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Relationship between social determinants of health and cognitive performance in an older American population: a cross-sectional NHANES study

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Abstract

Objective This study aims to investigate the influence of social determinants of health (SDoH) on cognitive performance.

Methods This study surveyed a sample of older adults aged 60 years and older from the 2011–2014 cohort of participants in the U.S. National Health and Nutrition Examination Survey (NHANES). Data were collected during each survey cycle on self-reported domains of SDoH, which included eight subscales: employment, family income-to-poverty ratio, food security, education level, health insurance coverage, type of health insurance, home ownership, and marital status. Cognitive performance was evaluated using three tests: the Digit Symbol Substitution Test (DSST) for processing speed, the Animal Fluency Test (AFT) for executive function, and a subtest from the Coalition to Establish an Alzheimer's Disease Registry (CERAD) for memory. Multifactorial linear regression modeling was employed to explore the association between SDoH and cognitive performance.

Results A total of 2,819 elderly subjects were included in this study for analysis, with a mean age of 69.14 ± 0.19 years, 54.36% female and 45.64% male. The study found a negative association between the accumulation of unfavorable SDoH factors and cognitive performance. Similarly, certain unfavorable SDoH domains were negatively associated with cognitive performance.

Conclusion The findings suggest that unfavorable SDoH domains, particularly when unfavorable SDoH factors accumulate, are linked to decreased cognitive performance. Actively investigating the relationship between these factors may be a crucial strategy for delaying dementia onset.

Keywords NHANES, Elderly population, National cross-sectional study, Cognitive performance, Social determinants of health

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Introduction

As the global population ages, the prevalence of cognitive impairment is on the rise [1]. Diverse forms of dementia, such as mild cognitive impairment (MCI) and Alzheimer's disease (AD), are all characterized by cognitive decline and are emerging as substantial global public health concerns [2]. Projections indicate that the global incidence of dementia will rise from 57.4 million cases in 2019 to 152.8 million cases by 2050 [3]. Similarly, in the United States, the population of adults aged over 65 with clinically diagnosed AD is anticipated to climb from 6.07 million in 2020 to 13.85 million by 2060 [4]. Consequently, the exploration of protective factors associated with cognitive performance is imperative for the prevention of cognitive decline [5]. The timely identification of risk and protective factors represents an effective strategy for preventing cognitive impairment in its early stages.

Socioeconomic status (SES) includes household income, educational attainment, occupation, health insurance, and food security. A growing body of research indicates that SES exerts an impact on cardiovascular health [6], obesity [7], diabetes [8], and respiratory diseases [9]. A recent study on SES and cognitive function discovered a correlation between higher SES and enhanced cognitive function performance [10]. The concept of SES has been further elaborated with the introduction of social determinants of health (SDoH), expanding to encompass the five domains delineated in Health 2030, incorporating Economic Stability, Education Access and Quality, Health Care Access and Quality, Neighborhood and Built Environment, and Social and Community Context [11]. However, the influence of SDoH on cognitive performance among older adults remains uncertain. Consequently, leveraging publicly available data from the National Health and Nutrition Examination Survey (NHANES) spanning the years 2011 to 2014, this study sought to explore the potential impact of cumulative SDoH on cognitive performance within a representative cohort of older Americans.

Methods

Data sources and study design

NHANES is a continuous survey administered by the Centers for Disease Control and Prevention (CDC) to gather health, nutritional, and sociological data on the civilian population in the United States. NHANES employs a multi-stage, intricate probability sampling approach to collect data through pertinent interviews, examinations, dietary surveys, and laboratory tests. Demographic and health-related data were acquired via questionnaires. Health interviews were carried out at participants' residences. This cross-sectional study included participants from two survey cycles conducted between 2011 and 2014 ($n = 19,931$). Initially, individuals younger than 60 were excluded ($n = 16,299$); subsequently, those with incomplete cognitive performance data were excluded ($n = 698$). Additionally, participants lacking critical covariate data ($n = 115$) were excluded, encompassing age, sex, ethnicity, body mass index (BMI), smoking, drinking, hypertension, stroke, and diabetes. Following stringent exclusion criteria, 2,819 older participants were included in the subsequent analysis (Fig. 1).

Assessments of SDoH

The specific identification of SDoH domains and their subcomponents (Supplementary Table S1) was based on Healthy People 2030, a framework aimed at improving future health and preventing diseases [12]. In this study, the framework adopts the five domains outlined in Healthy People 2030 to identify eight subsidiary facets of SDoH. These facets were derived from standardized domains and their subcomponents (Supplementary Table S1). Facets were extracted from standardized NHANES questionnaires across two survey cycles and categorized into advantageous and disadvantageous aspects. The subsidiary facets include Economic Stability (employment status, family income-to-poverty ratio (PIR), and food security), Education Access and Quality (education level), Health Care Access and Quality (incorporating health insurance coverage and type of health insurance), Neighborhood and Built Environment (indicating home ownership), and Social and Community Context (comprising marital status). According to previous studies [13], we calculated the cumulative count of adverse social determinants of health (SDoH) factors, ranging from 0 to 8. These metrics are determined by summing up adverse SDoH indicators across all eight subcomponents. A score of 0 indicated a favorable condition, while a score of 1 indicated that poor SDoH indicators had a negative impact on health.

