CLINICAL RESEARCH STUDY

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Dietary Fiber Intake is Associated with Cognitive Function in Older Adults: Data from the National Health and Nutrition Examination Survey

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ABSTRACT

BACKGROUND: Aging is a global health challenge that is associated with a decline in cognitive function. In the United States, most older adults (≥50 years) do not meet the recommended daily fiber intake, although preliminary evidence suggests that dietary fiber consumption could elicit clinical benefits on cognitive function. We investigated the associations between dietary fiber intake and cognitive function in older adults.

METHODS: We analyzed data from the US National Health and Nutrition Examination Survey (NHANES) between 2011 and 2014, with a study cohort of 1070 older adults (≥60 years). Cognitive function was assessed using the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) Word Learning Test (WLT), Word Recall Test (WRT) and their Intrusion Word Count Tests (WLT-IC and WRT-IC), the Animal Fluency Test (AFT), and the Digit Symbol Substitution Test (DSST). Multiple linear regression and cubic spline analyses were employed to examine the association between dietary fiber intake and cognitive performance on a test-by-test basis, after covariates adjustment (ie, age, sex, race, socioeconomic status, educational level, medical history, body mass index, alcohol, and energy intake).

RESULTS: Participants had a mean age of 69.2 years and were primarily non-Hispanic white of middle-high socioeconomic status with a college degree at minimum. The mean dietary fiber intake was 17.3 g/d. The analysis showed that dietary fiber intake was positively associated with DSST (P = .031). No associations with CERAD WLT (P = .41), WRT (P = .68), WLT-IC (P = .07), and WRT-IC (P = .28), and AFT (P = .40) scores were observed. A plateau in DSST score was revealed at a dietary fiber intake of 34 g/d.

CONCLUSIONS: Higher dietary fiber intake is associated with improved specific components of cognitive function in older adults aged 60 years and older. Public health interventions that target a recommended dietary fiber intake may provide a promising strategy to combat cognitive decline in high-risk groups of older adults.

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KEYWORDS: Aging; Cognitive function; Dietary fiber; Nutrition; Older adults

INTRODUCTION

Aging is associated with a progressive decline in cognitive performance that includes the deterioration of memory, mood, and lack of concentration. These impairments in cognitive function are caused, at least in part, by the degradation in brain structure that progresses with advanced age.[1] Cognitive decline also is associated with manifestation of physical symptoms

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such as loss of balance and manual handling.[2] Specifically, observation of grey and white matter microstructure shrinking, cortical thinning, and reduction in neuronal volume, dendritic arbor, spines, and synapses all have been reported with regard to brain aging and cognitive decline.[3,4] These perturbations to brain health lead to impairments in memory, executive function, and information processing skills.[5] Furthermore, age-related cognitive impairment may be partially modulated by nutritional status.[6] In this regard, emerging evidence suggests that diets low in dietary fiber content are associated with cognitive impairments.[7]

Dietary fiber is associated with a reduced cardiovascular disease and all cancer risk, highlighting its importance as part of a healthy diet.[8,9] In the United States, more than 90% of women and 97% of men among adults do not meet current recommends for dietary fiber intake.[10] This observation suggests that older adults may not optimize the cognitive benefits that stem from the recommended daily consumption of fiber. Therefore, an investigation into the relationship between dietary fiber intake and cognitive performance in older adults may help inform researchers and policy makers whether interventions aimed at increasing daily dietary fiber intake could provide a simple and effective nonpharmacological intervention to offset the age-related decline in cognitive performance.

The aim of this exploratory study was to examine the association between dietary fiber intake and cognitive function in older adults (≥60 years of age), using publicly available data from the National Health and Nutrition Examination Survey (NHANES) between 2011 and 2014.

CLINICAL SIGNIFICANCE

- Dietary fiber intake is positively associated with Digit Symbol Substitution Test score.
- The effect of dietary fiber intake plateaues at 34 g/d on this cognitive measure.
- Public health interventions aiming at recommended dietary fiber intake may be pivotal in combating cognitive decline associated with advanced age.

