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Income as a modifier of the relationship between cognitive impairment and education

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ABSTRACT

INCOME AS A MODIFIER OF THE RELATIONSHIP BETWEEN COGNITIVE IMPAIRMENT AND EDUCATION

By

LILLIAN MAUREEN MORGADO

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INTRODUCTION: Education is considered a protective factor against cognitive decline. However, the relationship between education and cognition may be further complicated by additional factors. Income may moderate the protective association of education against cognitive decline.

AIM: Here we evaluate the 2020 Health and Retirement Study (HRS) wave to examine the strength of the relationship between education, income, and cognitive impairment.

METHODS: A cross-sectional analysis of the education, income, and cognition scores of 15,412 respondents to the 2020 HRS survey.

RESULTS: Results from this analysis show lower income levels reduce the protective association between education and cognition. Education has a protective association against cognitive impairment. Adjusting the odds ratio for income increases the odds ratio from 0.46 (95% CI, 0.438, 0.477, P< .001) to 0.56 (95% CI, 0.537, 0.589, P< .001) and reduces the protective association between cognitive impairment and education. Controlling for income has a greater effect than controlling for race, nursing home residency, gender, and total comorbidities combined.

DISCUSSION: Education is the single modifiable risk factor most protective against cognitive impairment in this analysis, but income has a strong modifying effect on this relationship. Interventions and policy initiatives that focus on increasing education levels to protect against cognitive impairment in old age would be strengthened by integrating income in their analysis.

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EDUCATION

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APPROVAL PAGE

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Author's Statement Page

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INTRODUCTION

1.1 Background

Alzheimer's Disease, the most common form of dementia, was the 7th leading cause of death in the United States in 2022 [1]. As a chronic and degenerative condition, Alzheimer's Disease and Related Dementias (ADRD) create a burden for individuals and their communities. PLWD receive paid help at twice the rate of adults without dementia and require more hours of assistance[2]. The estimated lifetime cost of care for PLWD in the United States was $321,780 per person in 2015, more than double the cost of caring for someone without dementia[3]. The majority of this expense (70%) is paid out of pocket by the individual or their family[3]. The Alzheimer's Association estimates that unpaid caregivers for PLWD in the United States provided 18 billion hours of care in 2022 alone.[4]

Dementia is a clinical syndrome, collection of symptoms, that impede an individual's ability to independently complete activities of daily living. Dementia is the most advanced form of cognitive impairment. Cognitive impairment refers to "decline in one or more cognitive domains" (complex attention, executive functioning, learning and memory, language, perceptual-motor/visuospatial function, and social cognition)[5]. There is a spectrum of cognitive impairment ranging between cognitively healthy, mild cognitive impairment (MCI), and dementia[6]. MCI, occurring in 22% of adults over 65 [4], is defined as cognitive impairment that impedes on an individual's abilities in at least one domain but does not interfere with their everyday life. Dementia is characterized as impairment in at least two cognitive domains that interferes with everyday life. [5]

The underlying causes of cognitive impairment are diverse, including pathological changes caused by neurodegenerative disease Alzheimer's disease is the most common cause of cognitive impairment, including dementia, in those over 65 years old in the United States [4]. Alzheimer's Disease is characterized by the presence of amyloid plaques and neurofibrillary tangles of tau protein. Less common causes of cognitive impairment include vascular dementia (defined by brain degeneration due to vascular damage such as stroke), Fronto-temporal dementia (FTD)(defined by atrophy of the temporal and frontal lobes), and dementia with Lewy bodies (DLB). Together, these are referred to with the umbrella term "Alzheimer's disease and Related Dementias" or ADRD.

While etiologies differ, ADRD share similar risk factors including modifiable factors such as lifestyle, environment, and socio-demographic conditions. As much as 40% of dementias have been attributed to "less education, hypertension, hearing impairment, smoking, obesity, depression, physical inactivity, lack of social contact, excessive alcohol consumption, traumatic brain injury, and air pollution" by the Lancet Commission on Dementia Prevention[7].

Prior evidence has established educational attainment as a protective factor against cognitive impairment, largely by delaying the onset of cognitive decline and extending the amount of time that an individual is able to live cognitively normally[8]. Recent research has begun to investigate the interaction between the protective effect of education and other factors, such as income. Income influences health behaviors, brain health outcomes, and access to resources[9], benefits which overlap heavily with education. This manuscript reports on an evaluation of whether income is a modifier of the protective effect of education on cognitive

impairment while examining the effects of other known factors in the 2020 Health and Retirement Study population.

