Original Article

Association of sleep and plant-based diet with cognitive function in older adults—Based on a national cohort study

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Background and Objectives: To explore the relationship between sleep, plant-based diets, and cognitive function in the elderly, addressing the challenges of global aging. **Methods and Study Design:** Using data from the 2005 China Longitudinal Healthy Longevity Survey (CLHLS), cognitive function was assessed with the Mini-Mental State Examination (MMSE), dietary patterns through a short-form FFQ, and sleep duration and quality via self-report measures. A Cox regression model analyzed the associations between sleep, plant-based diet, and cognitive function, with mediating effect analysis to explore these relationships further. **Results:** A total of 5911 subjects were included in the study. In both univariate and multivariate Cox regression analysis, the sleep quality with average level (HR=1.26; 95%CI=1.06-1.48), sleep duration (HR=1.03; 95%CI=1.01-1.05), the unhealthful plant-based diet index (uPDI) (HR=1.02; 95%CI=1.01-1.03), the healthful plant-based diet index (hPDI) (HR=1.01; 95%CI=1.00-1.03), and the plant-based diet index (PDI) (HR=0.99; 95%CI=0.97-1.00) were always significantly correlated with cognitive function. The sleep quality with bad level (HR=1.28; 95% CI=1.03-1.58) was associated with cognitive function only in multivariate Cox regression analysis. In the mediating analysis, PDI and hPDI had a significant overall effect on cognitive function, and the proportion mediated by sleep duration were about 4.4% (95%CI=0.01-0.15) and 7.92% (95%CI=0.03-0.25). **Conclusions:** A significant correlation exists between sleep, plant-based diets, and cognitive function in older adults, with sleep duration mediating the relationship between diet and cognitive function. These findings emphasize the role of diet and sleep in preventing cognitive decline in the elderly.

Key Words: sleep quality, sleep duration, plant-based diet, cognitive function, the elderly

INTRODUCTION

The global population is ageing significantly, with the number of people over 60 expected to double to 2.1 billion by 2050. Studying cognitive function in older adults can help identify risk factors for cognitive decline in older adults, inform public health strategies, and support the development of interventions to improve quality of life and independence in the older population.

As people live longer, they are at increased risk for cognitive impairment, which is often seen as a transitional state between normal aging and dementia.[1,2] Identifying risk factors for cognitive impairment is important for the prevention of Alzheimer's disease. Risk mitigation factors may play a role in this decline. The main recognized risk factors for cognitive impairment are age, lifestyle factors (such as smoking), psychological factors (such as depression), and chronic diseases (such as high blood pressure).[3–6]

In addition, some studies have shown that sleep quality and sleep duration are positively correlated with cognitive function,[7,8] while others have shown an inverted U-shaped correlation between sleep duration and global cognitive decline.[9]

The sleep patterns of the elderly are often changed due to physiological changes, disease effects and environmental factors,[10–13] which are manifested as decreased sleep quality, increased number of night-time awakenings, decreased deep sleep and advanced biological clock, which may affect their cognitive function and overall health.

Globally prevalent dietary patterns for the prevention of cognitive decline include the Mediterranean diet, which is prevalent mainly in Mediterranean coastal countries; The Dietary Approaches to Stop Hypertension (DASH) diet, which originated in the United States and is

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designed to prevent high blood pressure; The Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet, which combines the principles of the Mediterranean and DASH diets, is designed to delay cognitive decline. The dietary pattern in Asia is predominantly plant-based,[14] with a predominance of plant-based foods and less animal-based foods, with an emphasis on cereals, vegetables and soy products. In older adults, whole grain intake is associated with improved cognitive function as assessed by the Mini-Mental State Examination (MMSE),[15,16] and the lowest one-fifth of vegetable intake is associated with a 100% increased risk of cognitive decline compared to the highest one-fifth.[17] The Chicago Health and Aging Study showed that high vegetable intake was significantly associated with reduced cognitive decline. Those who consumed two or more servings of vegetables per day had cognitive ages comparable to those five years younger.[18] Further studies assessed the quality of plant-based diets by dividing them into the plant-based diet index (PDI), healthy plant-based diet index (hPDI), and unhealthy plant-based diet index (uPDI). In a national community cohort study conducted in China, it was found that for every 10-point increase in PDI and hPDI, the risk of cognitive impairment was reduced by 26% and 30% respectively, while for every 10-point increase in uPDI, the risk of cognitive impairment was increased by 36%.[19]

