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FACTORS ASSOCIATED WITH COGNITIVE FUNCTION IN THE ELDERLY: EVIDENCE FROM NHANES 2011–2014

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Abstract

Introduction: With global life expectancy on the rise, cognitive impairment increasingly strains individuals and healthcare systems due to age being a primary risk factor. This study seeks to elucidate the influence of age on other risk factors associated with cognitive impairment.

Methods: To assess the risk factors of cognitive impairment, we analyzed data from the National Health and Nutrition Examination Survey (NHANES) from 2011–2014, totaling 2569 participants. By conducting multivariable logistic regression models and stratifying participants based on age (≤ 70 years old; > 70 years old), we further investigated the relationship between several risk factors and cognitive function status. Cognitive function status was defined by a Z-score (cognitive impairment defined as a z-score < –1), consisting of four cognitive tests (CERAD-WL, CERAD-DR, AFT, and DSST).

Results: The study found that participants over 70, particularly those of Mexican American, non-Hispanic Black, and multi-racial backgrounds, who were unmarried with lower education and family income levels, faced higher risks of cognitive impairment. As participant age increased, many risk factors diminished, though some, like being overweight and belonging to non-Hispanic White or multi-racial groups, remained exceptions.

Conclusion: This research studied age's significant impact on cognitive function development. Our findings can guide policy-making for cognitive impairment, benefiting both patients and healthcare professionals. Future research should explore why risk factors in non-Hispanic Whites aren't reduced with age and explore other potential risk factors that are not available in this study.

Keywords: *cognitive impairment, cognitive function status, cross-sectional, logistic regression, body mass index (BMI), risk factor*

Introduction

Cognitive impairment is when an aging individual has a cognitive decline greater than expected, ranging from minor problems with cognition (mild cognitive impairment) to severe problems with cognition (dementia). Individuals affected by cognitive impairment tend to have poorer quality of life (Lawson et al. 2014) and shorter life expectancy. Men with mild cognitive impairment can expect to live for 3.5 years, and women can expect to live for 4.2 years (Hale et al. 2020).

Over 55.7 million Americans were aged 65 and over in 2020, representing 17% of the US population; with this number projected to grow to 22% by 2040 (Administration of Community Living, 2022) With the rapid growth of the older population, an increasingly greater number of individuals will be at risk of developing cognitive impairment. At an average age of 70, approximately two out of three Americans develop cognitive impairment (Hale et al. 2020). Cognitive impairment is putting an increasingly heavy burden on both healthcare systems and families, with total payments for individuals with dementia projected to reach $345 billion in 2023 (2023 Alzheimer's Disease Facts and Figures, 2023).

Numerous studies have been conducted on the risk factors of cognitive impairment, including demographic (Díaz-Venegas et al. 2016; Chen and Cao 2020; Bloomberg et al. 2023), nutritional (Huang et al. 2021; Shen et al. 2023), and medical risk factors (Feinkohl et al. 2018). Obesity has been shown to be positively associated with cognitive impairment, with each 1 kg/m^2 increment in body mass index (BMI) associated with a 3% increased prevalence of cognitive impairment (Feinkohl et al. 2018). Other studies have found that older age, lower education level, lower income, lower social participation, no spouse, worse psychological well-being, being female, and less fruit/vegetable consumption increase the risk of cognitive impairment (Zhang et al. 2019; Aartsen et al. 2002). Some studies have found that poverty is associated with an increased risk of developing cognitive impairment (Chen and Cao 2020). A few studies have studied the association of country of residence on risk factors such as gender and education concerning cognitive function status. Education was found to be less accessible to women in middle-income countries compared to high-income countries, which is associated with a higher risk of developing cognitive impairment (Bloomberg et al. 2023). Although risk factors of cognitive impairment have been intensively studied, the literature is scarce on the effects of risk factors conditioned on a demographic variable, particularly age. Cognition deteriorates disproportionally as age increases. For this reason, cognitive impairment most often develops at age 70 or older (Aartsen et al. 2002). Therefore, the effects of the risk factors on cognitive impairment may differ significantly among different age groups.

