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Early Childhood Quality Of Education And Late-Life Cognitive Function In A Population-Based Sample From Puerto Rico

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EARLY CHILDHOOD QUALITY OF EDUCATION AND LATE-LIFE COGNITIVE FUNCTION IN A POPULATION-BASED SAMPLE FROM PUERTO RICO

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MEDICAL/CLINICAL PSYCHOLOGY

ABSTRACT

In general, greater years of education is associated with reduced risk of cognitive impairment in older adulthood, but the strength of this association has been found to differ by study population. Additionally, quality of education is understudied, despite evidence that quality of education and, in turn, literacy, may be additional indicators of cognitive reserve. This thesis examined years of education, literacy, and childhood quality of education indicators in relation to late-life cognitive outcomes in an older Puerto Rican population. We hypothesized that greater years of education, literacy, and quality of childhood education would be positively associated with each other, as well as with reduced cognitive decline and impairment in late life. Baseline and four-year follow-up data were collected for a population-based sample of community dwelling Puerto Rican adults aged 60 years and over for the Puerto Rican Elderly: Health Conditions (PREHCO) study. Cognitive impairment and decline were our main outcomes and were determined using the minimental Cabán (MMC). Years of education and literacy were self-reported at baseline. Quality of education was based on historical education and Census records and included school year length, student-teacher ratio, school attendance, and literacy rates by municipality of childhood residence. Childhood health status, child and adult SES, vascular risk factors, and depressive symptoms were used as covariates in linear regression models for cognitive decline and logistic regression models for cognitive impairment as the outcome. Years of education, literacy, quality of education, and cognitive performance were all positively and significantly associated with each other. In models adjusted for demographic covariates, years of education, literacy and a composite variable for quality of education were each significantly related to lower cognitive decline and incident cognitive impairment. However, years of education explained much of the associations between cognitive outcomes and quality of education indicators. This study provides further evidence that years of education, literacy, and quality of education are all interrelated and are important factors for cognitive functioning in older age, although years of education may be sufficient for capturing potential effects of quality of education in this population of older Puerto Ricans.

Keywords: Education, Cognitive aging, Health disparities

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INTRODUCTION

The number of racially and ethnically diverse older adults in the U.S. is steadily increasing (CDC, 2016b). As the population increases in age, the number of individuals diagnosed with cognitive impairment and dementia increases. Cognitive impairment is the hallmark feature of a dementia diagnosis, along with difficulty performing activities of daily living. Alzheimer's disease (AD) is the most common cause of cognitive impairment in older adults, and in 2015, AD was the sixth leading cause of death of all older adults (CDC, 2016a). Hispanic/Latino and Black/African American (AA) older adults are more likely to develop AD or other dementias than Non-Hispanic Whites (NHW), partly due to mixed AD and vascular pathology, socioeconomic factors, and cardiovascular health (Alzheimer's Association, 2018). Given the higher likelihood of developing AD in these groups, it is important for researchers to examine the factors that put these populations at a greater risk, including the potential effects of lower levels of education, higher rates of poverty, and early life health and nutrition. Education is especially relevant to understanding dementia disparities in diverse populations given the variability in educational attainment as well as quality of education in the U.S. Heterogeneity exists within many ethnic groups and is an important yet under researched issue. As the population of diverse older adults continues to grow, there is a greater emphasis for more research on diverse populations to better target or tailor medical interventions and develop public policy.

Education and Cognitive Aging

Education is the most widely studied early-life environmental factor in relation to risk of cognitive decline and dementia in older adulthood. The importance of education stems from its foundational role in brain development and its influence on cognitive functioning throughout the lifespan. Low levels of educational attainment have been found to predict cognitive function, cognitive impairment, and incident dementia in older adults (Glymour & Manly, 2008; Karp et al., 2004; Rogers et al., 2009; Sharp & Gatz, 2011). Along with negative health behaviors such as smoking and low physical activity, low levels of education predicted incident AD in a systematic review of 247 studies (Beydoun et al., 2014). Given that education is a modifiable risk factor for dementia, the importance of understanding the mechanisms underlying this connection could further support the importance of a good education in childhood and furthering education into adulthood.

The most frequently cited mechanism to explain the relationship between education and dementia is cognitive reserve theory (Sharp & Gatz, 2011; Stern, 2002). Researchers hypothesize that education increases “cognitive reserve” that serves as a buffer for the clinical expression of brain pathology. Those with greater reserve are thought to have better functioning of brain networks or neuronal compensations, which can delay the appearance of clinical symptoms of dementia despite presence of brain pathology due to Alzheimer’s disease or other forms of dementia (Tucker & Stern, 2011). Education may enhance neural networks and establish a cognitive reserve at a young age that can accumulate throughout the lifespan (Schmand, Smit, Geerlings, & Lindeboom, 1997). Additionally, individuals with higher education are more likely to engage in cognitively stimulating activities throughout the lifespan that are protective against dementia (Beydoun et al., 2014; Ngandu et al., 2007; Richards & Deary, 2005). Education may influence the brain during a critical time in development that sets the basis for future cognitive flexibility. While cognitive reserve may serve as a protective factor, many other adverse childhood variables may influence brain aging in negative ways.

In addition to low levels of education, low SES in childhood was found to have negative effects on cognition and health in later adulthood (Kaplan et al., 2001; Luo & Waite, 2005). Zeki Al Hazzouri et al. (2011) found in a sample of older Mexican Americans that social disadvantages early in life might put individuals at risk for dementia in older adulthood. Lower SES may negatively influence cognitive development in childhood and other life-course health issues, such as cardiovascular health, may mediate this relationship. Studies have also demonstrated that lower SES leads to accumulation of stress through the lifetime, which is also thought to have detrimental effects on the brain and cardiovascular health (Evans & Schamberg, 2009; Glymour & Manly, 2008; Kiecolt-Glaser et al., 2003; Lupien, McEwen, Gunnar, & Heim, 2009). Chronic stress is hypothesized to play a role in the development of dementia as well as reductions in hippocampal volume associated with the release of cortisol (Glymour & Manly, 2008; Magri et al., 2006). Evidence suggests that the negative effects of stress on the hippocampus can begin early in life as the hippocampus is still developing in childhood (Lupien et al., 2009).

Working memory has also shown to be associated with stress caused by childhood poverty. Adults that lived in poverty as children showed a lower working memory capacity compared to adults that grew up in middle-income families (Evans & Schamberg, 2009). The longer they lived in poverty the more stress built up over time, resulting in greater reductions of working memory in young adulthood (Evans & Schamberg, 2009). Cumulative inequality theory reinforces this finding. This theory posits that socioeconomic disadvantages starting in childhood can accumulate over time and can result in harmful health effects and lifestyle risks in adulthood (Ferraro, Schafer, & Wilkinson, 2016). Understanding how the brain is affected by the accumulation of poverty and chronic stress is important to understanding cognitive functioning in old age. These findings also emphasize that cognitive functioning throughout the lifespan is influenced by many intertwining factors that accumulate over time.