At present, there are few studies on the relationship between sleep and plant-based diet and cognitive function in the elderly. Based on the Chinese Longitudinal Healthy Longevity Survey (CLHLS) database, this study focused on individuals aged 65 and older to investigate the association between three plant-based diet patterns and cognitive impairment. The aim of this study is to investigate the potential mediating effects of sleep quality and sleep duration on the relationship between a plant-based diet and cognitive impairment in the elderly, with the aim of providing a scientific basis for cognitive health management in this population.

METHODS

Study population

The CLHLS survey has been approved by the Research Ethics Committees of Peking University and Duke University (IRB00001052-13074) and is conducted in strict accordance with the relevant ethical guidelines.

The study used data from CLHLS, a survey covering 23 provinces, municipalities and autonomous regions in China that included people aged 65 and above. The contents of the survey included health and quality of life self-assessment, cognitive function, daily activity ability, disease treatment and other aspects. The CLHLS project began with the baseline survey in 1998 (first wave), followed by subsequent follow-up surveys in 2000 (second wave), 2002 (third wave), 2005 (fourth wave), 2008-2009 (fifth wave), 2011-2012 (sixth wave), 2014 (seventh wave), and 2017-2018 (eighth wave). The investigation project has been approved by the Research Ethics Committees of Peking University and Duke University (IRB00001052-13074) and was conducted in strict accordance with relevant ethical guidelines. All subjects signed written informed consent. Since sleep-related data were first collected in the fourth wave (2005), this study used the fourth wave as the baseline. The fifth (2008), sixth (2011), seventh (2014), and eighth (2017-2018) waves are considered follow-up surveys. The fifth wave (2008), sixth wave (2011), seventh wave (2014), and eighth wave (2018) are considered follow-up. Figure 1 shows a detailed flow chart of participant selection for this study. A total of 15,638 participants participated in