The purpose of this study is to observe whether age influences the association between risk factors — such as gender, age, obesity, education, race, marital status, and annual family income — and cognitive function status. Since age has already been reported as a significant risk factor for cognitive impairment (Murman 2015), further research on how age affects other risk factors is necessary. Additionally, many studies have assessed cognitive function status by combining four cognitive tests (CERAD-WL, CERAD-DR, DSST, AFT), but very few have examined risk factors for each test individually. This study aims to contribute to the literature on the risk factors of cognitive impairment and provide insights that can help inform policies that benefit patients and healthcare providers. We hypothesized that between age groups, many risk factors would have a significant difference in effect on the development of cognitive impairment.

Methods

Datasets and Participants

We extracted data from the National Health and Nutrition Examination Survey (NHANES) between 2011 and 2014 since cognitive functioning test data was only available for these two cycles. The NHANES datasets are based on multistage, stratified surveys with a probability cluster design, and conducted by the National Center of Health Statistics of the Centers for Disease Control and Prevention (Huang et al. 2021). In this study, we selected a population aged 60 and over (n = 3472), excluding participants with no records of cognitive function status (559) or other covariates (344), leaving a final sample of 2569.

Outcomes

To assess cognitive function status, we used four cognitive tests: The Consortium to Establish a Registry for Alzheimer's Disease — Word Learning (CERAD-WL), Delayed Recall (CERAD-DR) (Fillenbaum et al. 2008), Digit Symbol Substitution Test (DSST) (Jaeger 2018) and Animal Fluency Test (AFT) (Canning et al. 2004). The CERAD-WL and CERAD-DR tests assess delayed and immediate learning for new verbal information. The CERAD-WL test consists of three learning tests, in which participants are presented with ten unrelated words on a computer one at a time. Participants are prompted to read aloud the words as they appear. Immediately after, participants try to recall as many of the words as possible, with each correct recall earning a point. This learning test is repeated two more times, with only the order of the words changing each time. The CERAD-DR test is completed after the DSST and AFT are completed (8–10 minutes after the start of the learning tests). Participants try to recall words from the learning tests, with each correct recall earning a point. The DSST assesses sustained attention, processing speed, and working memory. Participants are given a paper test with 133 boxes, each of which contains a number from 1 to 9. The test has a key containing 9 numbers paired with symbols, and participants are given two minutes to copy the corresponding symbols in each of the 133 boxes. Each correct match earns a point. The AFT evaluates categorical verbal fluency. Participants are given one minute to name as many animals as possible, with each animal earning a point (Sebaldt et al. 2009). We used a Z-score as a total cognitive function status score, consisting of the CERAD-WL test, CERAD-DR test, AFT, and DSST. Z-score was calculated with $Z = (x-u)/\sigma$, where x was the total number of points from the four tests, u was the population mean, and σ was the standard deviation. A Z-score of < -1 indicated that the participant had cognitive impairment (Wirth et al. 2017; Frith et al. 2018).

Covariates

Gender, age, education, race, marital status, and annual family income data were all obtained from household interviews. BMI data was measured in a NHANES Mobile Examination Center (MEC). Age was categorized into two groups: participants aged 70 and under and participants over 70. Education was categorized by each participant's highest grade or degree, with the four levels being less than high school, high school, college (or an AA degree), and college graduate. Race was categorized as Mexican American, non-Hispanic white, non-Hispanic black, and other race/multi-racial. Marital status was classified as married and not currently married (widowed, divorced, separated, or never married). Annual family income was divided into under $35,000, from $35,000 to $75,000, and over $75,000. Obesity was categorized according to the CDC's definitions of healthy weight (BMI from 18.5 to < 25), overweight (BMI from 25.0 to < 30), and obese (BMI over 30).

Statistical Analysis

All categorical variables were presented as frequencies, weighted percentages, and standard errors (SE). Chi-square tests were used to determine the association between covariates and cognitive function status. To assess the strength of the association between covariates and outcomes, we conducted weighted logistic regression models, where crude models include only one variable at one time and adjusted models include all variables. The results of the logistic regression models were reported as odds ratios (OR), 95% confidence intervals (CI), and p-values. We conducted additional logistic regression models for each of the four cognitive tests to assess the possible relationships between individual tests and covariates. We also employed a stratified logistic regression analysis to assess whether each covariate has a different effect on cognitive function status when separated by participants aged 70 and under and participants over 70. A p-value less than .05 was considered statistically significant. All analyses were conducted using R (http://www.r-project.org; version 4.3.1, The R Foundation).