Cognitive performance

In the NHANES study, participants underwent various cognitive performance assessments designed to evaluate their memory and executive functions. Conducted by the Alzheimer's Disease Word Learning Registry Consortium, the immediate and delayed verbal list-learning tests (known as CERAD-IRT and CERAD-DRT) assess individuals' cognitive function by evaluating their capacity to acquire new verbal information [14]. The CERAD-IRT comprised three distinct trials in which the word order differs, and the subject recalls ten words selected at random. The final result, ranging from 0 to 30, was the aggregate of the three experimental scores. The participants in the CERAD-DRT were given an approximate time frame of 8 to 10 min subsequent to the word learning trial to retrieve as many words as possible. The potential scores for this task were on a scale of 0 to 10. The

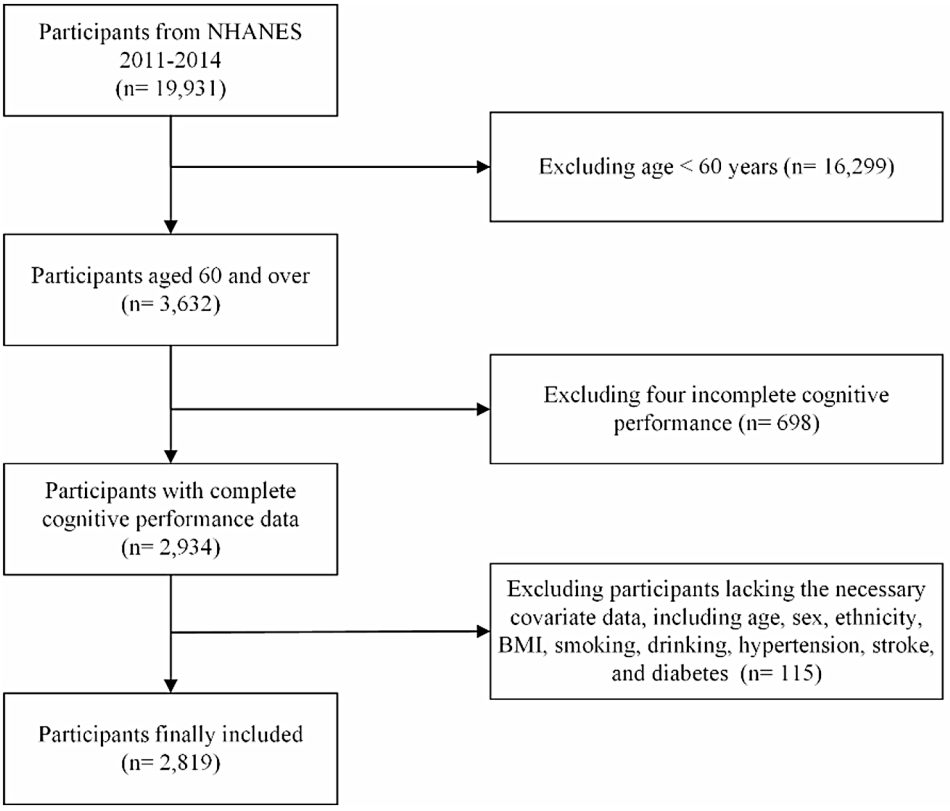

Fig. 1 Flow chart of participants selection

Animal Fluency Test (AFT) assesses verbal and executive skills by requiring participants to name as many animals as possible within one minute [15]. AFT scores were calculated by counting the number of animals named correctly within the one-minute period, yielding scores ranging from 3 to 39. Meanwhile, the Digit Symbol Substitution Test (DSST) was a timed assessment designed to assess processing speed and executive function [16]. Participants were given 2 min to match symbols to numbers across 133 boxes using the key provided at the top. DSST scores were determined based on the accuracy of matches, ranging from 0 to 133.

Covariates

The covariates examined in this study included age, sex, ethnicity, BMI, smoking, drinking, hypertension, stroke, and diabetes status. Age was treated as a continuous variable, whereas sex was categorized as male or female. Ethnicity was categorized into five groups: Mexican American, non-Hispanic white, non-Hispanic black, other Hispanic, and other races. BMI was categorized into three categories: < 25, 25–30, and ≥ 30. Smoking was categorized as "never," "former," or "current." Similarly, drinking was classified as "never," "former," or "current." Stroke was determined based on affirmative responses to the question: "Has a doctor or other health professional ever told you that you had a stroke?" Hypertension diagnosis was established using various criteria: self-reported medical history, systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg, or the use of antihypertensive medications. Having a random blood glucose level > 11.1 mmol/L, a fasting glucose level ≥ 7.0 mmol/L, a glycosylated hemoglobin level ≥ 6.5%, or a two-hour oral glucose tolerance test blood glucose level ≥ 11.1 mmol/L was considered to have diabetes. It also covers people who are now using antidiabetic drugs or who have had a medical diagnosis of diabetes.

Statistical analysis

Continuous variables were presented as weighted means ± standard deviations (SD). Categorical variables were presented as numbers (n) and weighted percentages (%). Baseline characteristics of various SDoH groups (quartiles) were compared using suitable statistical tests, including t-tests, one-way ANOVA, chi-square tests, or Fisher's exact tests. The association between SDoH and cognitive performance was assessed using a weighted multivariate linear regression model, and the association between different SDoH groups (quartiles) and cognitive performance was examined by calculating the p-value for trend analysis. Our analysis employed three models: the unadjusted crude model; Model 1, adjusted for age,

sex, ethnicity, and BMI; and Model 2, further adjusted for smoking, drinking, stroke, hypertension, and diabetes, based on Model 1. Analyses were performed to examine the relationships between different SDoH subscales and cognitive performance. Subgroup analyses investigated potential interactions between SDoH and cognitive performance across various subgroups, including age, sex, ethnicity, BMI, smoking, drinking, stroke, hypertension, and diabetes. Sensitivity analyses were conducted to reevaluate the baseline characteristics of various SDoH groups. All statistical analyses were performed using R software (version 3.6.2). Significance was established at the $p < 0.05$ level, with all hypothesis tests being two-sided.