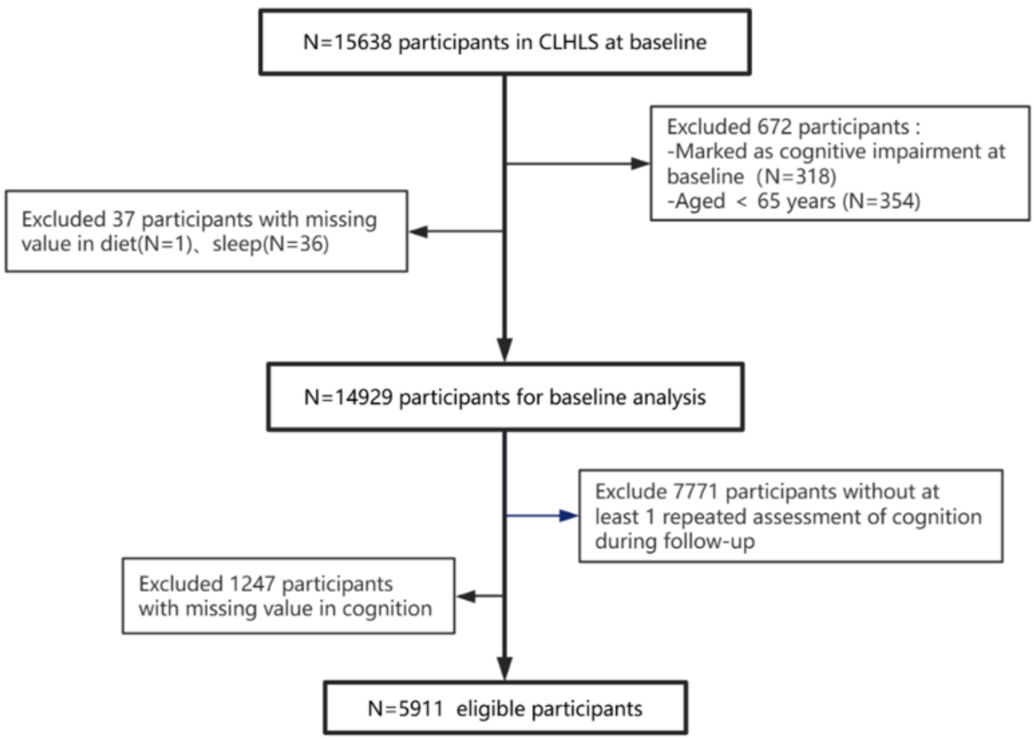

Figure 1. Flow chart of participants

the 2011 CLHLS cycle survey. Among them, at baseline, cognitive impairment (n = 318), age < 65 years (n = 354), lack of dietary information (n = 1), lack of sleep information (n = 36), failure to complete at least one follow-up (n = 7771), and failure to complete cognitive measures (n = 1247) were excluded. Finally, 5911 participants were included in the analysis. It is important to note that all data in this cohort were collected through face-to-face interviews, utilizing appropriate scales for assessing diet and cognition. Sleep-related data and other information were gathered using standardized self-report measures during these interviews.

Assessment of sleep quality and sleep duration

Sleep-related parameters were assessed through structured face-to-face interviews conducted by trained researchers. To evaluate subjective sleep quality, participants were asked, "How about the quality of your sleep?" Responses were recorded using a five-point Likert scale: Very Good, Good, Average, Poor, and Very Poor. For objective sleep duration measurement, the question "How long do you sleep normally?" was administered, with participants required to provide a numerical value in hours.

Assessment of cognitive function

The CLHLS employs the Chinese version of the MMSE to evaluate cognitive function, with scores ranging from 0 to 30. The use of MMSE in CLHLS is reliable and effective.[20] Since MMSE scores can be influenced by education level, scores of 18, 20, and 24 were used as cut-off points for subjects with no formal education, only primary education (1-6 years), and secondary or higher education (> 6 years), respectively. Subjects were classified as cognitively impaired if their MMSE score was below a specified threshold corresponding to their level of education. In addition, the duration of follow-up for everyone was from the time they entered the study to the time of first onset of cognitive impairment.

Measurement and calculation of plant-based diet

Dietary information for each participant was collected using simplified FFQ. In this study, the 12 foods included in the simplified FFQ questionnaire were divided into three categories based on their potential different health effects (Supplementary Table 1), including healthy plant foods (whole grains, fresh fruits, fresh vegetables, soy products, garlic, tea), unhealthy plant foods (refined grains, pickled vegetables, sugar), and animal foods (eggs, fish, meat). These data were used to calculate PDI, hPDI, and uPDI to assess plant-based diet quality, scoring the frequency of intake of 12 foods on a scale of 1 to 5, respectively. The animal food group scored the opposite (5 for least frequent consumption, 1 for most frequent consumption). For PDI, the plant food group scored positive (1 for least frequent consumption, 5 for most frequent consumption). For hPDI, healthy plant foods are given a positive score, while unhealthy plant foods were given a reverse score. For uPDI, healthy plant foods were scored in reverse, but unhealthy plant foods are given a positive score.

Assessment of covariates

Based on previous research, the following variables were included as covariates: age (years), sex (male or female), province (guangxi, jiangsu, henan, zhejiang, or other), education (years), ethnicity (han, zhuang, manchu, hui, or other), BMI (kg/ m^2), career (commercial, service, or industrial workers; agricultural, forestry, pastoral, or fishery workers; professional and technical personnel; domestic work or other); Smoke, drink, and exercise (current, past, or never), labor (yes or no), number of chronic diseases, marital status (cohabitation with spouse, separation, divorce, widowhood, or unmarried), age of primiparity (years), and age of last pregnancy (years).