Results

We extracted data from two continuous NHANES cycles (2011–2012 and 2013–2014), totaling 2569 participants after excluding participants with incomplete interviews. Table 1 shows the number and proportions of respondents grouped by cognitive function status. The percentage of respondents over 70 years old with cognitive impairment (69.1%) was significantly higher than those without (35.1%), with a p-value of less than .001. Similarly, the percentage of respondents with an education level of high school (26.1%) or less (45.6%) was higher than those without (21.2% and 12.1% respectively), with a p-value of less than .001. Conversely, the percentage of cognitively impaired non-Hispanic White Americans (54.2%) was much less than those without (83.1%), with a p-value of less than .001. The percentage of not currently married participants with cognitive impairment (53.6%) was much greater than those without (33.9%), with a p-value of less than .001. Likewise, the percentage of respondents with an annual family income of under $35,000 (66.8%) was significantly greater than those without (32.4%), with a p-value of less than .001. In summary, compared to normal participants, participants with cognitive impairment were more likely to be over 70 years old, not non-Hispanic White, and not currently married. Participants with cognitive impairment were also more likely to have an education level less than high school and an annual family income under $35,000. Neither the participants' gender nor obesity was significantly associated with cognitive function status.

Table 1. *Sample characteristics by cognitive function status*

	Normal		Impaired		p-value
	n(%)	SE	n(%)	SE	
Gender					
Male	1010(45.6)	1.1%	221(42.5)	2.2%	0.277
Female	1139(54.4)	1.1%	199(57.5)	2.2%	
Age					
70 and Under	1341(64.9)	1.4%	166(30.9)	3.7%	<0.001
Over 70	808(35.1)	1.4%	254(69.1)	3.7%	
Obesity					
Healthy	568(25.4)	1.4%	129(32.8)	2.7%	
Overweight	763(36.8)	1.2%	135(31.8)	2.7%	0.06
Obese	818(37.8)	1.4%	156(35.4)	3.4%	
Education					
Less than HS	378(12.1)	1.4%	249(45.6)	4.1%	
HS/GED	514(21.2)	1.4%	86(26.1)	3.2%	<0.001
Some College/AA	685(33.3)	1.3%	52(17.8)	2.8%	
College Grad or above	572(33.4)	2.3%	33(10.5)	2.5%	
Race					
Mexican American	163(2.7)	0.6%	55(9.3)	2.6%	
Non-Hispanic Black	468(7.0)	1.0%	136(19.9)	3.3%	<0.001
Non-Hispanic White	1141(83.1)	1.5%	124(54.2)	4.8%	
Other Race/Multi-Racial	377(7.3)	0.8%	105(16.6)	2.2%	
Marital Status					
Married	1266(66.1)	1.1%	189(46.4)	3.1%	<0.001
Not Currently Married	883(33.9)	1.1%	231(53.6)	3.1%	
Annual Family Income					
Under $35.000	942(32.4)	2.2%	299(66.8)	4.3%	
$35,000-$75.000	686(35.7)	2.0%	82(22.4)	3.4%	<0.001
Over $75.000	521(31.9)	2.4%	39(10.8)	2.4%	

Abbreviations: SE, standard error; HS, high school graduate; GED, General Educational Development diploma; AA, associate's degree