Results

Baseline characteristics

Table 1 presents the baseline characteristics of the cohort categorized according to quartiles of SDoH. The average age of the elderly participants was 69.14 ± 0.19 years,

Table 1 Characteristics of participants by SDoH quartiles

Variables	Total	Q1	Q2	Q3	Q4	*P*-value
Age	69.14 (0.19)	68.34 (0.30)	70.94 (0.34)	70.06 (0.35)	67.89 (0.39)	< 0.0001
Sex, n (%)						< 0.0001
Female	1448 (54.36)	489 (47.02)	292 (61.18)	426 (64.09)	241 (64.16)	
Male	1371 (45.64)	609 (52.98)	249 (38.82)	360 (35.91)	153 (35.84)	
Ethnicity, n (%)						< 0.0001
Mexican American	249 (3.40)	64 (1.67)	35 (2.50)	91 (6.32)	59 (10.27)	
Non-Hispanic Black	665 (8.29)	195 (4.37)	107 (7.31)	227 (14.87)	136 (21.45)	
Non-Hispanic White	1344 (79.53)	663 (88.28)	294 (80.96)	300 (66.41)	87 (48.03)	
Other Hispanic	290 (3.72)	58 (1.30)	46 (3.01)	99 (6.85)	87 (14.44)	
Other races	271 (5.06)	118 (4.37)	59 (6.21)	69 (5.56)	25 (5.81)	
BMI (kg/m^2)	29.07 (0.22)	28.49 (0.30)	29.12 (0.35)	30.23 (0.51)	30.15 (0.59)	0.002
Smoking, n (%)						< 0.0001
Never	1388 (49.60)	587 (52.95)	257 (47.97)	373 (46.29)	171 (38.57)	
Former	1071 (39.40)	433 (39.34)	222 (41.45)	290 (39.16)	126 (35.39)	
Now	360 (11.00)	78 (7.70)	62 (10.58)	123 (14.55)	97 (26.03)	
Drinking, n (%)						< 0.0001
Never	442 (12.93)	132 (9.40)	80 (14.16)	144 (18.16)	86 (21.31)	
Former	787 (23.11)	222 (17.42)	153 (24.69)	275 (32.58)	137 (35.05)	
Now	1590 (63.96)	744 (73.18)	308 (61.15)	367 (49.26)	171 (43.64)	
Stroke, n (%)						< 0.0001
No	2623 (93.63)	1053 (96.17)	500 (91.72)	717 (91.17)	353 (86.88)	
Yes	196 (6.37)	45 (3.83)	41 (8.28)	69 (8.83)	41 (13.12)	
Hypertension, n (%)						0.003
No	834 (33.44)	367 (36.98)	164 (34.70)	220 (27.30)	83 (21.14)	
Yes	1985 (66.56)	731 (63.02)	377 (65.30)	566 (72.70)	311 (78.86)	
Diabetes, n (%)						< 0.0001
No	1881 (72.82)	805 (78.43)	372 (72.80)	485 (63.30)	219 (57.72)	
Yes	938 (27.18)	293 (21.57)	169 (27.20)	301 (36.70)	175 (42.28)	
CERAD-IRT	19.77 (0.22)	20.50 (0.31)	19.65 (0.24)	18.60 (0.27)	17.92 (0.30)	< 0.0001
CERAD-DRT	6.26 (0.09)	6.56 (0.14)	6.19 (0.12)	5.78 (0.11)	5.60 (0.13)	< 0.001
AFT	18.18 (0.18)	19.46 (0.28)	17.73 (0.28)	16.26 (0.23)	15.13 (0.39)	< 0.0001
DSST	52.31 (0.56)	58.00 (0.63)	50.50 (0.78)	44.41 (0.84)	37.02 (1.26)	< 0.0001
Cumulative number of unfavorable SDoH						
0	484 (0.17)	484 (0.17)				-
1	614 (0.22)	614 (0.22)				-
2	541 (0.19)		541 (0.19)			-
3	454 (0.16)			454 (0.16)		-
4	332 (0.12)			332 (0.12)		-
5	249 (0.09)				249 (0.09)	-
≥ 6	145 (0.05)				145 (0.05)	-

BMI, body mass index; PIR, ratio of family income to poverty; CERAD-IRT, Alzheimer's Disease Word Learning Immediate Recall Test; CERAD-DRT, Alzheimer's Disease Word Learning Delayed Recall Test; AFT, Animal Fluency Test; DSST, Digit Symbol Substitution Test

with 54.36% female and 45.64% male. The majority of the cohort is non-Hispanic White (79.53%). Notably, participants in Q4 displayed tendencies towards younger age, elevated BMI, non-smoking status, now drinking, a higher prevalence of non-Hispanic White ethnicity, and a preponderance of females compared to participants in Q1. Moreover, an obvious pattern has emerged wherein the incidence rates of hypertension, stroke, and diabetes exhibited a gradual increase corresponding to the cumulative burden of SDoH. Furthermore, these individuals in the higher SDoH quartiles exhibited diminished cognitive performance across assessments encompassing CERAD-IRT, CERAD-DRT, DSST, and AFT.

