-life learning may be a viable approach to prevent (or slow) the development of Alzheimer's disease and related dementias.

Background and Objectives

An estimated 6.7 million adults aged 65 and older are currently living with Alzheimer's disease and related dementias (ADRD) in the United States (1). With continued population aging and an increase in the number of individuals affected by ADRD over the past several decades, there have been substantial investments in scientific research and public health campaigns dedicated to the prevention and management of ADRD in older adults (2,3). Although significant progress has been made in identifying underlying genetic risk factors for

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ADRD (ie, apolipoprotein ε4) (4), the role of modifiable risks for slowing cognitive decline is not fully understood.

In 2020, the Lancet Commission identified low educational attainment as one of 12 major risk factors for ADRD (3). Among the attributable fraction of all risk factors, low education in earlier life is estimated to account for approximately 7%–20% of dementia risk (3,5). It is hypothesized that adults who receive higher levels of education may develop a greater amount of cognitive reserve than those with relatively lower levels of education (6). In turn, this reserve is characterized by greater cognitive capacity and flexibility that can help the brain compensate for the pathological changes associated with aging and the development of ADRD (7).

Currently, only half (49.7%) of U.S. adults have obtained some college education or more in their early lives (8). As earlier-life education is not modifiable among older adults, a growing number of studies have now begun to focus on the role of later-life learning as a target that may increase cognitive reserve and potentially delay the onset of cognitive impairment (9). However, most studies have been limited to small samples and only capture participation in later-life learning at one point in time (10). Consequently, the short- and/or long-term benefits of later-life learning over time and whether these potential benefits vary among older adults from different socio-demographic backgrounds remain largely unknown.

To address these knowledge gaps, we examined whether and to what extent later-life learning was associated with cognitive performance and the rate of cognitive decline over 8 years in a large nationally representative longitudinal sample of U.S. older adults. We also assessed whether the associations between later-life learning and cognitive function differed by sex, race/ethnicity, or prior educational attainment in early life.

Research Design and Methods

Data Source

Data from the 2008–2018 Health and Retirement Study (HRS) were used for analysis. The HRS is an ongoing prospective cohort study conducted by the National Institute on Aging and the Institute for Social Research at the University of Michigan. Since 1992, the HRS has collected data every 2 years from a nationally representative sample of U.S. adults over the age of 50. The HRS uses a steady-state design with replenished sampling and includes more than 40 000 adults since its launch. The details of the multistage sampling design, implementation, and response rates for the HRS have been documented elsewhere (11). Starting in 2006, HRS has collected psychosocial and lifestyle data every 4 years by a self-administered questionnaire (also known as the leave-behind survey). A random 50% of the sample was selected to receive the psychosocial and lifestyle questionnaire in 2006, 2010, 2014, and 2018. The other 50% of the sample received the same questionnaire survey in 2008, 2012, and 2016. The current study was approved by the Duke Health Institutional Review Board (IRB Pro00109934).

This study used HRS data from the 2008 to 2018 surveys. Participation in later-life learning was assessed starting in 2008. A total of 13 131 HRS participants aged 65+ completed the psychosocial and lifestyle questionnaire. Participants who did not answer the question for later-life learning (n = 294) were excluded. We further excluded participants who were diagnosed with dementia at baseline (n = 385) and had missing data on cognitive function (n = 353). A total of 12 099 participants were included in the study (Figure 1) and provided up to 3 waves of data for analysis.

Measures

Later-life learning

At each wave, participants were asked the following question, "How often do you each activity: attended an educational or training course?" Responses included: never, not in the last month, at least once a month, several times a month, once a week, several times a week, and daily. Preliminary analyses showed that the distribution of the responses was highly skewed (Supplementary Figure 1). Following prior research (12), at each wave, participants were categorized into 3 groups indicating the frequency of participating in later-life learning: (1) at least once a month or more; (2) not in the last month; or (3) never. Later-life learning was measured as a time-varying variable that allowed us to capture within-person changes in the frequency of later-life learning over time.