Not all studies have found an association between education and dementia (Cobb, Wolf, Au, White, & D'agostino, 1995; Schmand et al., 1997; Wilson et al., 2002). In a systematic review of the literature, Sharp and Gatz (2011) found that 42% of studies investigating the link between education and dementia did not find a significant association. Methodological factors may explain some of these differences, including the finding that individuals with lower education tend to perform more poorly on cognitive testing despite no functional impairment differences compared to participants with more education (Schmand, Lindeboom, Hooijer, & Jonker, 1995; Sharp & Gatz, 2011; Tuokko, Garrett, McDowell, Silverberg, & Kristjansson, 2003). The inability of years of education to reflect true cognitive capacity could also contribute to these inconsistencies (Schmand et al., 1997; Sharp & Gatz, 2011). It may be that a low level of education itself is not a risk factor for dementia but is instead a marker for deleterious early childhood or adolescent environments that impede healthy brain development (Moceri et al., 2001; Moceri, Kukull, Emanuel, Van Belle, & Larson, 2000). Despite these inconsistencies, education is an important variable to study given its influence on the brain and influence on socioeconomic position in society.

The connection between education and late life cognitive functioning has been examined in previous research but information regarding the quality of early childhood education has been researched very little. Quality of education can explain racial differences in cognitive performance more so than years of education as the latter may not be reflective of the individual's actual cognitive capacity (Carvalho et al., 2015; Sharp & Gatz, 2011). Quality of education has previously been operationalized as reading ability in adulthood, specifically the Shipley Vocabulary scores or Wide Range Achievement (WRAT) scores in U.S. samples (Carvalho et al., 2015; Kave et al., 2012; Manly, Jacobs, Touradji, Small, & Stern, 2002; Schmand et al., 1997). Other definitions of quality of education include a combination of school funding, length of school year, and student-teacher ratio (Crowe et al., 2013; Sisco et al., 2015). One study found an association between quality of education and cognitive function only for individuals with less than 12 years of education, indicating that education greater than high school may be protective against poor quality schooling (Crowe et al., 2013). Research has shown that poorer educational quality is associated with lower cognitive performance (Crowe et al., 2013) and that quality of education variables (i.e. literacy) are better predictors of cognitive functioning in old age in African American samples (Kave et al., 2012; Sisco et al., 2015). However, we cannot draw the same conclusions about other minority populations such as Hispanic/Latinos, especially given the lack of prior research on education quality. Puerto Ricans are the second largest Hispanic/Latino group in the U.S. and their notable risk factors compared to other groups make them an important population to study. Greater exposure to early-life adverse conditions combined with chronic diseases in adulthood may put older Puerto Ricans at greater risk for developing cognitive impairment and subsequently dementia.

The current project proposes to examine whether education is associated with cognitive aging outcomes in a population-based sample of older adults in Puerto Rico. Further research is needed to understand how negative early-life circumstances affect health outcomes in diverse populations. This project will also differentiate the effects of education from other early childhood variables, such as poor nutrition and health in childhood, on adverse cognitive outcomes in later adulthood. Research on disentangling the effects of education from other early life variables is an area in need of further research. Understanding the social and environmental advantages and disadvantages that specifically affect diverse groups is an important step to tailoring diagnoses and personalizing treatment plans.

Research on Cognitive Aging in Hispanics

Many epidemiological studies of aging tend to group Hispanic/Latino populations together or exclude the group completely (Bowen & Gonzalez, 2010; Daviglus et al., 2012; Howard et al., 2005). Although Hispanic/Latino groups share many similarities, diversity exists in culture, diet, ethnic origins, sociodemographic factors, and health status (Daviglus et al., 2012; Gonzalez et al., 2015). Studies have shown that

Hispanic/Latino groups have high levels of risk factors for dementia and chronic diseases such as diabetes, with distinctive incidence rates and genetic risk factors (Ghani et al., 2013; Mainous, Diaz, Saxena, & Geesey, 2007; Mayeda, Glymour, Quesenberry, & Whitmer, 2016; Tang et al., 2001).

Specifically, Caribbean Hispanics were found to have a higher incidence rate of Alzheimer's disease compared to Non-Hispanic Whites (Tang et al., 2001). A study of Caribbean Hispanics, mainly Dominicans and Puerto Ricans, performed lower on neuropsychological testing compared to Mexican Americans (Gonzalez et al., 2015). Puerto Ricans also have a higher prevalence of disability, functional limitations, poorer overall health, and lower education compared to other Hispanic/Latino groups (Tucker, Falcon, Bianchi, Cacho, & Bermudez, 2000). Overall, the high rates of poor health and low levels of education put Puerto Ricans at risk for developing cognitive decline in later life.

Health Risks and Healthcare Accessibility in Puerto Rico

Puerto Rico presents a unique example for investigating the influence of childhood health and nutrition on cognitive aging. The 1920s to early 1940s marked a period of high unemployment on the island (McEniry, Palloni, Dávila, & Gurucharri, 2008). Many Puerto Ricans lived in rural areas and depended on the sugar cane industry for employment. McEniry et al. (2008) writes that although sugar cane was a main export of the island, the harvest season was periodical, leaving many workers with limited income for half of the year. During this same time hurricane season would bring hot and humid weather that facilitated the spread of infectious diseases. Variable income for food and susceptibility to disease created deleterious living conditions for many during this time (McEniry et al., 2008). The combination of food shortage and infectious diseases may have had an impact on physical and brain health of young children during this time.

The aging population in Puerto Rico has increased over time as medical innovations and public health interventions have decreased mortality rates due to disease (Palloni, McEniry, Dávila, & Gurucharri, 2005). Although the population is living longer, the standard of living and improvements in nutrition have not improved and while infectious diseases have decreased, they have not been eradicated (Palloni et al., 2005). Chronic diseases such as diabetes also affect the older population, resulting in the combined effects of chronic and infectious diseases (Palloni et al., 2005). In addition to chronic health concerns, a large portion of the population lives in poverty. Approximately 41% of the population aged 65 years and older in Puerto Rico was living below the poverty line in 2015 (Administration on Aging, 2016). In 2016, the median annual household income in Puerto Rico was less than half that of Mississippi's median household income, which is the poorest state in the U.S. (Guzman, 2017).

As a commonwealth of the U.S., Puerto Ricans pay into and qualify for Medicare, with about 74.1% of Medicare Beneficiaries enrolled in a Medicare Advantage plan (Rivera-Hernandez, Leyva, Keohane, & Trivedi, 2016). However, Rivera-Hernandez et al. (2016) found that Hispanic enrollees in Puerto Rico overall receive worse care compared to both Non-Hispanic Whites and Hispanic/Latinos in the U.S. Large differences were found, including inadequacies in controlling for cholesterol and HBA_{1c} levels for diabetes mellitus (Rivera-Hernandez et al., 2016). It is well established that Puerto Ricans in the U.S. and in Puerto Rico have high rates of poorly controlled diabetes mellitus compared to Non-Hispanic Whites (Johnson, Cavanagh, Jacelon, & Chasan-Taber, 2017; Palloni et al., 2005; Payne, 2015; Rivera-Hernandez et al., 2016; Tang et al., 2001; Tucker et al., 2000). Despite this disparity, preventative care is severely lacking. Only 14% of the diabetic population in Puerto Rico received a deep eye test, only 16% were monitored for nephropathy, and 82% had poorly controlled blood sugar (Payne, 2015).