Association between SDoH and cognitive performance

A multivariate linear regression model was constructed to assess the association between SDoH and cognitive performance (Table 2). The comprehensive analysis unveiled a substantial negative association between SDoH and cognitive performance ($p < 0.001$). In Model 2, after adjusting for confounding factors related to SDoH and cognitive performance, participants' lower cognitive performance was associated with the accumulation of SDoH scores (CERAD-IRT: β = -0.457, 95% CI (-0.643, -0.271); CERAD-DRT: β = -0.171, 95% CI (-0.258, – 0.084); AFT: β=-0.561, 95% CI (-0.702, -0.419); DSST: β=-3.055, 95% CI (-3.495, -2.614)). In Model 2, participants in the highest quartile (Q4) exhibited lower cognitive scores compared to the lowest quartile (Q1) (CERAD-IRT: β=-2.129,

Table 2 Association between SDoH and cognitive performance

	Crude model		Model 1		Model 2	
	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
CERAD-IRT						
SDoH	-0.594(-0.753,-0.434)	< 0.0001	-0.524(-0.701,-0.347)	< 0.0001	-0.457(-0.643,-0.271)	< 0.0001
SDoH quartiles						
Q1	ref		ref		ref	
Q2	-0.857(-1.631,-0.083)	0.031	-0.436 (-1.099, 0.226)	0.186	-0.37 (-0.991, 0.250)	0.223
Q3	-1.9 (-2.521,-1.279)	< 0.0001	-1.564(-2.269,-0.859)	< 0.001	-1.365 (-2.105,-0.626)	0.001
Q4	-2.58 (-3.317,-1.844)	< 0.0001	-2.498 (-3.261,-1.736)	< 0.0001	-2.129 (-2.929,-1.330)	< 0.0001
P for trend		< 0.0001		< 0.0001		< 0.0001
CERAD-DRT						
SDoH	-0.234(-0.312,-0.156)	< 0.0001	-0.201(-0.285,-0.117)	< 0.0001	-0.171(-0.258,-0.084)	< 0.001
SDoH quartiles						
Q1	ref		ref		ref	
Q2	-0.371 (-0.755, 0.013)	0.058	-0.159 (-0.467, 0.149)	0.295	-0.133 (-0.427, 0.160)	0.349
Q3	-0.776(-1.103,-0.449)	< 0.0001	-0.613(-0.967,-0.260)	0.002	-0.526(-0.898,-0.154)	0.009
Q4	-0.954 (-1.350,-0.558)	< 0.0001	-0.932 (-1.300,-0.564)	< 0.0001	-0.77 (-1.166,-0.374)	< 0.001
P for trend		< 0.0001		< 0.0001		< 0.001
AFT						
SDoH	-0.986(-1.202,-0.771)	< 0.0001	-0.683(-0.843,-0.524)	< 0.0001	-0.561(-0.702,-0.419)	< 0.0001
SDoH quartiles						
Q1	ref		ref		ref	
Q2	-1.738(-2.537,-0.938)	< 0.001	-0.814(-1.501,-0.126)	0.022	-0.694(-1.356,-0.032)	0.041
Q3	-3.203 (-3.927,-2.478)	< 0.0001	-2.091(-2.768,-1.414)	< 0.0001	-1.735(-2.387,-1.083)	< 0.0001
Q4	-4.338 (-5.514,-3.162)	< 0.0001	-3.291(-4.081,-2.501)	< 0.0001	-2.64 (-3.362,-1.918)	< 0.0001
P for trend		< 0.0001		< 0.0001		< 0.0001
DSST						
SDoH	-4.534 (-5.127,-3.940)	< 0.0001	-3.61 (-4.050,-3.170)	< 0.0001	-3.055 (-3.495,-2.614)	< 0.0001
SDoH quartiles						
Q1	ref		ref		ref	
Q2	-7.501 (-9.725, -5.278)	< 0.0001	-4.905 (-6.402, -3.408)	< 0.0001	-4.197 (-5.711, -2.683)	< 0.0001
Q3	-13.593(-15.869,-11.317)	< 0.0001	-10.207 (-12.077, -8.336)	< 0.0001	-8.501 (-10.370, -6.631)	< 0.0001
Q4	-20.976 (-24.244,-17.708)	< 0.0001	-17.509(-19.813,-15.205)	< 0.0001	-14.646(-17.064,-12.229)	< 0.0001
P for trend		< 0.0001		< 0.0001		< 0.0001

The SDoH was converted from a continuous variable to a categorical variable (quartiles). Data are presented as β (95% CI)

The crude model was adjusted with no covariates. Model 1 was adjusted for age, sex, ethnicity, and BMI. Model 2 was adjusted for age, sex, ethnicity, BMI, smoking, drinking, stroke, hypertension, and diabetes. β, beta; CI, confidence intervals; Q, quartile; SDoH, social determinants of health; BMI, body mass index; CERAD-IRT, Alzheimer's Disease Word Learning Immediate Recall Test; CERAD-DRT, Alzheimer's Disease Word Learning Delayed Recall Test; AFT, Animal Fluency Test; DSST, Digit Symbol Substitution Test