Cognitive function

At each wave, the HRS administered a series of validated cognitive tests to assess participants' global cognitive function, including orientation, memory, and executive function (11,13–15). These tests comprised 6 parts: immediate and delayed word recall (scored 0–20), recall of current date (scored 0–4), naming the president and vice-president (scored 0–2), serial 7′s test (scored 0–5), backward counting (scored 0–2), and objective naming test (scored 0–2). Correct responses from each measure were summed to create a cognitive score at each wave that ranged from 0 to 35, with higher scores indicating better cognitive function.

Covariates

Based on prior literature, we included a wide array of covariates to account for potential factors associated with cognitive function and participation in later-life learning (3,10). Sociodemographic background included age (in years), sex (male or female), race/ethnicity (non-Hispanic

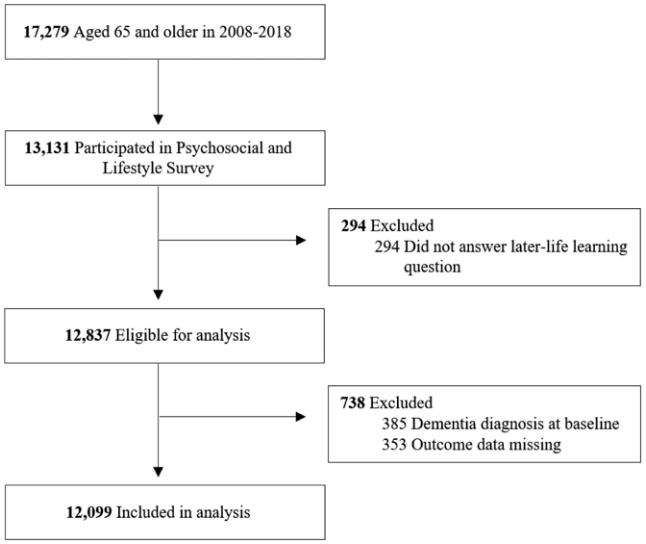

Figure 1. Selection of study participants from the Health and Retirement Study (HRS).

White, non-Hispanic Black, Hispanic, or non-Hispanic other race), living in the south (yes or no), educational attainment in earlier life (in years), employment status (currently employed or not), and household income (in thousands of dollars). Participants' occupation was also assessed in preliminary analyses but was removed due to multicollinearity with education, income, and employment. Psychosocial and behavioral factors included marital status (married/partnered or not), depressive symptoms measured by the Center for Epidemiological Studies—Depression scale (CES-D; range 0–8), tobacco use (never smoked, current smoker, or former smoker), alcohol use per day (never, 1–2, or ≥3 drinks per day), physical activity (never, ≥1 per week, or ≥1 per month and <1 per week). Health-related factors included body mass index (BMI, underweight [below 18.5], normal [18.5–24.9], overweight [25.0–29.9], and obese [30.0 and above]) and self-reported doctor-diagnosed conditions (hypertension, diabetes, heart disease, stroke, lung disease, and cancer). Preliminary analyses also included additional variables on social participation; however, these variables were highly correlated with the later-life learning variable and were therefore dropped from the final analyses.

Statistical Analysis

The baseline characteristics of study participants were computed for the overall sample and compared by participation in later-life learning using χ^2 tests for categorical variables and analysis of variance (ANOVA) or Kruskal–Wallis tests for continuous variables. Associations between later-life learning and trajectories of cognitive function were estimated using mixed-effects linear regression models. Our analytical approach first used unconditional models to assess fixed and random linear (age) and quadratic (age2) changes in cognitive function. We then estimated unadjusted differences in cognitive function associated with participating in later-life learning both at the mean levels (intercept) and changes over time (slope). The second set of analyses estimated differences in cognitive function associated with later-life learning while adjusting for socio-demographic background (sex, race, region, education, employment, and household income), psychosocial and behavioral factors (married/partnered, CES-D, tobacco use, alcohol use, and physical activity), and health-related factors (BMI, hypertension, diabetes, heart disease, stroke, lung, and cancer). A final set of analyses tested interactions to assess whether the association between later-life learning and cognitive function differed by sex, race/ethnicity, or prior educational attainment in earlier life. Stratified analyses were then performed when significant interaction(s) were found.