To investigate the relationship between cognitive function status and risk factors such as gender, age, obesity, education, race, marital status, and annual family income, we created a crude model (univariate logistic regression) and an adjusted model (multivariate logistic regression). Table 2 shows the association between cognitive function status and various risk factors. We found that age was significantly associated with cognitive function status in both the crude and adjusted models. The odds of developing cognitive impairment among participants over 70 was 4.15 times of those under 70 in the crude model (OR = 4.15, 95% CI (2.83.6.09), p < .001) and 4.77 after adjusting for other covariates (OR = 4.77, 95% CI (3.05.7.46), p < .001). Obesity was also significantly associated with cognitive function status in both crude and adjusted models. Overweight participants were 33% less likely to develop cognitive impairment compared to participants with a healthy weight in the crude model (OR = 0.67, 95% CI (0.49.0.91), p = .015) and 36% less likely to after adjusting for other covariates (OR = 0.64, 95% CI (0.46, 0.89), p = .015). The education level of the participants was significantly associated with cognitive function status, with higher levels of education having lower odds of cognitive impairment. Compared with an education level of less than high school, participants with an higher education level were less likely to have cognitive impairment based on individual tests, such as high school (OR = 0.33, 95% CI (0.23,0.47), p < .001), college (OR = 0.14, 95% CI (0.10,0.20), p < .001) and college graduate (OR = 0.08, 95% CI (0.05,0.14), p < .001) all had lower odds of developing cognitive impairment. We observed similar results after adjusting for covariates (high school: OR = 0.46, 95% CI (0.31,0.67), p = =.001; college: OR = 0.24, 95% CI (0.16,0.36), p < .001; college graduate: OR = 0.17, 95% CI (0.11,0.26), p < .001). Compared to Mexican American participants, non-Hispanic White participants were 81% less likely to develop cognitive impairment in the crude model (OR = 0.19, 95% CI (0.13,0.27), p < .001) and 76% less likely after adjusting for other covariates (OR = 0.24, 95% CI (0.16,0.35), p < .001). Participants who were not currently married had 2.26 times the odds of developing cognitive impairment compared with married participants in the crude model (OR = 2.26, 95% CI (1.76,2.90), p < .001) and 1.38 after adjusting for other covariates (OR = 1.38, 95% CI (1.02,1.87), p = .05). Annual family income was also significantly associated with cognitive function status in both models. Compared with participants with an annual family income under $35,000, participants with an annual family income between $35,000 and $75,000 (OR = = 0.30, 95% CI (0.20,0.47), p < .001) and over $75,000 (OR = 0.16, 95% CI (0.09,0.31), p < .001) had lower odds of developing cognitive impairment. We observed similar results after adjusting for covariates ($35,000 to $75,000: OR = 0.51, 95% CI (0.32,0.80), p = .009; over $75,000: OR = 0.45, 95% CI (0.25,0.83), p = .019 respectively).

Table 2. *Association between risk factors and cognitive function status by logistic regression models*

	Crude model (univariable)		Adjusted model (multivariable)	
	OR(LCI, UCI)	p-value	OR(LCI, UCI)	p-value
Gender				
Male		Ref.		
Female	1.14(0.91,1.42)	0.278	0.82(0.64,1.05)	0.139
Age				
70 and Under		Ref.		
Over 70	4.15(2.83,6.09)	<0.001	4.77(3.05,7.46)	<0.001
Obesity				
Healthy		Ref.		
Overweight	0.67(0.49,0.91)	0.015	0.64(0.46,0.89)	0.015

	Crude model (univariable)		Adjusted model (multivariable)	
	OR(LCI, UCI)	p-value	OR(LCI, UCI)	p-value
Obese	0.72(0.50,1.06)	0.107	0.67(0.46,0.98)	0.051
Education				
Less than HS		Ref.		
HS/GED	0.33(0.23,0.47)	<0.001	0.46(0.31,0.67)	0.001
Some College/AA	0.14(0.10,0.20)	<0.001	0.24(0.16,0.36)	<0.001
College Grad or above	0.08(0.05,0.14)	<0.001	0.17(0.11,0.26)	<0.001
Race				
Mexican American		Ref.		
Non-Hispanic Black	0.82(0.50,1.33)	0.418	0.90(0.55,1.46)	0.675
Non-Hispanic White	0.19(0.13,0.27)	<0.001	0.24(0.16,0.35)	<0.001
Other Race/Multi-Racial	0.65(0.39,1.08)	0.111	0.81(0.49,1.33)	0.409
Marital Status				
Married		Ref.		
Not Currently Married	2.26(1.76,2.90)	<0.001	1.38(1.02,1.87)	0.05
Annual Family Income				
Under $35,000		Ref.		
$35,000-$75,000	0.30(0.20,0.47)	<0.001	0.51(0.32,0.80)	0.009
Over $75,000	0.16(0.09,0.31)	<0.001	0.45(0.25,0.83)	0.019

Note: The crude model includes only the predictor variable, the adjusted model includes the predictor variable while factoring in all other covariates

Abbreviations: Ref., reference category of a predictor variable; OR, odds ratio of developing cognitive impairment; LCI, 95% lower confidence interval; UCI, 95% upper confidence interval.