1.2 Research Question/Hypothesis

We hypothesize that controlling for income will modify the relationship between education and cognitive impairment.

LITERATURE REVIEW

2.1 Relationship between cognitive impairment and socioeconomic status

Socio-economic status (SES) has been established as a risk factor for cognitive impairment [10] and has previously been shown to affect the relationship between other risk factors and cognitive impairment. For example, an analysis of air pollution and neighborhood socioeconomic status (nSES) in Metro Atlanta found that unless nSES was controlled for, air pollution (a known risk factor for dementia[7]) appeared to protect against cognitive impairment. The true effect that was being observed was that the protective effect of high nSES was so strong that it negated the risk factor of air pollution for cognitive decline. Upon including nSES for analysis, the protective effect of air pollution against cognitive decline vanished[11]. To properly understand the magnitude and effect of individual risk factors for cognitive impairment, we must understand how the components of SES interact with the risk of cognitive impairment. Researchers regularly collect information on participants' education, race, and gender to determine their SES, but less often collect data on individuals' income.

2.2 Education and Cognitive Impairment

Educational attainment is an established a protective factor against cognitive impairment, but how it is conceptualized, the dose that is studied, and the methodologies of the research it is applied to are varied. Longitudinal studies have shown that higher education levels protect against cognitive impairment by delaying its onset [8,12], but once an individual is cognitively impaired, education either has no effect on the rate of cognitive decline [13]or accelerates the

rate of decline [8] While accelerated decline may seem to be a poor outcome, because it is

accompanied by a longer period of cognitive normalcy, this is considered a net positive.

In the context of neurological studies, education is conceptualized as a proxy for cognitive

reserves, a theoretical concept postulating that cognitive stimulation over the lifetime acts as a

buffer against physical degeneration in the brain[7], either on its own or combined with a battery

of cognitive tests. In other types of studies, the protective effect of education can be explained

partially by the fact that education modifies other behaviors and risk factors, like smoking,

drinking, and BMI[14]. Several studies state that cognition and education levels are highly

associated, but do not specify a theoretical framework for studying it as a variable[13,15,16].

To further complicate the relationship between education and cognitive impairment, the

measurement and 'dose' of education vary widely between studies, ranging from literacy

versus illiteracy[13],the effect of one additional year of education, [15]total years of education

completed, [12] to the highest level of education attained. [17]

2.3 Prior evidence on cognition and education

Two main study types emerge in the literature regarding associations between cognition and

education. The first are longitudinal neurological studies which monitor cognitive decline using

brain scans and cognition tests[8,12,13,17]. The second type of study are analyses of large, de-

identified secondary data sets[15,16,18–20]. Longitudinal neurological studies consider education as

a proxy for cognitive reserves and include measurements for race, genetic risk factors, and level

of education, but do not collect income information[8,12,13,17]. The participants' educational levels,

brain scans, and cognitive test scores are compared to the results of ongoing brain scans and

cognitive tests to investigate physical changes in the brain, cognitive reserves, and cognitive decline over time. Analyses of secondary data set generally include some measure of cognitive impairment, but do not include brain scans or genetic information for participants. Education and sex are consistently included as measures of SES.[15,16,18,19] Race and ethnicity is measured in the US study[18], but not in the UK or Swedish study. The likely reason for this is their data sources; the UK study [16] analyzed the Whitehall II data set, which is primarily male and white[21] and the Swedish study[15] used the Swedish National Patient Register, which does not collect information on individuals' race or ethnicity[22].

2.4 Prior evidence on education, income, and cognitive impairment

In studies that investigate the effect of education on cognitive impairment in old age, controlling for income weakens the protective relationship of education[15], though this mediating effect varies between populations and countries[19]. These studies have been conducted primarily in large, de-identified data sets of European[15] populations. We located only two studies that use HRS data that examined the relationship between education and income specifically. One study analyzed HRS data from 1992 to 2016 and found an association between low wages in mid-life and accelerated memory decline in old age, even when controlling for education[23].   An additional study has been published using longitudinal HRS data from 1996-2016 showed that the three most important predictors of variations in cognitive function were education, race, and household wealth and income[18]. Based off of this literature review, we believe that this manuscript is the first paper to examine the relationship between education, income, and cognitive impairment using the HRS 2020 dataset.