Generally, Puerto Ricans have high rates of poor cardiovascular health as well as diabetes. Daviglus et al. (2012) found that the prevalence of 3 or more cardiovascular risk factors was highest among Puerto Rican men and women living in the U.S. compared to other Hispanic groups. This same study showed that the prevalence of 3 or more risk factors was significantly associated with low education for the Puerto Rican sample (Daviglus et al., 2012). An additional study found that proper control for cardiovascular care was found to be significantly lower for Puerto Ricans living in Puerto Rico compared to other Hispanic/Latino groups living in the U.S. (Rivera-Hernandez et al., 2016). Treatment was lacking for blood pressure control in hypertension, beta-blocker treatment after myocardial infarction, and control of LDL-C levels after a coronary event (Rivera-Hernandez et al., 2016).

Tang et al. (2001) found in a sample of Caribbean Hispanics (mostly Dominicans, Puerto Ricans, and Cubans) that heart disease was more frequent among this group compared to African Americans. This study also found that hypertension was more frequent in Caribbean Hispanics compared to Non-Hispanic Whites (Tang et al., 2001). Other research has found that Puerto Ricans in particular, when compared to Non-Hispanic Whites, have higher rates of hypertension (Tucker et al., 2000). Compared to other Hispanic/Latino groups in the U.S. (including Mexican and Dominican participants), Puerto Rican women had higher rates of hypertension, hypercholesterolemia, obesity, diabetes, and identified as a current smoker (Daviglus et al., 2012). Puerto Rican men were also found to have higher rates of both obesity and smoking habits (Daviglus et al., 2012). Overall, Daviglus et al. (2012) showed that Puerto Ricans exhibit significantly high rates of adverse cardiovascular disease (CVD) risk factors compared to other Hispanic groups. Both diabetes and CVD have been found to negatively influence cognitive functioning in late-life and represent serious health concerns for Puerto Ricans (Biessels, Koffeman, & Scheltens, 2006; Luchsinger et al., 2007).

Cardiovascular diseases represent a serious concern for Puerto Ricans and can contribute to cognitive impairment and decline in older adulthood. With the mixture of low education in childhood and low SES throughout life, the accumulation of these circumstances can have serious negative effects on brain health. The older generation of Puerto Ricans represents a unique population and this study presents an opportunity to further understand the contributions of education and other early life factors that contribute to cognitive impairment. Additionally, the significant subgroup differences among Hispanic/Latino groups warrants further investigation of risk factors for cognitive impairment in this population.

Specific Aims

The current project will contribute to our knowledge of cognitive aging in diverse populations by investigating the following aims in a population-based sample of more than 3,500 older adults (age 60+ years) from Puerto Rico.

Aim 1: To examine years of education as a predictor of cognitive decline and incident cognitive impairment in Puerto Rico.

Hypothesis 1a: Greater years of education will be associated with less cognitive decline over four years, as well as lower risk of incident cognitive impairment.

Hypothesis 1b: The association between education and cognitive outcomes will be partially explained by late-life diabetes and cardiovascular health conditions.

Hypothesis 1c: Literacy will be associated with less cognitive decline and reduced risk of cognitive impairment, independent from years of education.

Aim 2: To examine indicators of childhood quality of education and late life cognitive functioning.

Hypothesis 2a: Using data from historical education and Census records, longer school year, lower student-teacher ratio, and greater municipality-level literacy will predict reduced cognitive decline and impairment.

Hypothesis 2b: The association between quality of education variables and cognitive outcomes will be stronger for participants who did not complete high school.

METHOD

Population Description

A sample of 4,291 community dwelling adults aged 60 years and over agreed to participate in baseline data collection for the Puerto Rican Elderly: Health Conditions (PREHCO) study from 2002-2003 (Palloni et al., 2005). Interviews were conducted in participants' homes at baseline and four-year follow up. Information regarding participants' medical history, demographics, early life factors, and socioeconomic status (SES) were collected. In total 182 participants were excluded from the quality of education analyses because they did not attend primary school in Puerto Rico and could not be assigned Census or education data.

For participants with baseline cognitive impairment (based on minimental Cabán score < 11), a proxy informant completed an abbreviated questionnaire regarding late life health and functional status. Both self-report and proxy reports have been well validated and found to be good indicators of actual health status (Demissie et al., 2001; Palloni et al., 2005; Sagar, Cohen, Sullivan, Corkin, & Growdon, 1988; Villanueva & Garcia, 2006).

All interviews and cognitive tests were administered in Spanish. Participants were mainly recruited door-to-door based on census data and maps of the municipalities. Radio and television advertisements were also utilized. The study was originally approved by the University of Puerto Rico Institutional Review Board (IRB) and the current project was approved by the University of Alabama at Birmingham IRB.

Measures

Cognitive Function

The minimental Cabán (MMC) was used to measure global cognitive functioning at baseline and four-year follow-up. This measure was found to be superior to the Spanish translation of the Mini-Mental State Exam (MMSE) in detecting clinically diagnosed dementia (Sanchez-Ayendez et al., 2003). The measure is scored on a 0-20 scale with higher scores indicating better cognitive performance. For cognitive decline, we used the continuous MMC measure. Designation of cognitive impairment was based on scores derived from baseline regression models for the association between cognitive score and age, female sex, years of education, and literacy. Subjects were then classified as cognitively impaired if they fell below 1.5 standard deviations below the predicted score.

Quality of Education

Quality of education was created into a composite variable based on historical data of factors such as school year length, student-teacher ratio, attendance, and literacy levels for each municipality in Puerto Rico. Data was gathered from reports ranging from 1926 to 1945 (participants began schooling in the mid-1930s on average) from the U.S. Census Bureau and the Commissioner of Education in Puerto Rico (Education PRDo., 1940). There is no one source with a complete collection of these education reports, but many of them are available from the University of Puerto Rico library for the time period when participants began schooling (>95% of participants began schooling between 1920 and 1950). Information from education and Census reports were gathered and matched to the reported primary municipality of childhood residence before the age of 18 and indication of whether the participant lived in an urban or rural community. High values for student-teacher ratio were found but kept in the analysis because of the inherent importance in understanding the relationship between classroom size and cognition. Additionally, high values for individual variables were adjusted for when creating the composite. For example, in the municipality of Cataño in 1933, there was one teacher and average enrollment was 84 students. Ninety-five percent of the sample had at least a 1st grade schooling, but less than half the sample (46%) had education beyond 8th grade, emphasizing the relevance of studying elementary school quality of education for this sample.

Three reports were chosen from the Commissioner of Education reports for the fiscal years of 1926-1927, 1933-1934, and 1945-1946. These reports were chosen in order to have at least one report from each decade during which the majority of participants attended school. These report years included information on either school year length (1926; 1933) or student-teacher ratio (1945). To supplement the education reports, we also examined municipality-level Census data for the years 1935 and 1940. Data from 1935 included the number of children ages 7-13 attending school for each municipality. Census data from 1940 included the number of children 10 years or older that were able to read and write per municipality. Participants were then matched to these data based on report of the municipality he/she lived in the most before the age of 18 and whether they grew up in an urban or rural area.