Statistical analysis

Baseline features were described, the data are presented as frequency (percentage) and mean ± SD. For continuous variables, one-way analysis of variance (ANOVA) was used to compare the group differences among the five sleep quality groups, and the chi-square test was used to compare categorical variables. In R, the software packages "survival" and "survminer" were used to explore the relationship between sleep, plant-based diet and cognitive function in elderly people by establishing Cox regression models. Single-factor and multi-factor Cox regression analysis were carried out using “autoReg” function, and according to $p < 0.05$ control variable, stepwise regression method was used to enter the multi-factor regression model. Cox regression model was validated using cumulative hazard plot. To ensure the influence of the mediating variables on the outcome variables, regression analysis was used to assess the association between sleep and plant-based diet, testing for statistically significant associations. Finally, the “mediation” package was used to analyze the mediating effect of sleep duration and sleep quality between plant-based diet and cognitive function in the elderly. Tests were two-sided with statistical significance set as $p < 0.05$.

RESULTS

The baseline data in Table 1 were statistically described. A total of 5911 participants were included in the study, of whom 3074 were male, with a mean age of 79.95 ± 9.77 years at baseline. The proportion of sleep quality distribution was very good 840 (14.21%), good 3028 (51.23%), average 1429 (24.18%), bad 571 (9.66%), very bad 43 (0.39%), and the average sleep duration was 7.59 ± 2.36 hours. The mean values of PDI, hPDI and uPDI were 30.41 ± 4.87, 31.78 ± 4.42 and 32.66 ± 6.18, respectively. In addition, variables such as age, ethnicity, province, BMI, labor, marital status, and age at the last pregnancy had some significant differences in sleep quality among the five groups.

In the Cox regression analysis, both sleep quality with the average level (HR = 1.16; 95% CI = 1.06-1.48) and sleep duration (HR = 1.03; 95% CI = 1.01-1.05) were significantly associated with cognitive function in the elderly, in both univariate and multivariate models. Bad level of sleep quality (HR = 1.29; 95% CI = 1.04-1.59) was also linked to cognitive impairment after adjusting for variables. PDI was significantly associated with cognitive function in both models (univariate HR = 0.98;