METHODS

3.1 Data

To analyze the relationship between income, education, and cognitive impairment, we selected

the data from the 2020 Health and Retirement Study (HRS). This is an ideal data source for this

study since it is the most recently available version of this survey which includes detailed

financial, demographic, and health information of older adults in the United States. In addition

to being nationally representative[24], the 2020 HRS data set purposely oversamples Black and

Hispanic populations[25], allowing for accurate analysis of data from these groups.

The two specific files used for analysis were the RAND HRS Longitudinal 2020 (V1)[26] and the

Langa-Weir Classification of Cognitive Function 1995-2020[27]. Both data files are publicly

available from the HRS website and all data is de-identified. We analyzed the data set in SAS 9.4

for descriptive statistics, chi square tests of independence, and logistic regression.

3.2 Measures

3.2.1 Disease Measure – outcome of interest

The disease measure used for this study was 'cognitive impairment' measured in the

year 2020. The original data set classified cognition into three categories: normal, mildly

cognitively impaired but not demented, and demented[27]. For this manuscript we converted

cognition to a binary variable, combining 'mildly cognitively impaired but not demented' and

'demented' into one category called 'cognitively impaired'.

3.2.2 Main exposure or risk factor of interest:

Highest Level of Education

The original file presented respondents' highest level of education as an ordinal value with 5 levels: less than high school, GED, high school, some college, and college and above[26]. We reduced the number of levels to 4 by combining the GED and high school categories into a single category. We treated education as a categorical variable for the purpose of chi-square tests of independence, but coded education as a continuous variable in the final logistic regression model to better compare the odds ratios between education and income.

Income

The original data presented household income as a continuous dollar amount[26].   The codebook reported two high income outliers for the data set[26]. To minimize the effect of these outliers on results, this data was converted to quartiles. We treated income quartile as a categorical variable for the purpose of chi-square tests of independence and coded income as a continuous variable in the final logistic regression model to better compare the odds ratios between education and income.

3.2.3 Covariates

Age

This manuscript includes age as a continuous variable. Due to the subject of study being cognitive impairment linked to age, all respondents below the age of 50 were excluded from analysis. This includes both the traditional cut off 65 and older qualifying as 'geriatric' and still allows for the inclusion of marginalized populations shown to experience accelerated aging[28].

Total comorbidities

The 'total comorbidities' variable captures whether an individual has ever reported experiencing comorbidities associated with cognitive impairment including high blood pressure, diabetes, heart disease, stroke, psychiatric problems, or sleep disorders[7]. The Rand HRS file indicates whether a participant has ever reported any of these conditions on an HRS survey as of 2020[26]. All 'yes' responses to these questions were added together to create an ordinal value of 'total comorbidities'.

Additional Exposures

Additional exposure factors were chosen based on their association with cognitive impairment and dementia in the existing literature and their availability in the existing data set. We included race[7], gender[7] and nursing home residency at time of interview as categorical covariates in the model.

Variable from original data set	Transformation
gender	none
race	none
nursing home residency at time of interview	none
highest level of education	Combined GED and high school
age at time of interview	Remove younger than 50
Ever reported high blood pressure	Added together to create variable for 'total comorbidities'
Ever reported diabetes	
Ever reported heart disease	
Ever reported stroke	
Ever reported psychiatric problems	
Ever reported sleep disorder	
Household income	Broken into quartiles
cognition	Converted to binary value
table 3.2.3 summary of measures and transformations	

3.3 Statistical Analysis

All statistical analysis was completed using SAS 9.4. We conducted a chi-square test of

independence for all categorical and ordinal variables before testing for model fit to determine

if relationships between variables were statistically significant. To determine the largest

possible model to use for logistic regression, we performed a forward-selection algorithm test.

We modeled six separate logistic regression models to determine the odds ratios of cognitive

impairment, income, and education when controlling for different covariates. These odds ratios

were then compared to determine how much variation was attributable to the education,

income, and other covariates.

RESULTS

4.1 Sample

We merged the two files for analysis on household and individual ID number for each observation. After eliminating all non-respondents for the 2020 survey, a total of 15,724 observations remained. Two observations were not able to be merged. Eliminating these two observations does not significantly reduce the power of this sample. In addition to these two observations, excluding all observations younger than 50 years of age only eliminated 312 observations, reducing the size of the data set from 15,724 observations to 15,412. Not every observation contained all variables.