Table 3 Association between SDoH sub-items and cognitive performance

		Crude model		Model 1		Model 2	
		β (95% CI)	*P*	β (95% CI)	*P*	β (95% CI)	*P*
Employment							
	CERAD-IRT	-0.509(-1.159,0.140)	0.120	-1.271(-1.885,-0.656)	< 0.001	-0.773 (-1.450,-0.096)	0.029
	CERAD-DRT	-0.219(-0.566,0.128)	0.208	-0.633(-0.933,-0.333)	< 0.001	-0.488(-0.815,-0.160)	0.008
	AFT	-1.544(-2.386,-0.701)	< 0.001	-1.958 (-2.643,-1.274)	< 0.0001	-1.146(-2.065,-0.227)	0.020
	DSST	-5.375 (-8.138,-2.613)	< 0.001	-7.414 (-9.384,-5.443)	< 0.0001	-3.004(-4.767,-1.241)	0.004
PIR							
	CERAD-IRT	-1.898(-2.435,-1.361)	< 0.0001	-1.396(-1.974,-0.817)	< 0.0001	-0.827(-1.451,-0.204)	0.014
	CERAD-DRT	-0.777(-1.018,-0.537)	< 0.0001	-0.539(-0.811,-0.267)	< 0.001	-0.347(-0.688,-0.006)	0.047
	AFT	-2.864 (-3.640,-2.088)	< 0.0001	-1.758 (-2.365,-1.152)	< 0.0001	-0.954(-1.796,-0.111)	0.030
	DSST	-12.638(-14.673,-10.603)	< 0.0001	-9.022(-10.388,-7.656)	< 0.0001	-5.017(-6.660,-3.373)	< 0.0001
Food security							
	CERAD-IRT	-1.459(-1.984,-0.934)	< 0.0001	-1.558 (-2.061,-1.054)	< 0.0001	-0.56 (-1.344, 0.224)	0.142
	CERAD-DRT	-0.485(-0.778,-0.191)	0.002	-0.558(-0.835,-0.281)	< 0.001	-0.153 (-0.552, 0.246)	0.414
	AFT	-2.426 (-3.353,-1.499)	< 0.0001	-2(-2.730,-1.269)	< 0.0001	-0.621 (-1.777, 0.535)	0.259
	DSST	-12.089(-14.428,-9.750)	< 0.0001	-10.261(-12.008,-8.514)	< 0.0001	-4.166 (-6.619,-1.714)	0.004
Education level							
	CERAD-IRT	-2.734 (-3.477,-1.992)	< 0.0001	-2.038(-2.868,-1.207)	< 0.0001	-1.415(-2.364,-0.466)	0.008
	CERAD-DRT	-1.026(-1.350,-0.703)	< 0.0001	-0.69(-1.030,-0.350)	< 0.001	-0.39 (-0.812, 0.032)	0.067
	AFT	-4.025(-4.704,-3.346)	< 0.0001	-2.91 (-3.375,-2.445)	< 0.0001	-2.021(-2.684,-1.359)	< 0.0001
	DSST	-18.455(-20.588,-16.323)	< 0.0001	-13.372 (-14.918,-11.827)	< 0.0001	-8.808(-10.905,-6.710)	< 0.0001
Health insurance coverage							
	CERAD-IRT	-0.464 (-1.477,0.549)	0.357	-1.134(-1.948,-0.320)	0.008	-0.813(-1.587,-0.039)	0.041
	CERAD-DRT	-0.06(-0.499,0.379)	0.783	-0.482(-0.887,-0.077)	0.022	-0.355 (-1.315, 0.604)	0.432
	AFT	-0.591(-2.109,0.926)	0.433	-1.29 (-2.788, 0.208)	0.088	0.362 (-3.421, 4.145)	0.837
	DSST	-3.554(-7.729,0.620)	0.092	-5.623 (-8.796,-2.449)	0.001	-3.43 (-11.133, 4.272)	0.348
Type of health insurance							
	CERAD-IRT	-1.087(-1.592,-0.581)	< 0.001	-0.294 (-0.760, 0.172)	0.205	0.474 (-0.085, 1.032)	0.088
	CERAD-DRT	-0.466(-0.729,-0.203)	0.001	-0.092 (-0.349, 0.165)	0.468	0.267 (-0.024, 0.558)	0.068
	AFT	-2.081 (-2.790,-1.371)	< 0.0001	-0.86(-1.478,-0.242)	0.008	-0.073 (-0.709, 0.563)	0.804
	DSST	-10.388(-12.229,-8.547)	< 0.0001	-5.754 (-7.123,-4.385)	< 0.0001	-1.14 (-2.776, 0.496)	0.152
Home ownership							
	CERAD-IRT	-0.911(-1.552,-0.269)	0.007	-0.698(-1.350,-0.046)	0.037	0.224 (-0.455, 0.903)	0.479
	CERAD-DRT	-0.377(-0.701,-0.053)	0.024	-0.3 (-0.620, 0.020)	0.064	0.044 (-0.313, 0.400)	0.790
	AFT	-2.055(-2.758,-1.352)	< 0.0001	-1.203(-1.805,-0.601)	< 0.001	-0.295 (-1.033, 0.442)	0.393
	DSST	-9.193 (-11.369,-7.017)	< 0.0001	-6.129 (-8.128,-4.130)	< 0.0001	-1.564 (-3.471, 0.342)	0.097
Marital status							
	CERAD-IRT	-0.763(-1.251,-0.274)	0.003	-0.711(-1.237,-0.184)	0.010	-0.238 (-0.881, 0.405)	0.428
	CERAD-DRT	-0.287(-0.566,-0.008)	0.044	-0.234 (-0.493, 0.025)	0.075	-0.044 (-0.363, 0.276)	0.767
	AFT	-1.184(-1.773,-0.594)	< 0.001	-0.271 (-0.896, 0.354)	0.380	0.383 (-0.439, 1.205)	0.323
	DSST	-4.645 (-6.301,-2.988)	< 0.0001	-2.692 (-4.107,-1.277)	< 0.001	0.517 (-1.052, 2.086)	0.479

The crude model was adjusted with no covariates. Model 1 was adjusted for age, sex, ethnicity, and BMI. Model 2 was adjusted for age, sex, ethnicity, BMI, smoking, drinking, stroke, hypertension, diabetes, and seven other subsets of SDoH. β, beta; CI, confidence intervals; Q, quartile; SDoH, social determinants of health; BMI, body mass index; PIR, the ratio of family income to poverty; CERAD-IRT, Alzheimer's Disease Word Learning Immediate Recall Test; CERAD-DRT, Alzheimer's Disease Word Learning Delayed Recall Test; AFT, Animal Fluency Test; DSST, Digit Symbol Substitution Test

95% CI (-2.929, -1.330); CERAD-DRT: β=-0.77, 95% CI (-1.166, -0.374); AFT: β=-2.64, 95% CI (– 3.362, -1.918); DSST: β=-14.646, 95% CI (-17.064, -12.229)), and cognitive performance declined progressively with increasing SDoH scores ($p < 0.001$).