To account for potential selection bias in who and the extent to which they participated in later-life learning, we used a time-varying treatment approach to apply inverse probability weighting to account for this potential selection bias (16). To construct stabilized weights, we considered participants' age, sex, race/ethnicity, educational attainment, income, employment status, marital status, and prior participation in later-life learning up to the current wave (observed treatment exposure history) as confounders. The selection of confounders was based on prior literature (6,17). The balance plots (Supplementary Figure 2) demonstrated adequate balance in confounding factors across individuals with different levels of participation in later-life learning.

The percentage of missing values across all covariates was less than 2%. Results from the Little Missing Completely at Random (MCAR) test suggested that data were not missing completely at random ($\chi^2 = 65.88$, $p = .017$) (18). Therefore, we used multiple imputations to address missing data to reduce potential bias in estimation (19–21). To produce unbiased estimates and avoid inflated standard errors, sampling weights were not used in the analyses because the multivariable analyses accounted for variables used in the calculation of sampling weights (eg, age, sex, race) (22). All analyses were performed using Stata 17.0 SE (StataCorp LP, College Station, TX). p Values <.05 were considered statistically significant.

Results

Among the 12 099 study participants, the median age was 71 years, more than half (58.3%) were female, 75.4% were non-Hispanic White, and the average years of education was 12.8 at baseline (Table 1). Among them, 1 224 (10.2%) reported attending an educational or training course "at least once a month or more," 5 500 (45.5%) reported "not in the last month," and 5 355 (43.3%) reported "never" attending an educational or training course at each wave of the study. Participants who reported attending an educational or training course at least once a month were younger than those who participated in these activities less frequently or never. Compared with those who attended any educational or training courses, participants who reported never engaging in later-life learning had fewer years of prior education, had lower household income, reported higher levels of depressive symptoms, were more likely to smoke, had decreased levels of physical activity, and had a higher prevalence of hypertension, diabetes, and stroke At baseline, participants who engaged in later-life learning at least once a month had the highest cognitive scores (mean score: 23.6) and those who never participated in later-life learning had the lowest cognitive scores (mean score: 21.3).

Results from a series of unconditional models are presented in Supplementary Table 1. Tests of model fit indicate that a quadratic function best parameterized the trajectory of cognitive function in the data and there were no slope differences across different levels of later-life learning (Supplementary Table 1, Model 4). Table 2 presents results from the weighted linear mixed models estimating the associations between later-life learning and trajectories of cognitive function. Overall, cognitive function exhibited an accelerated rate of decline across age in older adults ($\beta_{Age} = -0.03$, 95% confidence interval [CI] = −0.06 to −0.01, $p = .036$, $\beta_{Age2} = -0.006$, 95% CI = −0.007 to −0.05, $p < .001$). Compared with no engagement in later-life learning, attending an educational or training course at least once a month ($\beta = 1.14$, 95% CI = 0.96–1.32, $p < .001$) or not in the last month ($\beta = 0.87$, 95% CI = 0.77–0.98, $p < .001$) was associated with consistently higher levels of cognitive function over time. These differences in cognitive function persist as people age (ie, no significant change in slope). More importantly, the benefit of later-life learning was only partially attenuated in the fully adjusted mixed model (Table 2, $\beta_{\text{At least once a month}} = 0.56$, 95% CI = 0.40–0.73, $p < .001$, $\beta_{\text{Not in the last month}} = 0.55$, 95% CI = 0.45–0.65, $p < .001$). Figure 2 plots the findings from the weighted mixed models to illustrate the age-related differences in cognitive function associated with participation in later-life learning. The results indicate that a 70-year-old who engaged in any later-life learning (regardless of the frequency) had better cognitive function than a 65-year-old who

Table 1. Baseline Characteristics of Study Participants by Later-Life Learning (*n* = 12 099)