Three municipalities, Cataño, Canóvanas, and Florida, are not included in the 1926 Commissioner of Education report because they did not become municipalities until 1927, 1970, and 1971 respectively. School data is therefore included in the previously established municipality names Barros (Cataño), Loíza (Canóvanas), and Barceloneta (Florida). The Commissioner of Education report and Census reports starting in 1933 and forward include Cataño as an independent municipality. All participants were born before the municipality of Río Piedras became a part of San Juan in 1951. Data for the separate municipalities was consolidated under the municipality of San Juan.

Literacy

Self-reported ability to read was coded as yes or no. Literacy is thought to be a proxy measure for childhood quality of education and self-reported ability to read has previously shown predictive validity for cognitive aging outcomes (Kave et al., 2012; Manly, Schupf, Tang, & Stern, 2005).

Covariates

Demographics. Age and sex were self-reported and was included in models examining cognitive outcomes.

Childhood SES, Health, and Nutrition

Childhood SES was measured by economic hardship measured by summing two items about participant's general economic conditions in the household (i.e. receiving proper medical attention, adequately clothed, and eating regularly) and a self-report of the type of economic conditions in which they grew up (good, average, or bad) with scores ranging from 0-3 with higher scores equaling worse SES. Participants rated childhood health on a 5-point scale (excellent, very good, good, average, or poor) which has been previously validated by the Health and Retirement Study (Elo, 1998). Higher scores on childhood health equaled better health. Measurements of knee height were also collected. Knee height equals the measured distance from the middle of the kneecap to the floor with no socks or shoes on. Gender-specific quartiles of knee height will serve as a measure of early stunting and poor nutritional status in childhood (McEniry, 2011). Higher scores represent shorter knee length.

Adult socioeconomic status. Adult SES was measured by summing two variables regarding difficulty to pay for daily living expenses (frequently, sometimes, or never) and difficulty paying for health care (frequently, sometimes, or never) with higher scores equaling worse SES conditions. Scores ranged from 0-4.

Vascular risk factors. To measure vascular risk factors a summed index score of vascular health conditions was calculated including self-reported diabetes, hypertension, myocardial infarction, congestive heart failure, and stroke/transient ischemic attack (TIA). Scores ranged from 0-5 with higher scores represent a greater number of vascular conditions.

Depressive symptoms. Depression was assessed using the 15-item Geriatric Depression Scale (GDS) (Sheikh & Yesavage, 1986). This questionnaire asks participants yes or no questions regarding depressive symptoms experienced within the last week. Higher scores reflect greater depressive symptoms.

Data Analysis

We first examined bivariate relationships between years of education and variables of interest. Spearman's correlations were used to examine associations between education and ordinal variables of interest, Pearson's correlation was used for relationships between education and continuous variables, and t-tests were utilized for the association between education and categorical variables. Analysis of cognitive decline used linear regression for years of education and literacy. Associations between individual variables and cognitive decline were initially analyzed adjusting only for baseline cognitive function. Analysis of incident cognitive impairment used logistic regression for years of education and literacy. Bivariate associations between individual variables and risk of cognitive impairment was initially completed without adjustment for any covariates. Additional models for both methods of analysis added variables sequentially with demographic variables first, then childhood factors, and then adult factors included in a final model. School year length, student-teacher ratio, attendance, and municipality-level literacy rates were transformed into z-scores and then summed to create a composite score of overall quality of education. Additional analyses include mixed effects modeling to account for nested data in analyses of municipality-based quality of education data. Mixed effects models were built by incorporating predictors sequentially, with the initial model including age, sex, time, and quality of education, next adding childhood variables in a second model, then adding adult factors in a third model. Subsequent models also included years of education and a time x quality of education interaction. For a two-tailed correlation with a sample size of 2,500, power at the 80% level is achievable for a small effect size (Faul, Erdfelder, Buchner, & Lang, 2009). Effect size significance was based on cutoffs outlined in Funder and Ozer (2019).

RESULTS

Assumption testing for linear regression models found that the assumptions of linearity between continuous variables, independence, and homoscedasticity were all met. The assumption of normality was violated for our cognitive outcome, although regression models are robust to normality violations and transformations limit interpretability; therefore, analyses for cognitive decline were considered exploratory and we additionally examined cognitive impairment as a dichotomous outcome in logistic regression models. The assumptions of logistic regression including appropriate outcome structures, observation independence, absence of multicollinearity, linearity of independent variables and log odds, and a large sample size were all met.

A total of 3,883 participants completed baseline cognitive testing. For participants with baseline cognitive impairment or a disability that prevented them from completing the questionnaire on their own, a proxy was used to complete an abbreviated questionnaire. Among proxies, 97% were family members, either a son/daughter or spouse. Qualifications for a proxy included knowing the participant for at least a year and being at least 18 years old. However, the proxy questionnaire did not include questions on childhood factors or depressive symptoms, therefore, the 329 participants with baseline proxy report were excluded from analyses.

At four-year follow up, 2,840 participants completed cognitive testing. Five hundred and forty-nine participants died, 151 were lost to follow-up, 120 refused and 43

Table 1

Baseline Characteristics of Participants

	N	M or %	SD	Range
Age	3883	72	8.46	60-102
Sex (Female), %	2329	59.98		
Education	3883	8.00	4.83	0-18
Non-literate, %	328	8.45		
Baseline cognition	3883	16.23	3.01	0-20
Low childhood SES, %	1005	27.27		
Childhood health	3688	3.45	1.19	1-5
Low childhood nutrition, %	958	25.79		
Low adult SES, %	307	8.32		
Vascular risk factors	3883	1.21	1.07	0-5
Depressive symptoms	3700	3.33	3.41	0-15

Note. Depressive symptoms are measured by the 15-item Geriatric Depression Scale where a score >5 indicates depressive symptomatology; vascular risk factors includes diabetes with higher scores equaling higher number of conditions; higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

were institutionalized. Participants that died (549) before follow-up were more likely to be older, female, less educated, and endorse more depressive symptoms at baseline. They were also more likely to have diabetes, stroke, myocardial infarction, and congestive heart failure but not hypertension. There were no differences in baseline cognition.

Using our regression-based categorization of cognitive impairment, there was incident impairment at follow-up for 192 individuals without baseline cognitive impairment. Baseline sample characteristics are shown in Table 1. Age range at baseline for our sample was 60 to 102 years (mean age 72) and approximately 60% of this sample was female. Approximately 54% of this sample had less than an 8th grade education and 328 participants were illiterate. A total of 27% of the participants had a GDS score greater than five, which is indicative of clinically significant depressive symptomatology.