Association between SDoH sub-items and cognitive performance

Multivariate linear regression models were developed to explore the association between different subscales of SDoH and cognitive performance (Table 3). In Model 2, fully adjusted for confounders, participants displayed lower cognitive performance with the accumulation of unfavorable factors related to Employment status, PIR,

and education level. The in-depth analysis revealed that Employment status and PIR were significantly associated with lower cognitive performance across all four cognitive tests (CERAD-IRT, CERAD-DRT, AFT, and DSST) ($p < 0.05$). While the association between Education level and CERAD-DRT did not reach statistical significance ($p > 0.05$), a notable decline in cognitive performance was evident across the remaining three cognitive tests (CERAD-IRT, AFT, and DSST) with a statistical significance ($p < 0.05$). Additionally, a negative association was observed between Food security and DSST ($p < 0.05$), consistently observed across the three models. Similarly, Health Care is negatively associated with CERAD-IRT ($p < 0.05$). Notably, the accumulation of unfavorable factors pertaining to food security, health care, health care type, personal housing, and marital status was associated with lower cognitive performance in the unadjusted crude model and Model 1. However, these associations failed to attain statistical significance in Model 2, which was fully adjusted for confounders.

Subgroup and sensitivity analysis

Moreover, we explored the potential interactions affecting the association between cognitive performance and SDoH, including age groups (60–70, 70–80, >80), sex (male vs. female), ethnicity (Mexican American, non-Hispanic White, non-Hispanic Black, other Hispanic, and other races), BMI categories (<25, 25–30, >30 kg/m^2), smoking (never, former, or current), drinking (never, former, or current), stroke (no or yes), hypertension (no or yes), and diabetes (no or yes).

Subgroup analysis results revealed an ethnicity interaction in the association between SDoH and DSST ($p = 0.006$). A lower cognitive performance was observed in the Mexican American population (β = -5.08, 95% CI (-7.347, -2.813), $p = 0.006$). Moreover, an interaction was observed between stroke and the association between SDoH and CERAD-DRT ($p = 0.014$). SDoH was negatively associated with cognitive performance in non-stroke patients (β = -0.251, 95% CI (-0.339, -0.162), $p < 0.0001$). However, in stroke patients, SDoH was positively associated with cognitive performance (β = 0.14, 95% CI (-0.137, 0.416), $p = 0.301$), with a weak association ($p > 0.05$). Furthermore, a compelling interaction effect was unraveled between diabetes and SDoH across all four cognitive tests (CERAD-IRT, CERAD-DRT, AFT, and DSST) ($p < 0.05$). Patients with diabetes exhibited less severe cognitive impairment across CERAD-IRT, AFT, and DSST (CERAD-IRT: β = -0.307, 95% CI (-0.461, -0.152), $p < 0.001$; AFT: β = -0.442, 95% CI (-0.713, -0.170), $p = 0.003$; DSST: β = -2.804, 95% CI (-3.545, -2.063), $p < 0.0001$). Regarding CERAD-DRT, non-diabetic patients had more severe cognitive impairment (β = -0.273, 95% CI (-0.393, -0.153), $p < 0.001$), while the association was weaker in diabetic patients ($p > 0.05$). No significant interactions between SDoH and the four cognitive performances were observed with other characteristics or disease states (Supplementary Table 2).

In the sensitivity analyses, we re-examined the baseline characteristics of various SDoH groups (quartiles) by analyzing participants who underwent all eight SDoH tests (Supplementary Table 3). The weighted multivariate linear regression modeling results regarding the association between SDoH and cognitive performance revealed a persistent negative association with all four cognitive tests, indicating a more robust association (Supplementary Table 4). In Model 2, after adjusting for confounders related to SDoH and cognitive performance, participants displayed lower cognitive performance as the accumulation of SDoH disadvantage (CERAD-IRT: β=-0.388, 95% CI (-0.596, -0.180), $p = 0.001$; CERAD-DRT: β=-0.130, 95% CI (-0.223, -0.037), $p = 0.009$; AFT: β=-0.563, 95% CI (-0.709, -0.418), $p < 0.0001$; DSST: β=-3.056, 95% CI (-3.524, -2.588), $p < 0.0001$). Similarly, in Model 2, when comparing different SDoH groups (quartiles) with cognitive performance, participants in the Q4 group demonstrated lower cognitive scores compared to Q1 (CERAD-IRT: β=-1.838, 95% CI (-2.685,-0.991), $p < 0.001$; CERAD-DRT: β=-0.586, 95% CI (-1.031,-0.141), $p = 0.013$; AFT: β=-2.541, 95% CI (-3.195,-1.886), $p < 0.0001$; DSST: β=-13.616, 95% CI (-15.821,-11.411), $p < 0.0001$), and cognitive performance decreased progressively with the accumulation of SDoH ($p < 0.05$).