Characteristics	Overall (*n* = 12 099)		At Least Once a Month (*n* = 1 244)		Not in Last Month (*n* = 5 500)		Never (*n* = 5 355)		*p* Value
Sociodemographic factors									
Age, median (IQR)	71	(10)	69	(8)	72	(9)	71	(11)	<.001
Female, *n* (%)	7 049	(58.3)	733	(58.9)	3 196	(58.1)	3 120	(58.3)	.871
Race/ethnicity, *n* (%)									<.001
Non-Hispanic White	9 121	(75.4)	880	(70.7)	4 451	(80.9)	3 790	(70.8)	
Non-Hispanic Black	1 655	(13.7)	229	(18.4)	616	(11.2)	810	(15.1)	
Hispanic	1 055	(8.7)	104	(8.4)	327	(5.9)	624	(11.7)	
Non-Hispanic other race	265	(2.2)	31	(2.5)	106	(1.9)	131	(2.4)	
Living in the South, *n* (%)	4 987	(41.2)	526	(42.3)	2 192	(39.9)	2 269	(42.4)	.021
Year of education, mean (*SD*)	12.8	(3.1)	14.1	(2.9)	12.9	(3.1)	12.7	(3.1)	<.001
Employment, *n* (%)	1 401	(11.6)	666	(12.1)	446	(8.3)	666	(12.1)	<.001
Household income, median (IQR)*	37.1	(47.8)	53.0	(74.6)	39.8	(50.4)	37.1	(47.8)	<.001
Psychosocial and behavioral factors									
Married/partnered, *n* (%)	7 610	(62.9)	787	(63.3)	3 519	(64.0)	3 304	(61.7)	.046
CES-D symptoms, mean (SD)	1.3	(1.8)	0.9	(1.4)	1.2	(1.8)	1.5	(1.9)	<.001
Tobacco use, *n* (%)									<.001
Never smoked	5 214	(43.1)	591	(47.5)	2 398	(43.6)	2 225	(41.5)	
Current smoker	1 198	(9.9)	56	(4.5)	499	(9.1)	643	(12.0)	
Former smoker	5 601	(46.3)	587	(47.2)	2 564	(46.6)	2 450	(45.8)	
Alcohol use per day, *n* (%)									<.001
Never or 0 drinks per day	7 964	(65.8)	758	(60.9)	3 559	(64.7)	3 647	(68.1)	
1–2 drinks per day	1 992	(16.5)	246	(19.8)	880	(16.0)	866	(16.2)	
≥3 drinks per day	2 128	(17.6)	239	(19.2)	1 056	(19.2)	833	(15.6)	
Physical activity, *n* (%)									<.001
≥1 per week	2 772	(23.0)	428	(34.4)	1 311	(23.8)	1 033	(19.3)	
≥1 per month	2 031	(16.8)	270	(21.7)	877	(15.9)	884	(16.5)	
Never	7 271	(60.2)	545	(43.9)	3 307	(60.1)	3 419	(63.8)	
Health-related factors, *n* (%)									
Body mass index (BMI)									
Underweight	119	(1.0)	5	(0.4)	50	(0.9)	64	(1.2)	.042
Normal	2 726	(22.5)	281	(22.6)	1 284	(23.3)	1 161	(21.7)	
Overweight	4 309	(35.6)	427	(34.3)	1 972	(35.9)	1 910	(35.7)	
Obesity	4 874	(40.3)	525	(42.2)	2 167	(39.4)	2 182	(40.7)	
Hypertension	8 070	(66.7)	774	(62.2)	3 574	(65.0)	3 722	(69.5)	<.001
Diabetes	3 091	(25.5)	281	(22.6)	1 271	(23.1)	1 539	(28.7)	<.001
Heart disease	3 641	(30.1)	323	(26.0)	1 679	(30.5)	1 639	(30.6)	.004
Stroke	1 176	(9.7)	84	(6.8)	525	(9.5)	567	(10.6)	<.001
Lung disease	1 475	(12.2)	132	(10.6)	674	(12.3)	669	(12.5)	.185
Cancer	2 307	(19.1)	242	(19.5)	1 019	(18.5)	1 046	(19.5)	.384
Cognitive score at baseline, mean (*SD*)	22.1	(4.8)	23.6	(4.5)	22.5	(4.7)	21.3	(4.9)	<.001

Notes: BMI = body mass index; CES-D = Center for Epidemiologic Studies—Depression; IQR = interquartile range; *SD* = standard deviation. Missing values for race/ethnicity (*n* = 3), south (*n* = 5), education (*n* = 2), married (*n* = 3), CES-D (*n* = 1), tobacco use (*n* = 86), alcohol use (*n* = 15), physical activities (*n* = 25), and BMI (*n* = 71).
*Reported in thousands of dollars.

reported never participating in later-life learning. This suggests a nearly 6-year age difference in cognitive function associated with later-life learning.