METHODS

Study Design and Participants

We extracted data from participants aged ≥60 years from two consecutive survey cycles published by NHANES: 2011-2012 and 2013-2014. A cut-off age of ≥60 years old was selected based on the availability of cognitive function-associated data and considering the acceleration in cognitive dysfunction that is commonly experienced by older adults.[11]

Dietary Assessment

Qualified personnel conducted in-home interviews via 24-hour dietary recalls using the US Department of Agriculture's Automated Multiple-Pass Method.[12] Total daily nutrient intake for food and beverages was calculated using the US Department of Agriculture's Food and Nutrient Database for Dietary Studies.[12] Daily energy (kcal), dietary fiber (g), and alcohol (g) intake were then calculated as averages from two daily dietary recalls.

Cognitive Assessment

Cognitive function was evaluated using the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) Word Learning Test (WLT), Word Recall Test (WRT) and their Intrusion Word Count Tests (WLT-IC and WRT-IC), the Animal Fluency Test (AFT), and the Digit Symbol Substitution Test (DSST).

The CERAD WLT, WLT-IC, WLRT, and WLRT-IC are routinely used to assess the immediate and delayed learning ability related to novel verbal information. These inventories consist of three progressive learning trials followed by a delayed recall challenge and range in scores between 0 and 10. The AFT evaluates executive function by examining categorical verbal fluency with scores from 3 to 39. The DSST constitutes a performance challenge from the Wechsler Adult Intelligence Scale-III that appraises processing speed, sustained attention and working memory, and is scored from 0 and 105. Higher test scores indicate better cognitive performance. Participants with no response for any of the tests were excluded from the study.

Covariates

Age (years), sex (male, female), race, socioeconomic status (family income to poverty ratio [FIPR]), education level (school qualification), medical history (history of memory-cognitive function loss and stroke), body mass index (BMI; kg/m^2), daily energy (kcal), and alcohol intake (g) were examined as covariates in the relationship between diet and cognitive function. All covariates were potential confounders in the relationship between dietary fiber intake and cognitive performance.

All participants with ≥60 years of age and were categorized into 60-69, 70-79, and 80 and older year groups. Race groups consisted of Mexican American, other Hispanic, non-Hispanic white, non-Hispanic Black, non-Hispanic Asian and other (multi)racial groups. Socioeconomic status was categorized as poor-low (FIPR <1) and moderate-high (FIPR ≥1). Education level was classified as no high school degree, at most a high school degree, or a college degree at minimum. Medical history in terms of loss of cognitive-memory function or stroke was categorized as Yes/No responses based on past incidence reported by a doctor or other health professional. BMI, daily energy intake, and alcohol intake were classified as low, moderate, or high. A BMI of <18 kg/m^2 was categorized as low, 18-24.9 kg/m^2 as moderate, and ≥25 kg/m^2 as high. Additionally, in older adult men, energy intake was classified as low if <2000 kcal/d, moderate if 2000-3000 kcal/d, and high if >3000 kcal/d. In older adult women, energy intake was

classified as low if <1600/d kcal, moderate if 1600-2400 kcal/d, and high if >2400 kcal/d. Finally, in men, alcohol intake was classified as low if <15 g/d, moderate if 15-30 g/d, and high if >30 g/d, whereas in older women alcohol intake was classified as low if <10 g/d, moderate if 10-20 g/d, and as high if >20 g/d.

Statistical Analysis

Multiple linear regression analyses were employed to examine the association between dietary fiber intake and cognitive function, as expressed on a test-by-test basis for the assessment of cognitive performance, after adjustment for all covariates. A restricted cubic spline was used to model the nonlinear and dose-response relationship between dietary fiber intake and cognitive performance after adjustment for covariates. Dietary fiber intake and cognitive performance were treated as continuous variables, and all covariates were categorical in type. Statistical significance was defined as $P < .05$. Statistical analysis was performed in IBM SPSS Statistics v28.

RESULTS

Characteristics of Study Population

Data for cognitive performance and dietary fiber intake were available for 1070 participants (Figure 1). Baseline information regarding sociodemographic, anthropometric, nutritional, and medical history characteristics of all participants are summarized in Table 1. The study cohort had a mean age of 69.2 years and was equally divided between males and females. Study participants were primarily non-Hispanic white (47.8%) and Black (27%), of middle-high socioeconomic status (83.5%) with a college degree at minimum (74.2%). A history of memory-cognitive function loss was reported in 12.3% of study participants, while a stroke incidence was found in 7.0%. Energy intake was primarily less than the recommended values (52.1%) or just within this range (40.2%). Alcohol intake was low (85.1%), and BMI was high (73.5%) for the majority of participants. Mean dietary fiber intake was 17.3 g/d.