Table 2

Correlations Among Early and Late Life Factors

	1	2	3	4	5	6	7	8	9
1. Age	-								
2. Education	-0.19**	-							
3. Baseline cognition	-0.24**	0.35**	-						
4. Low childhood SES	-0.01	-0.24**	-0.07**	-					
5. Childhood health	0.01	0.15**	0.09**	-0.28**	-				
6. Low childhood nutrition	0.04*	-0.08**	-0.05**	0.02	0.06**	-			
7. Low adult SES	-0.04*	-0.11**	-0.04*	0.08**	-0.06**	0.05**	-		
8. Vascular risk factors	0.07**	-0.08**	-0.08**	0.09*	-0.11**	0.02	0.06**	-	
9. Depressive symptoms	0.03	-0.15**	-0.13**	0.15**	-0.16**	0.01	0.16**	0.14**	-

Note. *p <.05; **p <.01 Spearman's correlation coefficients shown except for age, education, baseline cognition, and depressive symptoms where Pearson's correlation was used. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

Years of Education

In a correlation analysis, shown in Table 2, it was found that greater years of education was associated with higher baseline cognition. Older age was related to lower education and lower baseline cognition. Higher education was correlated with higher childhood health, fewer vascular risk factors, and lower depressive symptoms. Higher baseline cognition was related to lower vascular risk factors and lower depressive symptoms. Higher childhood SES, better nutrition, and higher adult SES were associated with higher years of education. The remainder of the correlation analysis can be found in Table 2. Less education was associated with lower levels of literacy, t(851.23) = -63.66, p = .0001. Being male was associated with higher levels of education, t(3881) = 2.20, p = .03.

Table 3

Associations Between Cognitive Decline and Individual Variables

	B	SE B	β
Age	0.12	0.01	0.30**
Sex (Female)	0.14	0.11	0.02
Education	-0.16	0.01	-0.26**
Literacy	-1.50	0.20	-0.13**
Low childhood SES	0.02	0.05	0.01
Childhood health	-0.05	0.04	-0.02
Low childhood nutrition	0.30	0.12	0.04*
Low adult SES	0.07	0.09	0.02
Vascular risk factors	0.17	0.05	0.06**
Depressive symptoms	0.04	0.02	0.05*

Note. **p* < .05; ***p* < .01. Variables are adjusted for baseline cognition. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

Initial models examining education, childhood, and adult factors and cognitive decline only adjusted for baseline cognition and results are in Table 3. Older age was significantly associated with greater cognitive decline. More years of education and

Table 4

Linear Regression Models of Years of Education and Cognitive Decline

	Model 1			Model 2			Model 3		
	B	SE B	β	B	SE B	β	B	SE B	β
Age	0.10	0.01	0.26**	0.10	0.00	0.26**	0.10	0.01	0.26**
Sex (Female)	0.01	0.10	0.00	0.00	0.10	0.00	-0.04	0.10	-0.01
Education	-0.15	0.01	-0.24**	-0.15	0.01	-0.24**	-0.15	0.01	-0.24**
Baseline cognition	0.64	0.02	0.52**	0.64	0.02	0.52**	0.65	0.02	0.52**
Low childhood SES				-0.08	0.05	-0.03	-0.10	0.05	-0.04*
Childhood health				0.00	0.04	0.00	0.02	0.04	0.01
Low childhood nutrition				0.13	0.11	0.02	0.13	0.11	0.02
Low adult SES							0.01	0.04	0.01
Vascular risk factors							0.10	0.05	0.04*
Depressive symptoms							0.02	0.02	0.02

Note. **p* < .05; ***p* < .01; higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

Table 5

Associations Between Cognitive Impairment and Individual Variables

	OR	95% Confidence Limits	
Age	1.09	1.07	1.12
Sex (Female)	1.38	1.00	1.90
Education	0.92	0.89	0.95
Literacy	0.50	0.32	0.80
Low childhood SES	0.90	0.78	1.03
Childhood health	0.94	0.83	1.07
Low childhood nutrition	1.25	0.90	1.73
Low adult SES	1.06	0.95	1.19
Vascular risk factors	1.13	0.99	1.30
Depressive symptoms	1.05	1.01	1.09

Note. **p* < .05; ***p* < .01. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

literacy were associated with reduced cognitive decline. Greater number of vascular risk factors and depressive symptoms were significantly associated with greater decline. To examine the association between years of education and cognitive decline after controlling for potential confounds, the sequence of covariate-adjusted linear regression models first included age, sex, education, and baseline cognition (Model 1, Table 4). In this first model, years of education remained significantly associated with reduced

Table 6

Odds Ratio for Years of Education and Cognitive Impairment

	Model 1			Model 2			Model 3		
	OR	95% Confidence Limits		OR	95% Confidence Limits		OR	95% Confidence Limits	
Age	1.09	1.07	1.11	1.09	1.06	1.11	1.09	1.06	1.11
Sex (Female)	1.31	0.94	1.82	1.27	0.91	1.77	1.20	0.86	1.70
Education	0.94	0.91	0.98	0.94	0.91	0.97	0.94	0.91	0.97
Low childhood SES				0.84	0.72	0.97	0.82	0.71	0.96
Childhood health				0.94	0.82	1.08	0.96	0.84	1.11
Low childhood nutrition				1.12	0.80	1.58	1.13	0.80	1.59
Low adult SES							1.03	0.91	1.16
Vascular risk factors							1.08	0.93	1.26
Depressive symptoms							1.03	0.98	1.08

Note. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

cognitive decline ($p < .01$). Baseline cognitive scores were positively associated with cognitive decline at four-year follow-up ($p < .01$). After adjusting for early life factors in Model 2, and late life factors in Model 3, estimates for years of education remained the same (Table 4). Self-reported vascular risk factors were significantly associated with cognitive decline over the four-year period but did not appear to reduce the association between years of education and cognitive decline.

Unadjusted bivariate associations between each of the individual variables used in analyses and cognitive impairment are shown in Table 5. Older age was associated with higher likelihood of cognitive impairment, with approximately 9% greater odds for each additional year of age. Greater education and literacy were significantly associated with lower odds of cognitive impairment. To examine incident cognitive impairment, logistic regression models adjusted for age, sex, and years of education in the first of the covariate-adjusted models (see Table 6). Years of education was significantly associated

Table 7

Linear Regression Models of Literacy and Cognitive Decline

	Model 1			Model 2			Model 3		
	B	SE B	β	B	SE B	β	B	SE B	β
Age	0.11	0.01	0.29*	0.10	0.01	0.26**	0.10	0.01	0.26**
Sex (Female)	0.03	0.10	0.00	-0.02	0.10	0.00	-0.05	0.10	0.00
Literacy	-1.70	0.2	-0.15**	-0.80	0.21	-0.07**	-0.79	0.21	-0.07**
Baseline cognition	0.60	0.02	0.48*	0.65	0.02	0.52**	0.66	0.02	0.53**
Education				-0.13	0.01	-0.21**	-0.13	0.01	-0.21**
Low childhood SES				-0.07	0.05	-0.02	-0.09	0.05	-0.03
Childhood health				0.00	0.04	0.00	0.02	0.04	0.00
Low childhood nutrition				0.13	0.11	0.02	0.13	0.11	0.02
Low adult SES							0.01	0.04	0.01
Vascular risk factors							0.11	0.05	0.04*
Depressive symptoms							0.02	0.02	0.02

Note. *$p < .05$. **$p < .01$; higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

with reduced odds of cognitive impairment in Model 1 (OR = 0.94; 95% CI = 0.91, 0.98; p = 0.0007), indicating approximately 6% lower odds of impairment for each additional year of schooling. Childhood SES, health, and nutrition indicators were added in the second model, followed by late life factors in the third model. Childhood socioeconomic status was related to cognitive impairment in the fully adjusted third model (OR = 0.82; 95% CI = 0.71, 0.96; p = 0.01). The association between years of education and reduced odds of cognitive impairment was similar for both adjusted and unadjusted analyses.