A final set of analyses examined whether the influence of later-life learning on cognitive function differed by sex, race/ethnicity, or prior educational attainment. We found a significant interaction by sex (Figure 3) with results showing that women had a slightly larger benefit from engaging in any later-life learning than men (Supplementary Table 2, $\beta_{\text{At least once a month}\times\text{Female}} = 0.30$, 95% CI = −0.03 to 0.63, $p = .076$; $\beta_{\text{Not in the last month}\times\text{Female}} = 0.24$, 95% CI = 0.04–0.43, $p = .016$). No other significant interactions were found and suggested that participating in later-life learning was consistently beneficial for cognitive function regardless of race/ethnicity (Supplementary Table 3) and prior educational attainment (Supplementary Table 4).

Table 2. Mixed Model Estimates of the Association Between Later-Life Learning and Cognitive Function (n = 12 099)

Variable	β	(95% CI)	β	(95% CI)
Fixed-effects parameters				
Age	−0.03***	(−0.06 to −0.01)	−0.03*	(−0.05 to −0.01)
Age^2	−0.006***	(−0.007 to −0.005)	−0.006***	(−0.007 to −0.005)
Later-life learning				
At least once a month	1.14***	(0.96–1.32)	0.56***	(0.40–0.73)
Not in the last month	0.87***	(0.77–0.98)	0.55***	(0.45–0.65)
Female			0.94***	(0.81–1.08)
Race/ethnicity				
Non-Hispanic Black			−2.81***	(−3.02 to −2.61)
Hispanic			−1.32***	(−1.59 to −1.04)
Non-Hispanic other race			−1.62***	(−2.06 to −1.19)
South			−0.21**	(−0.34 to −0.08)
Years of education			0.50***	(0.47–0.53)
Employment			0.16	(−0.01 to 0.32)
Household income			0.26***	(0.20–0.32)
Married/partnered			−0.08	(−0.22 to 0.06)
CES-D symptoms			−0.17***	(−0.20 to −0.14)
Tobacco use				
Current smoker			−0.14	(−0.37 to 0.09)
Former smoker			0.01	(−0.14 to 0.14)
Alcohol use per day				
1–2 drinks per day			−0.41***	(−0.55 to −0.28)
≥3 drinks per day			0.13	(−0.04 to 0.29)
Physical activity				
≥1 per week			0.22***	(0.10–0.35)
≥1 per month			0.15*	(0.03–0.28)
Body mass index (BMI)				
Underweight			−0.17	(−0.64 to 0.30)
Overweight			0.22**	(0.07–0.36)
Obesity			0.40***	(0.24–0.57)
Hypertension			−0.11	(−0.24 to 0.02)
Diabetes			−0.24***	(−0.37 to −0.10)
Heart disease			0.07	(−0.05 to 0.19)
Stroke			−1.03***	(−1.24 to −0.83)
Lung disease			−0.01	(−0.18 to 0.18)
Cancer			0.16*	(0.02–0.30)
Mortality	−1.65***	(−1.84 to −1.46)	−0.81***	(−0.98 to −0.64)
Intercept	23.05***	(22.88–23.22)	14.40***	(13.65–15.15)
Random-effects variance components				
Level 1: Within-person	5.63	(5.41–5.86)	5.67	(5.45–5.89)
Level 2: Intercept	15.08	(13.96–16.29)	8.54	(7.72–9.45)
Level 2: Slope	0.02	(0.02–0.03)	0.02	(0.02–0.03)

Notes: CES-D = Center for Epidemiologic Studies—Depression; CI = confidence interval. Estimated coefficients (95% CIs) are reported based on weighted mixed models.
*p < .05.**p < .01.***p < .001.