Table 1 Socio-Demographic, Anthropometric, Nutritional, and Medical History Characteristics of Participants (n = 1070)*

Characteristics	
Sex	
Males	518 (48.4)
Females	552 (51.6)
Age	
60-69	601 (56.2)
70-79	307 (28.7)
≥80	162 (15.1)
Race	
Mexican American	67 (6.3)
Other Hispanic	116 (10.8)
Non-Hispanic White	511 (47.8)
Non-Hispanic Black	289 (27.0)
Non-Hispanic Asian	69 (6.4)
Other Race, Including Multiracial	18 (1.7)
Socioeconomic status	
Low-Middle	177 (16.5)
Middle-High	893 (83.5)
Educational level	
No high school degree	125 (11.7)
High school degree	151 (14.1)
College degree	794 (74.2)
Energy intake	
Low	557 (52.1)
Moderate	430 (40.2)
High	83 (7.8)
Body mass index	
Low	10 (0.9)
Normal	274 (25.6)
High	786 (73.5)
Alcohol intake	
Low	911 (85.1)
Moderate	69 (6.4)
High	90 (8.4)
Medical history	
Memory-cognitive function loss	132 (12.3)
Stroke	75.0 (7)
Fiber intake	
Minimum	0.9 g
Average	17.3 g
Maximum	118.4 g

*Values are expressed as count (percentage).

Dietary Fiber Intake and Cognitive Performance

Dietary fiber intake was positively associated with DSST (β:0.106, P = .031) score following adjustment for sociodemographic, anthropometric, nutritional, and medical history characteristics (Table 2). No associations were determined between dietary fiber intake and CERAD WLT (β:0.004, P = .41), WRT (β:0.003, P = .68), WLT-IC (β:−0.002, P = .07) and WRT-IC (β:−0.002, P = .28), and AFT (β:0.016, P = .40) scores following adjustment. Dose-response curves displayed an approximate linear relationship between dietary fiber intake and DSST score after covariates adjustment (Figure 2). According to our restricted cubic spline model, a trend for a plateau in DSST score was apparent at a dietary fiber intake of 34 g/d.

DISCUSSION

Our study investigated the relationship between dietary fiber intake and cognitive function in older adults (≥60 years of age) by retrospective analysis of data collated from NHANES between 2011 and 2014. Our findings demonstrated a significant association of dietary fiber intake with DSST score, even after adjustment for multiple sociodemographic, anthropometric, nutritional, and medical history covariates. These findings highlight the importance of

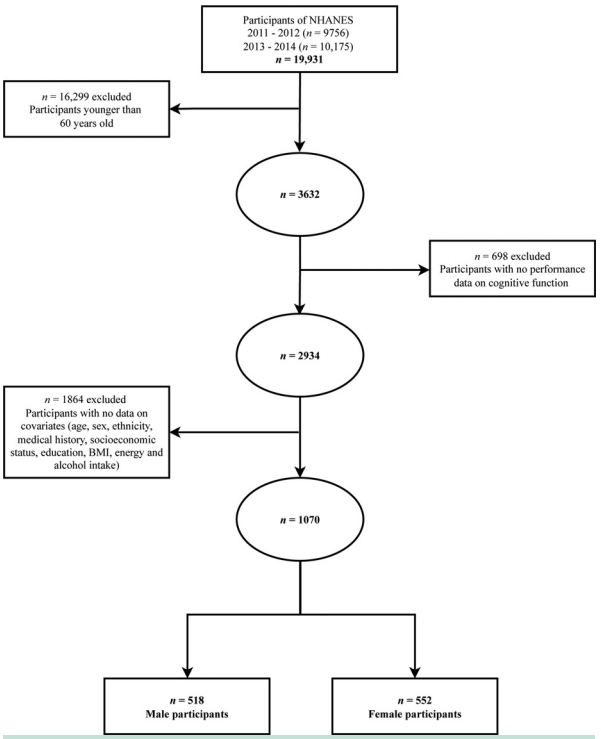

Figure 1. Flow chart of the screening process for the selection of eligible participants in the National Health and Nutrition Examination Survey (NHANES).