To examine the relationship between literacy and cognitive decline, linear regression models adjusted for demographic variables, literacy, and baseline cognition in the first model (see Table 7). Literacy was significantly associated with less cognitive decline (p < .01) in Model 1. In Model 2, after the addition of years of education and childhood variables, the association between literacy and cognitive decline decreased over 50% but remained statistically significant.

Table 8

Odds Ratio for Literacy and Cognitive Impairment

	Model 1			Model 2			Model 3		
	OR	95% Confidence Limits		OR	95% Confidence Limits		OR	95% Confidence Limits	
Age	1.09	1.07	1.11	1.09	1.07	1.11	1.09	1.06	1.11
Sex (Female)	1.30	0.94	1.82	1.27	0.91	1.77	1.20	0.86	1.69
Literacy	0.56	0.34	0.91	0.85	0.49	1.48	0.88	0.51	1.53
Education				0.94	0.91	0.98	0.94	0.91	0.98
Low childhood SES				0.84	0.72	0.98	0.82	0.71	0.96
Childhood health				0.94	0.82	1.08	0.96	0.84	1.10
Low childhood nutrition				1.12	0.80	1.08	1.12	0.80	1.58
Low adult SES							1.03	0.91	1.16
Vascular risk factors							1.09	0.94	1.26
Depressive symptoms							1.03	0.98	1.08

Note. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

The association between literacy and cognitive impairment was also examined (Table 8). In the first model, literacy was significantly related to reduced odds of cognitive impairment (OR = 0.56; 95% CI = 0.34, 0.91; p = 0.02). However, after the addition of education and early life factors, the relationship between literacy and cognitive impairment was no longer statistically significant.

Quality of Education

Descriptive data on quality of education variables are available in Table 9. The average number of school days in session was 183 days in 1926 and 181 days in 1933. The average classroom size was 54 students per teacher but reached up to 84 students in rural municipalities. A third of the sample was born before 1928, another third from 1928 to 1935, and the last third after 1935.

A correlation of indicators of quality of education, years of education, and low childhood SES was conducted to examine intercorrelations and relationships with years of education (Table 10). Among quality of education variables, the number of days in session for 1926 was most highly correlated with years of education. Years of education

Table 9

Indicators of Educational Quality from 1926-1945 Department of Education and Census Records

	M	SD	Range
Days of school (1926)	183.54	3.89	174 - 190
Days of school (1933)	181.54	4.89	140.2 - 188.9
School attendance (1935)	62.89	7.04	43.32 - 78.59
Literacy (1940), %	69.28	6.56	46.67 - 80.84
Student-teacher ratio (1945)	54.47	6.01	28 - 84

Note. Percent literate is at the municipality level and is equal to the amount of people aged 10 years and older who could read and write. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

Table 10

Correlations Among Indicators of Quality of Education

	1	2	3	4	5	6	7
1. Education	-						
2. Low childhood SES	-0.22	-					
3. Days of school (1926)	0.27**	-0.09**	-				
4. Days of school (1933)	0.11**	-0.04*	0.50**	-			
5. Student-teacher ratio (1945)	-0.15**	0.04*	-0.40**	-0.12**	-		
6. School attendance (1935)†	0.18**	-0.07**	0.25**	0.12**	-0.22**	-	
7. Literacy (1940)†	0.20**	-0.09**	0.37**	0.32**	-0.11**	0.70**	-

Note. **p* < .05; ***p* < .01; † School attendance is the percentage of persons ages 7-13 who attended school in 1935. Literacy rate is the percentage of persons age 10 years or older who could read or write in 1940 at the municipality level. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

was significantly positively correlated with total school days in session for both 1926 and 1933, attendance, and literacy rates. Years of education was significantly negatively correlated with student-teacher ratio, indicating more years of education was associated with less students per classroom. There was a small, significant correlation for the relationship between years of education and attendance at school and literacy rates for 1940.

Table 11

Correlations of Quality of Education and Psychosocial Factors

	1	2	3	4	5
1. Age	-				
2. Quality of education	-0.00	-			
3. Education	-0.21	0.27**	-		
4. Depressive symptoms	0.03**	-0.06**	-0.16**	-	
5. Baseline cognition	-0.25**	0.12**	0.35**	-0.14**	-

Note. **p* < .05; ***p* < .01. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES. Pearson correlation shown.

Table 12

Standardized Estimates for Associations Between Quality of Education and Cognitive Function From Mixed Effects Models

	Model 1			Model 2			Model 3			Model 4			Model 5		
	B	SE B	t	*B*	SE B	t	*B*	SE B	t	*B*	SE B	t	*B*	SE B	t
Age	-0.09	0.00	-22.49**	-0.09	0.00	-21.85**	-0.09	0.00	-21.44**	-0.07	0.00	-17.47**	-0.09	0.00	-19.15**
Sex	0.11	0.07	1.63	0.10	0.07	1.43	0.19	0.07	2.68**	0.24	0.07	3.57**	0.19	0.08	2.47*
Time	-0.87	0.07	-13.09**	-0.85	0.07	-12.71**	-0.90	0.07	-13.04**	-0.89	0.06	-13.80**	-0.04	0.04	-0.99
Quality of education	0.06	0.01	4.47**	0.06	0.01	3.98**	0.05	0.01	3.90**	-0.01	0.01	-0.56	0.10	0.03	2.94**
Low childhood SES				-0.07	0.03	-2.18*	-0.04	0.03	-1.09	0.08	0.03	2.56*	-0.21	0.09	-2.39*
Childhood health				0.12	0.03	3.91**	0.08	0.03	2.60**	0.04	0.03	1.39	-0.06	0.03	-1.98
Low childhood nutrition				-0.18	0.08	-2.27*	-0.18	0.08	-2.30*	-0.09	0.08	-1.20	-0.08	0.04	-2.26*
Low adult SES							-0.04	0.03	-1.52	0.03	0.03	1.03	-0.07	0.01	-5.74**
Vascular risk factors							-0.08	0.03	-2.43*	-0.07	0.03	-2.30*	-0.89	0.06	-15.66**
Depressive symptoms							-0.07	0.01	-6.62**	-0.06	0.01	-5.71**	0.07	0.01	5.27**
Education										0.16	0.01	21.39**	-	-	-
Time*Quality of education													-0.01	0.02	-0.68

Note. *$p < .05$; **$p < .01$; † Model includes all demographic variables, childhood health, childhood SES, knee height, adult SES, vascular risk factors, and depressive symptoms. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

Correlations among the quality of education composite, early childhood factors, and late life factors are available in Table 11. The composite quality of education variable was significantly positively correlated with years of education and baseline cognitive scores. Higher quality of education was also significantly associated with better childhood health, fewer vascular risk factors, and fewer depressive symptoms.