Discussion and Implications

Using a nationally representative sample of U.S. older adults, the findings from this study demonstrate that attending any educational or training courses in later life was associated with better cognitive function over time. The association between later-life learning and cognitive function was only partially attenuated after accounting for sociodemographic, psychosocial, behavioral, and health-related factors. Overall, we found that the benefits of later-life learning were equivalent to a nearly 6-year age difference in cognitive function among older adults. In addition, the cognitive benefits of education in later life were slightly greater in women than in men; and were consistently beneficial for cognitive function regardless of race/ethnicity and prior educational attainment.

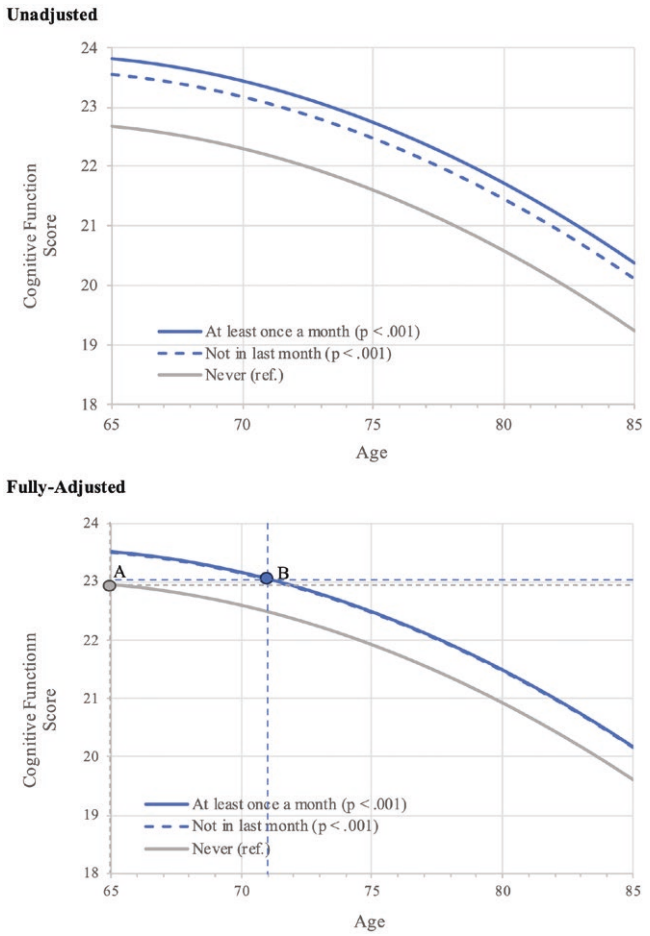

Figure 2. Plots of the unadjusted and adjusted mixed model estimates for the association between later-life learning and cognitive function (n = 12 099). Estimates were obtained from the weighted mixed models in Table 2 for the unadjusted and fully adjusted association between later-life learning and cognitive function across age. (A) Estimated cognitive score for a 65-year-old without any later-life learning. (B) Estimated cognitive score for a 71-year-old with later-life learning either at least once a month or not in the last month.