Table 3 shows the association between the four cognitive tests (CERAD-WL, CERAD-DR, DSST, AFT) used to determine cognitive function status and risk factors. We observed that gender, age, education, race, marital status, and annual family income had a significant association with at least one of the four cognitive tests, while obesity did not. Compared to male participants, female participants were 48% less likely to develop cognitive impцairment as assessed by the CERAD-DR (OR = 0.52, 95% CI (0.42,0.65), p < .001) and 36% less likely to as assessed by the DSST (OR = 0.64, 95% CI (0.49,0.83), p = .003). Age had a significant association with all four tests. When compared to participants 70 and under, participants over 70 had much higher odds of developing cognitive impairment(CERAD-WL: OR = 3.63, 95% CI (2.81,4.70), p < .001; CERAD-DR: OR = =3.08, 95% CI (2.34,4.06), p < .001; DSST: OR = 4.57, 95% CI (3.11,6.72), p < .001; AFT: OR = 2.71, 95% CI (2.09,3.51), p < .001). Compared with an education level of less than high school, participants with an education level of high school (CERAD-WL: OR = 0.62, 95% CI (0.42,0.92), p = .027; DSST: OR = 0.37, 95% CI (0.28,0.48), p < .001), college (CERAD-WL: OR = 0.40, 95% CI (0.23,0.68), p = .003; CERAD-DR: OR = 0.57, 95% CI (0.38,0.85), p = .013; DSST: OR = 0.20, 95% CI (0.15,0.27), p < .001; AFT: OR = 0.43, 95% CI (0.31,0.61), p < .001) and college graduate (CERAD-WL: OR = 0.28, 95% CI (0.16,0.48), p < .001; DSST: OR = 0.10, 95% CI (0.07,0.15), p < .001; AFT: OR = 0.29, 95% CI (0.21,0.41), p < .001) all had lower odds of developing cognitive impairment. Compared to Mexican American participants, non-Hispanic White (CERAD-WL: OR = 0.63, 95% CI (0.42,0.93), p = .032; DSST: OR = 0.22, 95% CI (0.15,0.32), p < < .001) and Other Race/Multi-Racial (DSST: OR = 0.61, 95% CI (0.41,0.89), p = .019) participants had lower odds of developing cognitive impairment shown by the CERAD-WL and DSST, but non-Hispanic Black (OR =

Table 3. *Logistic regression models for individual tests*

	CERAD-WL		CERAD-DR		DSST		AFT	
	OR(LCI, UCI)	p-value	OR(LCI, UCI)	p-value	OR(LCI, UCI)	p-value	OR(LCI, UCI)	p-value
Gender								
Male	Ref.							
Female	0.82(0.51,1.33)	0.428	0.52(0.42,0.65)	<0.001	0.64(0.49,0.83)	0.003	0.90(0.65,1.24)	0.521
Age								
70 and Under	Ref.							
Over 70	3.63(2.81,4.70)	<0.001	3.08(2.34,4.06)	<0.001	4.57(3.11,6.72)	<0.001	2.71(2.09,3.51)	<0.001
Obesity								
Healthy	Ref.							
Overweight	0.90(0.60,1.36)	0.633	1.06(0.77,1.46)	0.718	0.72(0.53,0.98)	0.051	0.82(0.63,1.07)	0.159
Obese	0.79(0.57,1.09)	0.169	0.84(0.60,1.17)	0.309	0.74(0.47,1.19)	0.231	0.77(0.55,1.08)	0.140
Education								
Less than HS	Ref.							
HS/GED	0.62(0.42,0.92)	0.027	0.86(0.52,1.41)	0.554	0.37(0.28,0.48)	<0.001	0.83(0.56,1.21)	0.344
Some College/AA	0.40(0.23,0.68)	0.003	0.57(0.38,0.85)	0.013	0.20(0.15,0.27)	<0.001	0.43(0.31,0.61)	<0.001
College Grad or above	0.28(0.16,0.48)	<0.001	0.58(0.35,0.97)	0.052	0.10(0.07,0.15)	<0.001	0.29(0.21,0.41)	<0.001
Race								
Mexican American	Ref.							
Non-Hispanic Black	0.78(0.53,1.14)	0.213	0.86(0.58,1.28)	0.48	1.06(0.77,1.47)	0.72	2.20(1.49,3.23)	<0.001
Non-Hispanic White	0.63(0.42,0.93)	0.032	0.73(0.51,1.05)	0.111	0.22(0.15,0.32)	<0.001	0.66(0.46,0.95)	0.038
Other Race/Multi-Racial	1.02(0.72,1.45)	0.896	0.69(0.46,1.04)	0.093	0.61(0.41,0.89)	0.019	1.69(1.16,2.47)	0.014
Marital Status								
Married	Ref.							
Not Currently Married	1.29(1.01,1.65)	0.057	0.99(0.75,1.32)	0.97	1.35(1.06,1.72)	0.023	1.04(0.71,1.54)	0.833
Annual Family Income								
Under $35,000	Ref.							
$35,000-$75,000	0.65(0.48,0.87)	0.01	0.56(0.42,0.76)	0.001	0.46(0.34,0.62)	<0.001	0.83(0.58,1.18)	0.31
Over $75,000	0.65(0.43,0.99)	0.06	0.52(0.36,0.74)	0.002	0.33(0.18,0.61)	0.002	0.67(0.46,0.99)	0.056