Initial mixed effect models included age, sex, time, and quality of education. Higher quality of education was associated with higher cognitive functioning (Table 12).

Table 13

Standardized Estimates for Associations Between Quality of Education and Cognitive Function by Level of Education

	Education <12 y						Education ≥ 12 years					
	Adjusted for Time, Age, and Sex			Fully Adjusted Models†			Adjusted for Time, Age, and Sex			Fully Adjusted Models†		
	B	SE B	t	B	SE B	t	B	SE B	t	B	SE B	t
Age	-0.09	0.01	-17.34**	-0.09	0.01	-16.26**	-0.07	0.01	-10.64**	-0.07	0.01	-10.45**
Sex	-0.02	0.09	-0.25	0.03	0.09	0.39	0.43	0.10	4.43**	0.47	0.10	4.74**
Time	-1.10	0.09	-12.99**	-1.12	0.09	-12.89**	-0.46	0.10	-4.83**	-0.46	0.10	-4.80**
Quality of education	0.02	0.02	0.98	0.01	0.02	0.57	0.02	0.02	0.85	0.02	0.02	1.10
Low childhood SES				0.07	0.04	1.58				0.01	0.05	0.15
Childhood health				0.06	0.04	1.51				0.05	0.05	1.12
Low childhood nutrition				-0.14	0.10	-1.41				-0.14	0.12	-1.17
Low adult SES				0.02	0.04	0.58				-0.04	0.04	-0.81
Vascular risk factors				-0.07	0.04	-1.74				-0.10	0.05	-2.12*
Depressive symptoms				-0.07	0.01	-5.32**				-0.05	0.02	-3.08**

Note. *$p < .05$; **$p < .01$; † Model includes all demographic variables, childhood health, childhood SES, knee height, adult SES, vascular risk factors, and depressive symptoms. Higher scores for low childhood SES equal worse SES; higher scores on low childhood nutrition equal worse childhood nutrition; higher scores for low adult SES equal worse SES.

Older age was related to lower cognitive functioning. Significant associations remained after adjustment for childhood variables. When adult factors were included as covariates in the next mixed effect model, vascular risk factors and depressive symptoms were associated with lower cognitive performance, but quality of education remained significantly associated with cognition. With the addition of adulthood variables in the third model, childhood SES was no longer significantly related to cognition. When years of education was added to the model, quality of education was no longer significantly associated with cognition. Models restricting years of education to less than 12 years did not indicate that the association between quality of education and cognitive function differed according to years of schooling achieved (Table 13).

Post-hoc Analyses

In post-hoc sensitivity analyses, total score on the MMC was used as an outcome in logistic regression analyses to check the impact of how our regression-based definition of cognitive impairment (which incorporated both years of education and literacy) may have influenced results. Using the standard MMC cutoff score of ≤10 points for all participants, 191 individuals were excluded due to cognitive impairment at baseline and at four-year follow up 129 participants had incident cognitive impairment. For comparison, using the regression-based definition, 292 were excluded due to baseline impairment and 192 participants were cognitively impaired at four-year follow up. In Model 1, using the standard MMC cutoff definition, greater years of education was significantly related to lower risk of incident impairment (OR = 0.84; 95% CI = 0.80, 0.88; p = < 0.0001). In Model 2 after adjusting for childhood SES, health, and nutrition the OR for years of education decreased slightly and remained significant (OR = 0.83; 95% CI = 0.79, 0.87; p = < 0.0001). Higher childhood SES was significantly associated with a lower odds of cognitive impairment (OR = 0.79; 95% CI = 0.66, 0.95; p = 0.01). Childhood SES was not significantly related to cognitive impairment in the regression-based analyses. After adjusting for adult factors in the third model, the association between years of education and cognitive impairment remained the same. Years of education was significantly associated with cognitive impairment using both definitions, however, the OR for the total MMC score analyses was lower than the OR using the regression-based definition of cognitive impairment (OR = .94 across the three models). The confidence intervals for these two definitions did not overlap, suggesting significant differences in the association between education and cognitive impairment depends on the definition used.

We also examined the association between literacy and the total MMC score definition. The initial model included age, sex, and literacy. The ability to read was significantly associated with decreased odds of cognitive impairment (OR = 0.20; 95% CI = 0.12, 0.32; p = < 0.0001). The second model included years of education and childhood factors and the estimate for literacy decreased but remained significant (OR = 0.52; 95% CI = 0.30, 0.93; p = 0.03). The third model included adult factors and the association between literacy and cognitive impairment remained significant (OR = 0.54; 95% CI = 0.30, 0.96; p = 0.04). When years of education was added to the model using the regression-based cognitive impairment definition, similar to previous analyses, the association between literacy and cognitive impairment became nonsignificant.

DISCUSSION

Years of education was significantly related to reduced cognitive decline and cognitive impairment while controlling for several demographic factors, supporting our hypothesis. Literacy was significantly related to cognition, but contrary to our hypothesis educational attainment accounted for a larger portion of decline in cognition. Vascular risk factors were significantly related to cognitive decline in education and literacy models but was no longer significant when examining cognitive impairment. These findings did not support our hypothesis that late-life diabetes and vascular conditions would explain the association between education and cognitive functioning. We found that quality of education was significantly related to cognition across the two time points supporting our hypothesis. Contrary to our hypothesis, the association between quality of education and cognitive outcomes for participants with less than 12 years of education was not statistically significant.

Years of education was negatively correlated with childhood financial problems. This indicates that the more financial strain families had the less education the participants received, most likely from dropping out of school and working to help the family. Older participants were less likely to be able to read and had less education, which is expected for older generations.

Consistent with our Aim 1 hypothesis, years of education was related to cognitive decline and impairment at 4-year follow-up. The addition of early childhood and late life factors to the model did not change the relationship between education and cognition. Literacy was significantly related to cognitive decline over four years and cognitive impairment at follow up. However, adding years of education in linear regression models resulted in a reduction of over 50% of the variance and logistic regression models were no longer significant when education was added. This is contrary to our hypothesis predicting that literacy would be associated with cognitive decline and impairment independent of years of education.

Our results are not consistent with past research on quality of education in which studies have found that literacy is a better predictor of cognition than years of education (Kave et al., 2012; Schmand et al., 1997; Sisco et al., 2015). There are notable differences in these prior study populations compared to our sample. Two studies were conducted in Europe with different education systems and curriculum (Kave et al., 2012; Schmand et al., 1997). Another study comparing Black/AA and NHW participants in northern Manhattan found that 30.1% of Black/AA participants had less than an 8th grade education while in this sample 47.6% participants had less than an 8th grade education (Sisco et al., 2015). For this sample, simply staying in school and the addition of every year may have a greater impact on cognitive functioning. In other samples, it may be standard that most participants have at least an 8th grade education and more likely to attend, and graduate, high school. The quality of their education and literacy levels play a larger role in their cognitive functioning compared to our sample. The quantity of school for our sample seems to be more important for cognition in late life.