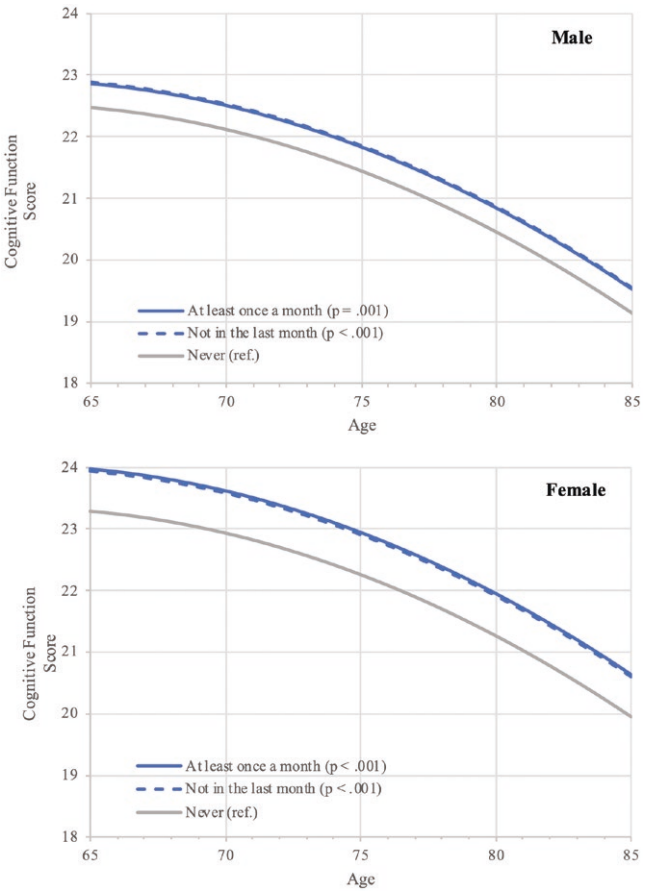

Figure 3. Plots of the adjusted mixed model estimates for the association between later-life learning and cognitive function in men and women (n = 12 099). Estimates were obtained from fully adjusted weighted mixed models in men and women. Interaction terms were tested for gender differences in the association between later-life learning and cognitive function (p = .076 for at least once a month × sex; and p = .016 for not in the last month × sex).

Most research that has targeted cognitive reserve uses cognitive stimulating activities that include brain-stimulating exercises and/or cognitive training (23,24). Although most of these training activities focus on multiple domains of cognitive function, these cognitive training interventions are typically intensive, delivered in well-controlled settings, and often short term (eg, 8–12 weeks) (23,24). Furthermore, a few other studies focused on participation in real-world mentally stimulating activities in later life (25–27). Still, this prior research included mixed cognitive and social activities (eg, watching movies, visiting a library, craft activities) that limited its ability to identify the most beneficial activity (25–27). In this study, we assessed the cognitive benefits of engaging in one single cognitive stimulating activity—later-life learning—among older adults in a real-world setting. By accounting for the time-varying nature of later-life learning, results from our study demonstrate that participating in any later-life learning is associated with significantly better cognitive function. Furthermore, we found that the cognitive benefit of participating in later-life learning translated to an approximately 6-year age difference in cognitive function. Taken together, these results provide real-world evidence to the emerging literature that suggests engagement in later-life learning may be a viable approach to prevent (or slow) the development of ADRD.

Results from our study also demonstrated that the cognitive benefits of later-life learning persist over time. Similar results were found in prior studies that showed how early-life educational attainment was only associated with baseline cognitive function and not the slope of cognitive decline (28,29). According to cognitive reserve theory, it is possible that education can have a long-lasting positive influence on cognitive function and that these benefits do not ameliorate as people age (7,30,31). However, this explanation was only partially supported by the findings from prior 2 longitudinal population-based studies (17,32). In brief, these findings suggested a somewhat weaker association between mid/later-life cognitive activity and the rate of cognitive decline (32); and a stronger association between cognitive activity and baseline cognitive function (17). The differences in these findings may be due in part to the study's sample/design (Minnesota, CA), relatively short follow-up period, and focus on cognitive activities/early–midlife education versus later-life learning. Future research is needed to further assess the potential long-term benefits of participation in later-life learning on cognitive decline.

In our study, we did not find a significant interaction between prior educational attainment and participation in later-life

learning on cognitive function. This result did not support findings from a previous Irish cohort study that only showed cognitive benefits from engaging in later-life learning among participants with secondary education or less (10). This discrepancy may be due to the relatively younger sample of adults with ≥secondary education in the Irish cohort (mean age: 59 years and better baseline cognitive function) (10). Likewise, younger adults with higher levels of education likely maintained higher levels of cognitive function during the 4-year follow-up period, thus contributing to the positive and pronounced impact of education in later life (33). In our study, however, all participants were over age 65 and demonstrated more substantial cognitive benefits from engaging in later-life learning—perhaps attributable to their overall lower levels of baseline cognitive function and faster rates of decline relative to those at younger ages.