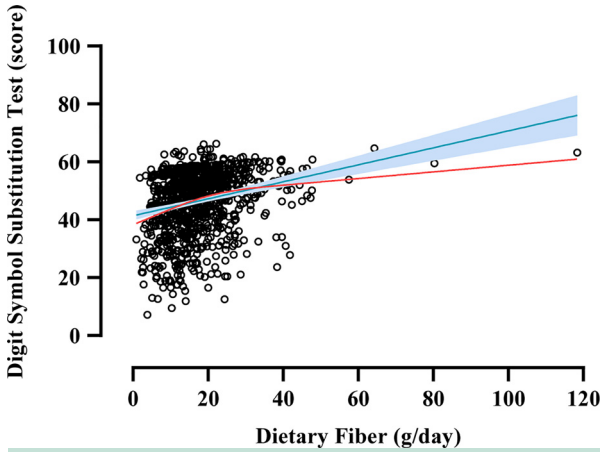

Figure 2 Dose-response curves displayed an approximate linear relationship between dietary fiber intake and Digit Symbol Substitution Test score, after covariates adjustment.

dietary fiber intake for maintaining specific aspects of cognitive function with advanced age.

A positive association between dietary fiber intake and cognitive function in older adults has been previously described by prospective, observational studies.[13,14] In this regard, a low dietary fiber intake was associated with cognitive decline in a 13-year cohort of older adult women.[13] In addition, a significant improvement in cognitive function over a 10-year period following a diet highly enriched in fiber in a cohort of adults ≥50 years who were free of major comorbidities (ie, cancer, stroke, coronary artery disease).[14] However, both extreme (ie, high and low) dietary intakes were inversely associated with overall cognitive function in 40- to 69-years old adults.[15] The authors reasoned that this observation may be attributed, at least in part, to the effects of bioactive polyphenol compounds that may be beneficial to only brain region-specific actions.[16,17] Given that a high dietary fiber intake typically results from vegan or vegetarian diets, the former discrepancy may also be the lack of meat and fish products, which consist of cognitive-enhancing nutrients (ie, B vitamins, omega-3 fatty acids).[18] Nevertheless, the study by Hepsomali and Groeger[15] observed that very high dietary fiber intake may attenuate cognitive function, although the specific amount of daily fiber intake was not reported in this study.

Table 2 Multiple Linear Regression Analysis of the Association Between Dietary Fiber Intake and Cognitive Function by Test Cognitive Performance

Cognitive Function	β	P	R^2
CERAD WLT	0.004	.41	0.229
CERAD WRT	0.003	.68	0.211
CERAD WLT-IC	−0.002	.07	0.034
CERAD WRT-IC	−0.002	.28	0.018
AFT	0.016	.40	0.156
DSST	0.106	.031	0.391

AFT = Animal Fluency Test; CERAD = Consortium to Establish a Registry for Alzheimer's Disease; DSST = Digit Symbol Substitution Test; WLT = Word Learning Test; WRT = Word Recall Test; WLT-IC = Word Learning Test – Intrusion Word Count; WRT-IC = Word Recall Test – Intrusion Word Count.

To our knowledge, this is the first study to observe favorable DSST scores following higher dietary fiber intake. It follows that individuals consuming a high-fiber intake are likely to benefit from greater information processing speed, sustained attention, and working memory, all of which classically constitute measures of frontal lobe executive function.[19,20] Furthermore, we observed no associations between dietary fiber intake and CERAD WLT, WRT, WLT-IC and WRT-IC, and AFT scores,although it is unclear as to what may have contributed to the differential benefits of dietary fiber on different domains of cognition based on the current scarcity of literature on the topic. Accordingly, future studies are warranted to fully elucidate the dose-response relationship between dietary fiber intake and cognitive function in older adults. This insight will enable specific dietary fiber recommendations to be devised for older adults with regard to combatting the age-related decline in cognitive function.