Note: These models include the predictor variable while factoring in all other covariates

= 2.20, 95% CI (1.49,3.23), p < .001) and Other Race/Multi-Racial (OR = 1.69, 95% CI (1.16,2.47), p = .014) participants were found to have greater odds of developing cognitive impairment in the AFT, with the exception of non-Hispanic White (OR = 0.66, 95% CI (0.46,0.95), p = .038) participants. Participants who were not currently married had 1.35 times the odds of developing cognitive impairment compared with married participants (OR = 1.35, 95% CI (1.06,1.72), p = = .023) as assessed by the DSST. Finally, compared with participants with an annual family income under $35,000, participants with an annual family income between $35,000 and $75,000 (CERAD-WL: OR = 0.65, 95% CI (0.48,0.87), p = .01; CERAD-DR: OR = 0.56, 95% CI (0.42,0.76), p = .001; DSST: OR = = 0.46, 95% CI (0.34,0.62), p < .001) and over $75,000 (CERAD-DR: OR = 0.52, 95% CI (0.36,0.74), p = .002; DSST: OR = 0.33, 95% CI (0.18,0.61), p = .002) all had lower odds of developing cognitive impairment as assessed by the CERAD-WL, CERAD-DR and DSST.

Abbreviations: Ref., reference category of a predictor variable; OR, odds ratio of developing cognitive impairment; LCI, 95% lower confidence interval; UCI, 95% upper confidence interval.

To investigate whether age moderates the association between other risk factors and cognitive function status, we conducted a stratified multiple logistic regression analysis for participants aged 70 and under and participants over 70. Table 4 shows the association between cognitive function status and risk factors stratified by age (≤ 70 and > 70). Overall, several risk factors differed significantly in ORs between the two age groups. Obesity was not significantly associated with cognitive function status in participants 70 and under. However, among participants over 70, being overweight (OR = 0.6, 95% CI (0.39,0.93), p = .033) or obese (OR = 0.51, 95% CI (0.31,0.87), p = .021) was significantly associated with lower odds of developing cognitive impairment. Higher education levels were protective for CF impairment for both age groups, but there was a reduction in the protective effects for the participants over 70 (high school: OR = 0.58, 95% CI (0.39,0.87), p = .014; college: OR = 0.36, 95% CI (0.23,0.58), p < .001; college grad: OR = 0.24, 95% CI (0.14,0.42), p < .001) compared to participants 70 and under (high school: OR = 0.32, 95% CI (0.18,0.55), p < .001; college: OR = 0.11, 95% CI (0.04,0.26), p < .001; college grad: OR = 0.09, 95% CI (0.03,0.28), p < .001). Non-Hispanic White participants had lower odds of developing cognitive impairment, with an increase in the protective effects of the participants over 70 (OR = 0.19, 95% CI (0.11,0.31), p < .001) compared to participants 70 and under (OR = 0.26, 95% CI (0.11,0.61), p = .006). Other Race/Multi-Racial participants 70 and under were not significantly associated with cognitive function status, but participants over 70 were less likely to develop cognitive impairment (OR = 0.46, 95% CI (0.24,0.89), p = .032). For participants 70 and under, participants who were not currently married had higher odds of developing cognitive impairment (OR = 1.94, 95% CI (1.08,3.49), p = .038) compared to married participants. However, for participants over 70, marital status was not significantly associated with cognitive function status. Similar to obesity, annual family income was not significantly associated with cognitive function status in participants 70 and under. However, among participants over 70, an annual family income between $35,000 and $75,000 (OR = 0.48, 95% CI (0.28,0.83), p = .015) or over $75,000 (OR = 0.49, 95% CI (0.26,0.91), p = .036) was significantly associated with lower odds of developing cognitive impairment.