In a literature review by Sharp and Gatz (2011), after presenting conflicting evidence amongst studies examining education, literacy, geography, sex, and ethnicity, the authors concluded that years of education is most indicative of cognitive functioning when it reflects intellectual ability and not just privilege. This explains why some studies find that literacy is a better predictor of cognition for racial minorities than years of education because it accurately reflects cognitive abilities. For this sample, results suggest that years of education may be a more accurate reflection of actual cognitive capacity compared to both literacy and quality of education. Crowe et al. (2013) found in a sample of older adults from Alabama that in 1935 the average number of days in school was 130 for Black/AA participants and 161 for NHW, which is much lower than the average 181 days in 1933 for this sample. The Great Depression may have affected schools and funding in the U.S. more than Puerto Rico and prevented longer school years. During the early 1900's the U.S. government made a concerted effort to assimilate Puerto Rican citizens including remodeling the educational system that may have implemented strict academic guidelines. Additionally, in Puerto Rico the student-teacher ratio was much higher compared to the Alabama sample. In Alabama, the average classroom was 46 students for African American schools and 31 for White schools with a range of 35-57 students and 16-40 students, respectively. In Puerto Rico, the average classroom was 54 students with a range of 28 to 84 students. While Puerto Rican students on average had a longer school year than Alabama students, their classroom were much larger, especially for rural schools. Disparities between schools across Puerto Rico were much smaller compared to schools in Alabama, which were segregated during this time.

Our results suggest that vascular risk factors can contribute to decline in cognitive functioning but not cognitive impairment in this population. One possible reason vascular risk factors and cognitive impairment may not be related in this study is that participants that already had cognitive impairments due to stroke or other vascular events may have been excluded at baseline. Our definition of cognitive impairment was stringent and may have been too strict, consequently excluding minor cognitive changes. We had a small sample of participants that met the impairment cutoff and there may not have been enough power to produce significant findings. Several studies have found diabetes to be associated with poor cognitive performance on neuropsychological tests (Palta et al., 2017) and increased risk and rate of cognitive decline specifically in minority populations (Cuevas, 2019). A review of cognitive and diabetes literature explains that diabetes is related to slight decreases in cognition over time that is not necessarily indicative of progression to dementia but can still have noticeable effects in cognition (Geert Jan Biessels, Strachan, Visseren, Kappelle, & Whitmer, 2014). In this sample, 28% of participants had self-reported diabetes and Puerto Ricans in general have high rates of diabetes, which may put them at a higher risk for cognitive decline as they age. However, vascular risk factors for cognitive impairment did not explain associations between education and cognitive outcomes in our sample.

Although higher quality of education was associated with better cognitive performance, when including years of education in the last mixed effects model, quality of education was no longer significant. Results suggest that both quality of education and years of education are important but years of education may be an adequate estimate for cognition in this sample. These findings differ from those in Crowe et al. (2013) in which the authors found that student-teacher ratio and school funding were predictive of cognitive performance in a sample of Black/AA and NHW adults from Alabama. Additional studies found that quality of education predicts cognitive performance better than years of education (Carvalho et al., 2015; Manly et al., 2002). However, these studies compared Black/AA and NHW participants in the mainland U.S. and a major difference between these groups during this time was the impact of segregated schools in the U.S. Two studies were specifically set in the South while one was in a predominantly Hispanic/Latino and Black/AA community in Northern Manhattan. In the U. S., research has shown that higher student to teacher ratio, lower school funding, and shorter school days are more common and negatively influence predominantly Black/AA schools. It may be that the quality of education was worse for Black/AA in the U.S. than the educational quality in Puerto Rico and is a better estimate of cognitive functioning in older age for this population.

This paper examined indicators of quality of education at the municipality (similar to county) level instead of statewide data. The benefit to this is that we can examine within state variability in quality of education at a more refined level. County-level data can provide clarity on literacy levels per county, disparities between urban and rural counties, or disparities in student-teacher ratios across counties.

This paper is relevant to the current educational status in Puerto Rico that is facing major restructuring in the aftermath of Hurricane Maria. Puerto Rico closed hundreds of schools both before and after the hurricane due to lack of funding and structural damage to schools, which were predominantly elementary schools in rural areas (Hinojosa, Meléndez, & Severino Pietri, 2019). There has also been a decline in school enrollment due to families migrating to the mainland U.S. that has been occurring for years but was exacerbated by the hurricane (Trines, 2018). This has resulted in a "brain drain" on the island since many of those leaving are highly educated professionals (Trines, 2018). With a declining population and less children enrolling in school, projections for the educational system include more public school closures resulting in overcrowding in some areas and the privatization of school systems, which will result in unequal educations (Trines, 2018). The restructuring of the Puerto Rican school system may have negative implications on the quality of education children receive and, in turn, long-term consequences in terms of aging and health.

Limitations & Future Directions

There are some limitations to this study. It would have been more informative to have the WRAT-4 word-reading test or other test of word knowledge as opposed to the yes or no question of whether the participant can read. This is because formal testing would allow us to understand what level these individuals could read. Many can read but knowing the level at which they can read would give us even more information about their quality of education. Given that this study was able to find significant results using a dichotomous question for ability to read, it is indicative that other cross-cultural studies could utilize this yes/no question if budget, time, or language constraints are present. We also used a measure of cognitive impairment that adjusted for education and literacy, which were the main outcomes of our analysis. Despite using this definition of cognitive impairment, we still found significant results suggesting that education has a strong influence on cognition even when it is accounted for multiple times in analyses. Another limitation is that this study did not ask participants whether they attended private schools, and data from the education reports applied to public school systems. Students that attended private schools may have received better quality of education and stayed in school longer compared to public schools. Although, only 4.1% of elementary children were attending private school in 1940 and therefore represent a small percentage of the total number of children attending school during the time period of interest for our sample (Ladd & Rivera-Batiz, 2006). Although regression analyses are robust to violations of normality, we note that this is a limitation of this study. This study was unable to administer full neuropsychological batteries or clinical diagnoses of dementia by a health care professional. Having data from formal neuropsychological testing and confirmed diagnoses would have allowed a more fine-grained analysis of cognitive outcomes. Future research could examine the interrelationship of education, life course SES, and occupation in relation to cognition in older age given that these factors have all been individually linked to late-life cognitive outcomes. In addition, future research could use data collected as part of this study to conduct cross-cultural comparisons of associations between indicators of education quality and cognitive aging outcomes.

CONCLUSION

This study provides evidence that years of education, literacy, and quality of education are all associated with reduced cognitive decline and cognitive impairment in a sample of older Puerto Rican adults. However, years of education largely explained associations between cognitive outcomes and quality of education indicators in this sample of older Puerto Ricans. These findings are somewhat contrary to previous studies in the mainland U.S. that have found quality of education and literacy to be superior estimates of cognitive decline and impairment, although all these studies support the finding of a positive associations between quality of education, literacy, and years of education. One notable difference is that this sample had an average educational level of eight years, compared to other studies in the mainland U.S. that on average completed some high school or were high school graduates. It is also possible that quality of education may have been more homogenous across Puerto Rico as opposed to the U.S. where discrimination and segregation of schools created a significant gap between African Americans and NHW. This study provides further evidence that years of education, literacy, and quality of education are all intertwined and are important factors for understanding risk of negative cognitive outcomes in older age, but that years of education largely explained associations between cognitive decline and indicators of education quality.

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