Discussion

In a cross-sectional NHANES cohort study involving 2,819 older participants, we examined the relationship between social determinants of health (SDoH) and cognitive performance. The study revealed a significant association between the cumulative burden of SDoH disadvantages and diminished cognitive performance. Additionally, in further sensitivity analyses, we observed a negative association between SDoH scores and four cognitive performances, suggesting that higher SDoH scores are associated with lower cognitive performance. Further investigation of adverse SDoH factors is essential for slowing the progression of cognitive impairment.

Research on SDoH underscores a substantial impact on cognitive processes, revealing a nexus between socioeconomic disparities and cognitive well-being within the geriatric population of the United States. For instance, Velez-Coto identified a detrimental relationship between unemployment and cognitive performance, showing how lower educational attainment and prolonged unemployment are closely intertwined with declines in adult literacy, memory, executive function, and processing speed [17]. The mechanisms underlying these effects may be multifaceted, including the psychological burden of

unemployment, which contributes to stress and adversely affects brain health over time. Conversely, protective factors such as gainful employment, higher educational attainment, and cohabitation with a partner have been associated with enhanced cognitive performance in older Croatian workers, particularly in areas such as numeracy and verbal recall [18]. These factors significantly contribute to better cognitive performance, mitigating the adverse effects of unemployment and poor health. The research indicated partial agreement; older persons who were unemployed and had completed less than high school were strongly associated with poorer performance on four cognitive performance, while marital status was not significantly related to cognitive performance.

Food insecurity, a pervasive issue, exhibits a negative association with cognitive performance, particularly the decline in executive function, thereby heightening the susceptibility to cognitive impairment over time [19–21]. Wong et al. [22] elucidated an accelerated trajectory of cognitive decline, particularly in executive function, among individuals aged 40–75 years in the United States experiencing food insecurity, underscoring the critical need for interventions targeting food insecurity. The stress and nutritional deficiencies associated with food insecurity likely accelerate cognitive decline, as inadequate nutrition can impair brain health and function over time. Proactive screening combined with tailored interventions to ensure access to adequate, nutritious diets has significant potential to mitigate cognitive deficits, particularly in executive function, among disadvantaged populations [23]. By targeting the underlying nutritional inadequacies and stressors associated with chronic food insecurity, these interventions can help prevent the accelerated decline in cognitive health. Moreover, the provision of supplementary financial assistance to older adults in low- and middle-income countries can enhance cognitive performance, particularly episodic memory, by improving food security and increasing healthcare utilization, leading to significant gains in episodic memory, as evidenced by significant improvements in both immediate and delayed recall [24]. However, while food insecurity was linked to poorer executive function in this research, no significant association was found with CERAD-IRT or CERAD-DRT performance, suggesting that certain cognitive domains may be more susceptible to the effects of food insecurity than others.

Education level also plays a crucial role in cognitive health. Individuals with higher education and income demonstrate significantly better cognitive performance, as higher education is associated with enhanced memory, improved executive function, and superior working memory, compared to those with lower education and income levels [25]. Similar conclusions were reached in the present study, where participants with PIR levels below 300% and less than high school educational level were significantly negatively associated with the four cognitive performances. Notably, higher educational attainment are positively associated with enhanced cognitive performance, particularly in domains such as memory recall and attention, underscoring the importance of education in fostering cognitive performance [26]. Furthermore, higher educational attainment serves as a protective factor against cognitive decline, particularly in memory and executive function, while individuals with lower education levels are more vulnerable to cognitive decline. This is especially evident in delayed verbal recall and executive tasks, where those with higher education demonstrate greater cognitive performance [27]. Educational attainment primarily shapes cognitive skills by fostering individual differences in memory, executive function, and processing speed, which are established in early adulthood and persist into old age, contributing to sustained cognitive performance over time [28]. The association between education and cognitive health suggests that interventions aimed at improving educational opportunities for vulnerable populations could have long-lasting benefits for cognitive health, particularly in preventing cognitive decline in older age.

A recent study by Mullins et al. [29] explored the association between limited healthcare access and the higher prevalence of cognitive impairment in the United States. One possible explanation is that limited healthcare access may delay the diagnosis and treatment of cognitive disorders, leading to poorer cognitive outcomes. The study specifically identified a correlation between the absence of health insurance and diminished performance on the CERAD-IRT, without establishing a strong association between health insurance status or type and other cognitive performance measures. The study also found no significant correlation between homeownership and cognitive performance. Additionally, the research highlighted the association between housing vulnerability, characterized by individuals with compromised living conditions, and their diminished sleep quality and cognitive capabilities relative to the general populace [30]. Notably, residents in low-rental apartment neighborhoods exhibited a higher prevalence of cognitive impairment (26.2%) compared to high-ownership housing neighborhoods (16.1%), and residing in low-rental apartment neighborhoods was independently associated with poorer cognitive performance (β = -1.41, SD = 0.58, $p < 0.01$) and cognitive impairment (adjusted odds ratio 5.13, 95% CI 1.98–13.34) after adjusting for other sociodemographic variables [31]. These findings emphasize the importance of considering environmental factors, such as housing conditions and healthcare access, when addressing cognitive health disparities.

The influence of marital status on cognitive performance stands as another critical factor deserving consideration. Marital dissolution in midlife may negatively affect cognitive performance, especially memory recall and orientation, increasing susceptibility to cognitive decline and dementia later in life [32]. Moreover, individuals who have experienced long-term divorce, separation, or widowhood face a significantly higher risk of cognitive impairment compared to those who have undergone such marital disruptions for a shorter duration [33]. This suggests that the duration and psychological burden of marital dissolution may have long-lasting effects on brain health, potentially increasing the risk of cognitive decline.