Table 4. *Logistic regression models stratified by age (≤ 70 and > 70)*

	≤ 70		> 70		
	OR(LCI, UCI)	p-value [a]	OR(LCI, UCI)	p-value [a]	p-value [*]
Gender					
Male					
Female	0.63(0.33,1.19)	0.17	0.96(0.67,1.38)	0.825	0.4930
Obesity					

	≤ 70		> 70		
	OR(LCI, UCI)	p-value [a]	OR(LCI, UCI)	p-value [a]	p-value [*]
Healthy					
Overweight	0.76(0.42,1.4)	0.393	0.6(0.39,0.93)	0.033	0.2646
Obese	1.17(0.6,2.28)	0.651	0.51(0.31,0.87)	0.021	
Education					
Less than HS					
HS/GED	0.32(0.18,0.55)	<0.001	0.58(0.39,0.87)	0.014	
Some College/AA	0.11(0.04,0.26)	<0.001	0.36(0.23,0.58)	<0.001	0.0192
College Grad or above	0.09(0.03,0.28)	<0.001	0.24(0.14,0.42)	<0.001	
Race					
Mexican American					
Non-Hispanic Black	0.92(0.49,1.73)	0.795	0.75(0.38,1.46)	0.4	
Non-Hispanic White	0.26(0.11,0.61)	0.006	0.19(0.11,0.31)	<0.001	0.2269
Other Race/Multi-Racial	1.39(0.76,2.55)	0.296	0.46(0.24,0.89)	0.032	
Marital Status					
Married					
Not Currently Married	1.94(1.08,3.49)	0.038	1.2(0.76,1.88)	0.445	0.2593
Annual Family Income					
Under $35,000					
$35,000-$75,000	0.6(0.27,1.32)	0.219	0.48(0.28,0.83)	0.015	0.6036
Over $75,000	0.49(0.13,1.82)	0.299	0.49(0.26,0.91)	0.036	

Note: These models include the predictor variable while factoring in all other covariates. P-value [a] refers to each level of the predictor in a multiple logistic regression model. p-value [*] refers to the interaction term between predictors and age, and p-value[*] < .05 indicates significant difference in the effects between ≤ 70 and > 70

Discussion

In this study of 2569 participants aged 60 and over, we explored the relationship between several risk factors and cognitive function status. Mexican American, non-Hispanic Black, and other race/multi-racial participants who were over 70, not currently married, and had a low level of education and low annual family income were the most likely to develop cognitive impairment. Non-Hispanic White participants who were 70 or under, married, and had a high level of education and high annual family income were the least likely to develop cognitive impairment. Consistent with our hypothesis, many risk factors had significantly different effects on cognitive function status across age groups. Compared with the lower age group, many of the risk factors' effects on cognitive function status were attenuated in the older age group. Exceptions include the non-Hispanic White and overweight risk factors, which both saw an increase in protective effect. Obesity and being other race/multi-racial were associated with an increased risk of developing cognitive impairment for participants 70 and under but were associated with a decreased risk for participants over 70. Additionally, being either overweight or obese is protective against developing cognitive impairment, although only in the older age group. We found no significant association between gender and cognitive function status.

Overall, our findings were consistent with much of the existing literature. A study on the association between numerous risk factors and cognitive impairment (Zhang et al. 2019) found that older age, lower education level, less income, being female, and no spouse are associated with greater risk of developing cognitive impairment. These results are consistent with ours, with the exception of gender as we found that gender did not have a significant association with cognitive function status. This inconsistency in results could be due to the use of the Mini-Mental State Examination instead of the four tests we used to determine cognitive function status, or that the study's sample was Chinese participants aged 64 and above while our sample was American participants aged 60 and above. One study found that poverty is associated with a greater chance of developing cognitive impairment (Chen and Cao 2020). We found similar results, as participants with an annual family income of under $35,000 had approximately a 2 times greater risk of developing cognitive impairment when compared to participants with an income of $35,000 or over. Another study (Bloomberg et al. 2023) found that education was associated with cognitive function status, with lower levels of education associated with a higher risk of cognitive impairment. These findings are consistent with our study, with each higher level of education providing a greater resistance to developing cognitive impairment. Finally, a study on obesity and cognitive impairment (Feinkohl et al. 2018) found that obesity is positively associated with cognitive impairment, with an 1 kg/m2 increase in BMI associated with a 3% increased prevalence of cognitive impairment. We found that being overweight or obese decreased the risk of developing cognitive impairment for those over 70 years of age. The difference in results could be due to a smaller sample size (1545 vs. 2569), the use of log-binomial regression analyses instead of logistic regression analyses. This disparity of obesity status's effects between our study and Feinkohl et al indicate other confounding variables may play a role in the association between obesity and cognitive impairment.