4.2 Demographics

Demographics are summarized in table 4.2 below. Members of this data set are majority female (58.85%), white (65.72%), cognitively unimpaired (78.09%), with a high school education or higher (84.73%) and live outside of a nursing home (97.87%). Ages ranged from 50 to 104, with a median age of 68. Total comorbidities ranged from 0 to 6, with a median of 2 comorbidities per person.

		All
Gender		
Male		6277
Female		9070
All		15347
Race		
White/Caucasian		10130
Black/African American		3388
Other		1829
All		15347
Cognition		
Normal		12036
Impaired		3311
All		15347
Income Quartile		
1st (Less than or equal to 25%)		3822
2nd (Greater than 25% and less than or equal to 50%)		3868
3rd (Greater than 50% and less than or equal to 75%)		3831
4th (Geater than 75%)		3826
All		15347
Nursing Home Residency		
No		15084
Yes		263
All		15347
Highest Level of Education		
Less than high school		2344
GED/high school		4787
Some college		4172
College and above		4044
All		15347
Age at interview	**Min**	50.00
	Mean	68.61
	Median	67.00
	Max	104.00
Total Comorbidities	**Min**	0.00
	Mean	1.73
	Median	2.00
	Max	6.00

table 4.2: demographics

4.3 Chi-Square Test of Independence

Results of the chi-square test of independence are summarized in table 4.3 below. Before performing logistic regression, we ran a Chi-square test for independence on all categorical and ordinal values to assess whether these variables have a statistically significant relationship, defined as $p \leq 0.05$, with the logic that variables that do not have a statistically significant relationship with either education or income quartile should be excluded from model testing. Statistically significant associations were found between all values except education and nursing home residency. The variable with the weakest, though statistically significant, relations was gender. Results of Chi-square tests are summarized in table 3. All variables were included for model testing as they had a statistically significant relationship with either education or income.

Chi Square Value P value							
	Cognitive Impairment	Income Quartile	Education	Nursing Home Residency	Race	Total Comorbidities	Gender
Cognitive Impairment	--	<.0001	<.0001	<.0001	<.0001	<.0001	0.0115
Income Quartile	<.0001	--	<.0001	<.0001	<.0001	<.0001	<.0001
Education	<.0001	<.0001	--	0.0657	<.0001	<.0001	<.0001
Nursing Home Residency	<.0001	<.0001	0.0657	--	<.0001	<.0001	0.0028
Race	<.0001	<.0001	<.0001	<.0001	--	<.0001	<.0001
Total Comorbidities	<.0001	<.0001	<.0001	<.0001	<.0001	--	0.0055
Gender	0.0115	<.0001	<.0001	0.0028	<.0001	0.0055	--
Table 4.3 results of chi-squared test of independence							

4.4 Model Selection for Logistic Regression

The largest model for logistic regression was chosen using stepwise regression with forward selection in SAS 9.4. We used this larger model to create the 6 models in table 4. Models 1 and 2 each included only one exposure of interest. Model 3 includes both exposures of interest and Models 4, 5, and 6 include both exposures of interest and other covariates.

4.5 Odds Ratios

As highlighted in table 4.5, we examined the association between education, income and cognitive impairment using multivariable logistic regression. We found moderate protective associations against cognitive impairment for both education and income. When adjusted for each other the protective association of both income and education against cognitive impairment decreases, but they are both still moderately protective.

Model	Education	Income	Age	Nursing Home	Total Comorbidities	Race: Black	Race: Other	Gender: Female
1	0.457 (0.438, 0.477)	--	--	--	--	--	--	--
2	--	0.487 (0.468, 0.507)	--	--	--	--	--	--
3	0.562 (0.537, 0.589)	0.592 (0567, 0.618)		--	--	--	--	--
4	0.474 (0.453, 0.496)	--	1.057 (1.052, 1.062)	8.418 (6.175, 11.476)	1.233 (1.194, 1.273)	2.526 (2.278, 2.802)	1.933 (1.687, 2.215)	0.792 (0.726, 0.865)
5	--	0.536 (0.513, 0.560)	1.050 (1.046, 1.055)	6.755 (4.992, 9.140)	1.205 (1.167, 1.244)	2.219 (2.003, 2.46)	2.029 (1.775, 2.32)	0.679 (0.623, 0.742)
6	0.552 (0.526, 0.579)	0.654 (0.624, 0.686)	1.051 (1.046, 1.056)	8.321 (6.079, 11.388)	1.197 (1.159, 1.237)	2.198 (1.978, 2.443)	1.731 (1.507, 1.988)	0.686 (0.627, 0.751)

Table 4.5: Odds ratios for each model
Ref= White, male, in nursing home

4.5.1 Education

Odds ratios for education are summarized in figure 1 below. When examined alone in model 1, a one-unit increase in educational attainment is moderately protective against cognitive impairment [OR=0.457 (0.438, 0.477)]. Model 3, controlling for income alone, modifies the

relationship between education and cognitive impairment the most [OR=0.562 (0.537, 0.589)].