Prior studies have demonstrated that older adults who are women, from racial/ethnic minority groups, and those with low socioeconomic status are disproportionately affected by ADRD (28,34,35). Our study showed that the benefits of later-life learning on cognitive function did not significantly differ by race/ethnicity or prior educational attainment. One possible explanation could be that irrespective of race/ethnicity, or early-life educational attainment, individuals who engage in educational or training courses in later life have a relatively better cognitive capacity to process and retain new information (36). We also found that participation in later-life learning had a greater impact on cognitive function among women than among men. These findings were similar to prior studies demonstrating that women had greater cognitive reserve than men (34,37,38). However, additional research is needed to replicate these findings in other cohorts and further assess the mechanisms that may be contributing to sex differences in the association between later-life learning and cognitive function. Taken together, these findings suggest that promoting participation in later-life learning may be an effective real-world strategy to promote healthy cognitive aging at a population level across all groups.

Despite the potential cognitive benefits of later-life learning, only about 1-in-10 participants in our study regularly engaged in these activities at least once a month, and nearly half never participated in any later-life learning. Therefore, it will be essential to develop programs and policies to further promote engagement in later-life learning among older adults. Many publicly funded universities offer lifelong learning programs for older adults who wish to engage in educational and training courses (39). Throughout the coronavirus 2019 (COVID-19) pandemic, there has been an increasing number of older adults who use digital technology (40). In addition, a growing number of public libraries have expanded their access to electronic resources that allow the general public to better access educational and learning materials (41). Relatedly, offering online courses and training may be a viable approach to overcoming barriers to access that some older adults face. In our study, we found little difference in the relationship between the frequency of engaging in later-life learning and cognitive function, suggesting that participating in late-life learning regardless of the frequency would be beneficial. As such, more research is needed to further identify the optimal modality, content, duration, and frequency of later-life learning that is both cognitively beneficial and appealing to older adults.

Several limitations of this study should be acknowledged. First, although the measures of cognitive function have been well documented in the HRS and other observational studies, we were unable to assess the role of later-life learning for different domains of cognition. Second, we lacked detailed information on the specific types and/or content of courses and training that the participants took and the duration of these activities. In this study, "learning" primarily refers to formal learning activities, such as courses or training programs. Informal learning is also an essential component of lifelong learning. However, due to the lack of available data, we were unable to account for any informal learning activities that participants may have engaged in. In addition, the measure for the frequency of these later-life learning activities was relatively crude. Therefore, we were not able to explore what training(s) and/or course(s) may be most helpful to maintain cognitive function. Relatedly, the HRS did not collect information on why people participated in later-life learning. Although we used inverse probability weighting to account for potential selection bias, we could not assess whether people's motivation to engage in these activities would have an impact on their cognitive performance. Also, other potential confounders—such as personality, social participation, health literacy, early-life cognitive function, and family history of ADRD—were unavailable in the current data and were thus not included in the analyses. Our preliminary analyses included social participation and found that it had high collinearity with later-life learning. It is possible that one of the key underlying mechanisms linking later-life learning to cognitive function was through the social engagement associated with the learning activities. We encourage future studies to integrate qualitative methods, such as interviews with participants at lifelong learning programs or community colleges, to gain deeper insights into the mechanisms linking learning activities with cognitive outcomes and psychological well-being. Last, a potential limitation of our study is the possibility of reverse causality, where individuals with higher baseline cognitive functioning and sufficient cognitive capacity are more likely to engage in later-life educational activities. This may partially explain the observed associations, as pre-existing cognitive differences could enable participation in such activities. Future studies with instrumental variable approaches are needed to address this issue more robustly.

Conclusion

In summary, engaging in any later-life learning was associated with significantly better cognitive function and was beneficial regardless of sex, race/ethnicity, and prior educational attainment. Overall, we found that the benefits of education in later life were equivalent to a nearly 6-year delay in cognitive decline among older adults. The results from this study underscore the potential cognitive benefits associated with participation in educational activities in later life and shed new light on the significant implications of later-life learning for healthy aging and cognitive function. Lifelong learning represents a cost-effective strategy with substantial potential to mitigate cognitive decline and enhance mental health during the aging process, making it a valuable intervention in addressing the challenges of a globally aging population.

Supplementary Material

Supplementary data are available at *Innovation in Aging* online.

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Conflict of Interest

None.

Data Availability

Data reported in this article is available on request. The study was not preregistered.

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