Our study showed that age significantly moderated the association between risk factors and cognitive function status. Higher levels of education correspond with a lower risk of developing cognitive impairment in both age groups, with a similar pattern found in both the crude and adjusted models. Education plays a larger role in the development of cognitive impairment for participants 70 and under, consistent with other studies (Hale et al. 2020). Compared to participants with an education level lower than high school in the lower age group, participants with an education level of high school (68% decrease), college (89% decrease), and college graduate (91% decrease) all had lower odds of developing cognitive impairment compared with the higher age group (42%, 64%, 76% decrease respectively). While higher levels of education are associated with a higher cognitive ability and slower cognitive decline, levels of education up until high school are associated with slower cognitive decline while levels of education past high school are associated with higher income, which in turn is negatively associated with the development of cognitive impairment (Zahodne, Stern, and Manly 2015). Overweight and obese participants who were 70 and under were not associated with cognitive function status, but both overweight and obese participants over 70 had a lower chance of developing cognitive impairment when compared to participants with a healthy weight. In our crude and adjusted models, only overweight participants were significantly associated with a 36% decrease in the odds of developing cognitive impairment after adjusting for covariates. For overweight participants over 70, this reduction increases to 40%. Although the underlying mechanism is still unknown for this relationship, weight may be confounded by economic status since obesity is inversely associated with income (Andoy-Galvan et al. 2020).

Notably, the only case where the risk of developing cognitive impairment was higher for the lower age group than the older age group was for non-Hispanic White participants. Non-Hispanic White participants who were 70 and under had a 74% decrease in the odds of developing cognitive impairment, while non-Hispanic White participants who were over 70 had an 81% decrease in the odds. No association was found with non-Hispanic black participants, and other race/multi-racial participants over 70 had a 54% decrease in the odds of developing cognitive impairment. Being married plays a huge role in protecting against cognitive impairment in participants 70 and under, as participants who were not currently married were 94% more likely to develop cognitive impairment. For participants over 70, there is no significant association between marital status and cognitive function status. Finally, compared with participants over 70 with an annual family income of less than $35.000, an annual family income of $35,000-$75.000 and over $75.000 is associated with a 52% and 51% decrease in the likelihood of developing cognitive impairment respectively. For participants 70 and under, there is no significant association between annual family income and cognitive function status. Age attenuates the effect of many protective factors, indicating that to create a more effective and personalized prevention/treatment plan, healthcare providers or policymakers need to allocate more resources to individuals who have protective factors more vulnerable to age. Further research is needed to identify risk factors for the lower age group.

Our study has several strengths. First, we used a large sample from NHANES, creating a more accurate representation of our population. In addition, we individually assessed the relationship between each risk factor and the four cognitive tests to provide more insight than would be possible with only the total score. Moreover, we assessed the risk factors stratified by age group, enabling us to delve into the disparities of the risk factors' effects between the two age groups. However, our study is not without limitations. First, this study is cross-sectional, preventing us from demonstrating any causality between the risk factors and cognitive function status. Furthermore, not all possible variables are included and adjusted for in the study, so unmeasured variables could yield different results. Additionally, some risk factors like annual family income are self-reported, so the data could contain inaccuracies. Finally, although we used a large sample, the study population is limited to US residents.

Conclusion

Age, obesity, education, race, marital status, and annual family income are all significantly associated with cognitive function status. Many of the risk factors are attenuated by age, some are significant only for participants 70 and under (marital status), and others are significant only for participants 70 and over (obesity and annual family income). Our results can help inform policies related to cognitive impairment to benefit patients and healthcare providers. Further studies could investigate why certain risk factors are not attenuated by age or include covariates not present in this study such as alcohol use or smoking.

Declaration

Ethics Statement

The CDC's National Center for Health Statistics Institutional Research Ethics Review Board approved the NHANES survey protocol. Every participant provided written informed consent, and this study was approved by the NCHS Research Ethics Review Board (https://wwwn.cdc.gov/nchs/nhanes/default.aspx).

Author Contributions

SW conducted data collection, conducted analyses, and wrote the manuscript. XY modified the manuscript. SW and XY conducted data interpretation. SW and XY made the tables. XY designed the study and reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability Statement

Data is available upon request.

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