Controlling for other variables (see models 4 and 6) does not significantly impact the odds ratio.
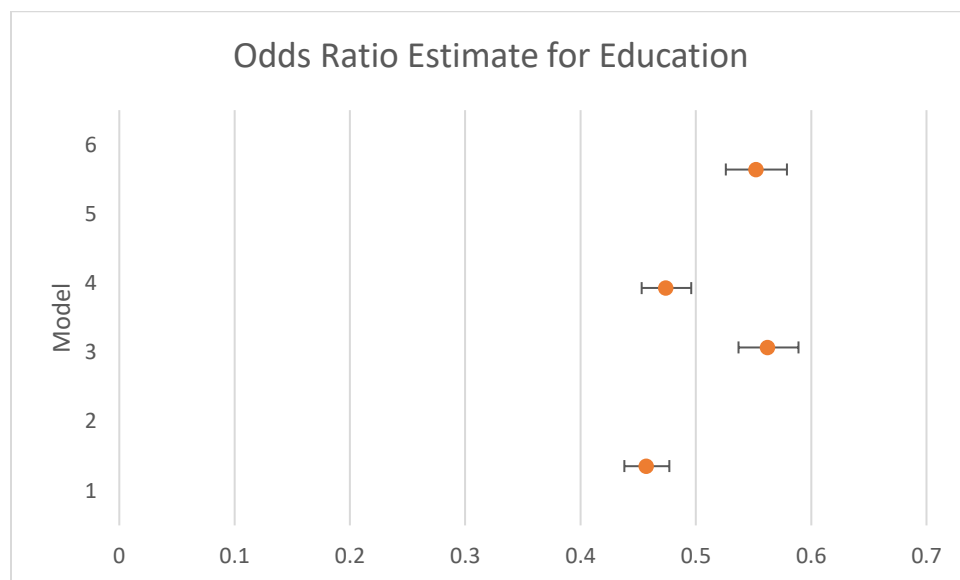
Fig 4.5.1 odds ratio estimates for education

4.5.2 Income Quartile

Odds ratios are summarized in figure 2 below. We found a similar association when examining income and cognitive impairment. A one unit increase in income was moderately protective against cognitive impairment [OR= 0.487 (0.468)] (Model 2). Controlling for education (Model 3) significantly weakened the protective effect of income against cognitive impairment [OR=0.592 (0567, 0.618)]. Controlling for other variables (see models 5 and 6) weakens the protective association between income and cognitive impairment, but not significantly.
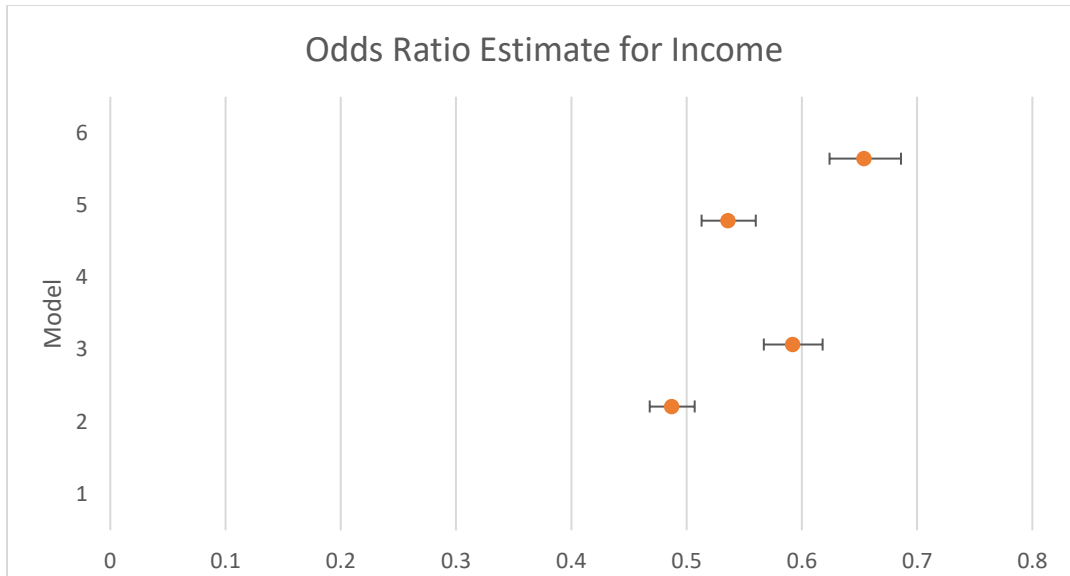
Fig 4.5.2: odds ratio estimates for income