Our dose-response analysis revealed a tendency for a linear relationship between daily dietary fiber intake and cognitive function, with an apparent plateau in cognitive performance (DSST scores) reached at 34 grams of dietary fiber intake per day. In practical terms, this daily dose of

fiber is in excess of current recommendations for daily fiber intake. Despite the lack of experimental evidence, only dose-specific effects of fiber intake on cognitive performance have been explored. For instance, long-term administration (12 weeks) with 3.6 g/d of mixed saccharides was shown to improve immediate recall and recognition memory compared with placebo in middle-aged (45-60 years) adults,[21] while a mixture of berries enhanced working capacity after 5 weeks of consumption.[22] In contrast, the acute administration of 7 g/d mixed saccharides was shown to elicit no effect on measurements of memory compared with placebo (glucose) in middle aged adults,[23] although acute consumption of 4 g/d non-starch polysaccharides resulted in higher recognition and working memory scores.[21] The findings from these clinical trials suggest that the effects of dietary fiber intake on cognitive function may also be dependent on fiber type. This notion is supported by multiple clinical trials that demonstrate the type and fermentability of fiber may promote distinct cognitive responses, although most research has been conducted in younger cohorts.[24]

The potential mechanisms that underpin the protective effects of dietary fiber consumption on cognitive function may be attributed to gut function and specifically the gut microbiota maintaining the intestinal and blood-brain barrier integrity.[25] Gut microbiota ferments dietary fiber in the colon for the promotion of short-chain fatty acids (SCFAs) as end products. SCFAs (ie, acetate, butyrate, propionate) exert metabolic benefits via gut-brain neural circuits,[26] suggesting a role for the gut-brain axis in mediating the improvement in cognitive function with dietary fiber consumption.[24] At the mechanistic level, G protein-coupled receptors (GPR41 and GPR43) serve as SCFA receptors in intestinal epithelial and innate immune cells.[27] GPR41 and GPR43 preserve the intestinal epithelial barrier and gut microbiota homeostasis by inhibiting pro-inflammatory cytokine activation.[27] It is intuitive that a normal microbial microenvironment balance maintains the blood brain barrier, allowing brain-derived neurotrophic factor (BDNF) transportation. This response conceivably optimizes N-methyl-D-aspartate receptor (NMDAR) function as a marker of neuronal integrity in the brain that is linked with cognitive function.[28]

Preliminary evidence also exists that indigestible fiber (ie, prebiotics) may increase BDNF expression.[29,30] Clinical trials have demonstrated that supplementation with *Lactobacillus plantarum* species enhances attention, memory, and verbal learning in middle-aged adults.[31,32] In older adults with or without mild cognitive impairment, *Bifidobacterium bifidum* and *Bifidobacterium longum* species have been shown to increase serum BDNF concentrations and memory function.[33-35] It follows that the production of specific bacterial strains could underpin the changes in cognitive function and its different domains. Taken together, SCFA intake may serve as an effective dietary intervention that targets the gut-brain axis by modulating the gut microbiota environment.[36,37]

Strengths and Limitations

Our study used a large, nationally representative, dataset that has undergone rigorous quality control. In our analysis, multiple confounders were adjusted to accurately estimate the association between dietary fiber intake and cognitive function in older adults. However, this study also has several limitations. By definition, observational studies that use data from cross-sectional surveys cannot reveal a causal relationship between dependent and independent variables. Furthermore, dietary data were collected from two 24-hour dietary recall interviews and thus cannot be used to represent long-term dietary intakes. Equally, data pertained to body composition measures were not available for participants aged 60 years and older. Further studies controlling for other nutrients including fat, protein and carbohydrate intake, type of fiber (soluble and insoluble) and comorbidity status, are also warranted. Finally, NHANES uses multiple tests of cognitive performances that may not fully represent cognitive function. This issue is likely prudent because cognitive function is underpinned by multiple mental processes, and thus, more sophisticated assessment tools are warranted. For example, backward number recall may produce a greater activation of the frontal, occipital, parietal, and temporal cortices as reported in functional magnetic resonance imaging scans and may require a higher energy demand compared to forward recall.[38]

CONCLUSIONS

Dietary fiber intake is positively associated with cognitive function in a cohort of US older (>60 years) adults, as determined based on DSST score. No associations were observed between dietary fiber intake and CERAD WLT, WRT, WLT-IC and WRT-IC, and AFT scores. Public health strategies may target a sufficient intake of fiber to reduce cognitive impairments associated with advanced age. Future studies are warranted to characterize the dose-response relationship between dietary fiber intake and indices of cognitive function in older adults.

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