Previous studies have established an association between individual socioeconomic variables and cognitive performance. Building on this, we developed a composite SDoH variable that incorporates various socioeconomic factors to provide a more comprehensive analysis. The relationship between SDoH and cognitive performance shows that cognitive health is closely tied to socioeconomic disparity among older Americans. Therefore, the imperative task of exploring interventions to address socioeconomic gaps becomes paramount, offering potential avenues for ameliorating cognitive decline.

In subgroup analyses, we observed an ethnicity interaction in the relationship between SDoH and DSST, with Mexican American populations exhibiting lower cognitive performance tendencies. The lower cognitive scores among Mexican Americans may be due to language barriers, cultural factors, and lower socioeconomic status. This trend may result from a combination of factors, such as language barriers, cultural differences, and lower socioeconomic status, which can negatively impact both access to resources and cognitive health. This finding emphasizes the importance of considering ethnicity and cultural factors when designing public health interventions reducing cognitive disparities.

Additionally, an interaction between stroke status and the association between SDoH and CERAD-DRT scores was identified. Socioeconomic factors did not significantly impact cognitive performance in stroke patients compared to non-stroke patients, which indicated that stroke itself may be the primary cause of cognitive decline rather than socioeconomic factors. Post-stroke cognitive impairment represents a prevalent phenomenon, with a substantial proportion of stroke patients experiencing cognitive deficits post-event. While some instances of cognitive impairment post-stroke may be reversible during the early recovery phase, alarming statistics show that up to one-third of stroke survivors may progress to develop dementia within five years [34]. In contrast, in non-stroke patients, the association between lower socioeconomic status and poorer cognitive performance was more pronounced, suggesting that socioeconomic factors play a more prominent role in cognitive decline in the absence of stroke. This reinforces the notion that socioeconomic factors can serve as both risk and protective factors for cognitive health, depending on the presence of other medical conditions such as stroke.

In this study, diabetes was observed to interact with the association between SDoH and all four cognitive tests (CERAD-IRT, CERAD-DRT, AFT, and DSST). Cognitive performance was better in individuals with diabetes compared to non-diabetic participants, a phenomenon that may be attributed to the proactive health behaviors often adopted by individuals managing diabetes. These behaviors include a healthy diet, regular exercise, controlling blood glucose levels, and receiving more frequent medical monitoring and treatment, which could collectively contribute to preserving cognitive performance and mitigating cognitive decline. Studies have shown a negative association between fasting blood glucose levels and cognitive performance, with poorer glycemic control linked to worse outcomes on memory tests [35]. Therefore, controlling blood sugar levels emerges as a critical factor in slowing the progression of cognitive impairment. In contrast, non-diabetic patients showed lower cognitive performance, likely due to other health issues, lifestyle factors, or more unfavorable socioeconomic conditions. Further investigation into the interaction between SDoH and cognitive performance regarding ethnicity, stroke, and diabetes is essential for developing targeted and effective health socioeconomic strategies to slow cognitive decline.

Limitations

However, this study has several limitations. Firstly, despite considering a broad range of covariates to enhance the validity and accuracy of our multivariate analyses, the observational nature of the study limits our ability to fully eliminate the potential for residual confounding. Secondly, socioeconomic factors related to health measured in later life precluded an examination of whether changes in SDoH over the life course are associated with cognitive performance in older adults. Therefore, it is crucial to investigate the contribution of SDoH to cognition using a life course approach. Additionally, regarding the self-reported indicators of social determinants, while these measures reflect their impact on health to some extent, certain limitations in the NHANES database variables hinder a comprehensive understanding of the complex characteristics in the target domains. For instance, home ownership, as a representative indicator within the “Neighborhood and Built Environment” domain, primarily captures economic status but inadequately assesses community safety and environmental quality. Similarly, marital status in the “Social and Community Context” domain can only partially represent

social support networks, and fails to fully encompass the complexity of social relationships and individual levels of social engagement. These limitations may introduce biases in interpreting the findings related to these domains. Finally, the cross-sectional design of NHANES limits our ability to establish causality in research, rendering our conclusions anchored solely in statistical inferences. Therefore, future prospective studies and intervention trials are needed to understand the causal relationship between SDoH and cognitive performance and to explore the underlying mechanisms.

Conclusion

In conclusion, our study provides strong evidence that the cumulative disadvantage of SDoH is independently linked to lower cognitive performance in the elderly American population. These findings highlight the urgent need for interventions to improve cognitive performance and reduce socioeconomic inequalities in older populations. Future studies should adopt longitudinal designs to validate our results and explore strategies to address social determinants of health.

Abbreviations

SDoH	Social determinants of health
NHANES	National Health and Nutrition Examination Survey
DSST	Digit Symbol Substitution Test
AFT	Animal Fluency Test
CERAD	Coalition to Establish an Alzheimer's Disease Registry

Supplementary Information

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Supplementary Material 1

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Author contributions

ZY and XS designed the study. ZY wrote the manuscript. XS, XH, and XW collected, analyzed, and interpreted the data. LW critically reviewed, edited, and approved the manuscript. All authors read and approved the final manuscript.

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Data availability

Publicly available datasets were analyzed in this study. This data can be found here: www.cdc.gov/nchs/nhanes/.

Declarations

Ethics approval and consent to participate

All participants provided written informed consent, and the Research Ethics Review Board of the National Center for Health Statistics approved the study. The experimental procedures adhered to the ethical guidelines of the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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