4.5.3 Additional variables:

The combined effect of age, nursing home residency, total comorbidities, race, and gender on education and income is weaker than the effect of education and income on each other. The risk of cognitive impairment increases slightly with additional year of age (OR= 1.05) and each additional comorbidity (OR= 1.2 to 1.23). Female gender (OR= 0.68 to 0.79) is weakly protective against cognitive impairment, and non-white race is a moderate to strong risk factor for cognitive impairment (OR= 1.73 to 2.52). Nursing home residency was found to be strongly associated with cognitive impairment (OR=6.8 to 8.4).

CHAPTER V DISCUSSION

5.1 Context in Literature

Our results indicate that income weakens the protective effect of education against cognitive impairment in old age. Controlling for income modified the protective effect of education more than age, total comorbidities, nursing home residency, race, and gender combined. The same pattern emerged between the relationship between income and cognitive impairment.

Our findings are consistent with the some of the existing literature. This manuscript, like previous research, found education to be protective against cognitive impairment [7,13,17]. Longitudinal studies show that this works by delaying the onset of cognitive impairment, extending the time that older adults remain cognitively normal[8]. Non-white individuals in this manuscript are at a higher risk of cognitive impairment, which is uniform with existing research using HRS data [18]. It is important to note that race is not a genetic or biological category, but rather a proxy measure for the experience of racial discrimination[28]. The risk of cognitive impairment increases with age in our manuscript, which also matches the existing literature[7]. Nursing home residency was very strongly associated with cognitive impairment in our study. This was expected, as 61% of nursing home residents have moderate to severe cognitive impairment[29]. The factor that did not match the existing literature was gender; the existing literature finds that female gender is a risk factor for cognitive impairment, but this manuscript found female gender to be protective. This could be a result of how the data was grouped: some literature compares data on PLWD to people who are not living with dementia [13,15]as opposed to people with or without cognitive impairment.

Education and income's similar odds ratios are likely attributable to the fact that the two factors are tightly intertwined. Higher levels of educational attainment are linked to higher lifetime income levels, which are in turn linked to things like shorter term periods of unemployment, increased longevity, and lower divorce rates[30] The relationship found between income, education, and cognitive impairment is consistent with the 2023 study of HRS data from 1996-2016 , which found personal education and household income were responsible for the most between-person residual variance in slope, though they each explained less than 2% of variance on their own[18]. The relationship between income and cognitive impairment is also backed up by a 2022 study of the relationship between low wages in midlife and accelerated cognitive impairment in old age[23].

5.2 Limitations

This manuscript was created using a US-specific data set. The effect of selected variables for this data set may vary in other countries. This manuscript also did not consider genetic risk factors, geographic variations in cost-of-living and average income, or risk behaviors like smoking, drinking, or diet. As this manuscript is a cross-sectional analysis of the data, causation cannot be determined, only association between exposures (education and income) and disease (cognitive impairment).

5.3 Conclusion

Based off our findings and the results of the limited literature on the relationship between income, education, and cognitive impairment, future researchers would benefit from collecting information on income or other financial measures when researching cognitive impairment,

particularly when looking at the relationship between cognitive impairment and education. Differences in income could capture resource disparities, discrimination, and other risk factors that would otherwise go unmeasured. Income and cognition influence each other in multiple different life stages. Postponing retirement is considered protective against cognitive decline[31], but does working longer preserve cognition, or does existing cognitive decline cause individuals to leave the workforce earlier? Failing to take income or other financial measures into account may distort the effect of other risk and protective factors for cognitive impairment, leading to public health policies that do not properly address underlying risk factors.

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