Table 1. Characteristics of the study population at baseline

Variable	Sleep quality					*p* value
	Very good	Good	Average	Bad	Very bad	
N	840	3028	1429	571	43	
Age(years)	79.1 ±9.54	80.1 ±9.87	80.6 ±9.81	78.6 ±9.26	80.0±9.37	<0.001**
Sex, Female	355 (42.3)	1505 (49.7)	812 (56.8)	371 (65.0)	31 (72.1)	<0.001**
Ethnic						<0.001**
Han	800 (95.2)	2809 (92.8)	1295 (90.6)	537 (94.0)	41 (95.3)	
Hui	8 (1.0)	20 (0.7)	7 (0.5)	5 (0.9)	1 (2.3)	
Manchu	11 (1.3)	25 (0.8)	6 (0.4)	1 (0.2)	0 (0.0)	
Zhuang	19 (2.3)	149 (4.9)	99 (6.9)	21 (3.7)	1 (2.3)	
Other	2 (0.2)	25 (0.8)	22 (1.5)	7 (1.2)	0 (0.0)	
Province						<0.001**
Guangxi	80 (9.5)	465 (15.4)	317 (22.2)	66 (11.6)	5 (11.6)	
Henan	70 (8.3)	305 (10.1)	143 (10.0)	58 (10.2)	6 (14.0)	
Jiangsu	128 (15.2)	287 (9.5)	146 (10.2)	44 (7.7)	2 (4.7)	
Zhejiang	77 (9.2)	351 (11.6)	123 (8.6)	52 (9.1)	3 (7.0)	
Other	485 (57.7)	1620 (53.5)	700 (49.0)	351 (61.5)	27 (62.8)	
Smoke						<0.001**
Current	229 (27.3)	782 (25.8)	278 (19.5)	119 (20.8)	7 (16.3)	
Never	452 (53.8)	1787 (59.0)	924 (64.7)	374 (65.5)	28 (65.1)	
Past	159 (18.9)	459 (15.2)	227 (15.9)	78 (13.7)	8 (18.6)	
Drink						<0.001**
Current	222 (26.4)	762 (25.2)	290 (20.3)	101 (17.7)	3 (7.0)	
Never	496 (59.0)	1875 (61.9)	960 (67.2)	408 (71.5)	30 (69.8)	
Past	122 (14.5)	391 (12.9)	179 (12.5)	62 (10.9)	10 (23.3)	
Exercise						<0.001**
Current	452 (53.8)	1110 (36.7)	437 (30.6)	189 (33.1)	15 (34.9)	
Never	318 (37.9)	1560 (51.5)	799 (55.9)	311 (54.5)	22 (51.2)	
Past	70 (8.3)	358 (11.8)	193 (13.5)	71 (12.4)	6 (14.0)	
Labor, No	172 (20.5)	513 (16.9)	269 (18.8)	83 (14.5)	7 (16.3)	0.03
Education(years)	4.16±4.07	3.46 ±3.74	3.42 ±4.01	3.35 ±4.04	2.81 ±3.75	<0.001**
Career						<0.001**
Agricultural, forestry, pastoral or fishery workers	419 (49.9)	1940 (64.1)	903 (63.2)	357 (62.5)	26 (60.5)	
Commercial, service or industrial worker	184 (21.9)	460 (15.2)	207 (14.5)	91 (15.9)	2 (4.7)	
Houseworker	48 (5.7)	204 (6.7)	105 (7.3)	49 (8.6)	9 (20.9)	
Professional and technical personnel	56 (6.7)	168 (5.5)	73 (5.1)	27 (4.7)	3 (7.0)	
Other	133 (15.8)	256 (8.5)	141 (9.9)	47 (8.2)	3 (7.0)	
Marital status						0.02*
Currently married and living with spouse	414 (49.3)	1322 (43.7)	587 (41.1)	246 (43.1)	13 (30.2)	
Separated	20 (2.4)	78 (2.6)	33 (2.3)	17 (3.0)	0 (0.0)	
Divorced	7 (0.8)	15 (0.5)	7 (0.5)	6 (1.1)	0 (0.0)	
Widowed	391 (46.5)	1592 (52.6)	787 (55.1)	300 (52.5)	29 (67.4)	
Never married	8 (1.0)	21 (0.7)	15 (1.0)	2 (0.4)	1 (2.3)	
Age of primiparity(years)	24.1 ±5.08	23.8 ±4.85	24.1±5.06	23.7 ±4.97	24.0 ±5.48	0.33
Age at last pregnancy (years)	36.8 ±6.34	37.2 ±6.41	37.1 ±6.32	36.6 ±5.91	37.6 ±6.30	0.09
Sleep duration(hours)	8.55 ±2.35	8.14 ±2.10	6.91 ±2.08	5.16 ±2.04	4.42 ±2.20	<0.001**
PDI	34.9 ±5.12	34.2±4.77	34.0±4.63	34.3±4.79	35.2±5.09	<0.001**
uPDI	30.8 ±6.24	32.4 ±5.97	33.3 ±6.07	34. 6 ±6.54	37.6 ±5.93	<0.001**
hPDI	32.0 ±4.64	31.7 ±4.39	31.8 ±4.36	32.0 ±4.40	32.3 ±4.20	0.12
BMI(kg/m^2)	21.8±4.46	20.8 ±4.09	20.22±4.14	20.3± 3.89	20.3±4.34	<0.001**
Number of chronic diseases	0.79 ±1.03	0.78 ±1.09	1.02 ±1.31	1.29 ±1.39	1.40 ±1.66	<0.001**

PDI: the plant-based diet index; hPDI: the healthful plant-based diet index; uPDI: the unhealthful plant-based diet index.
**p*<0.05, ***p*<0.01, ****p*<0.001.

95% CI = 0.97-0.99; multivariate HR = 0.99; 95% CI = 0.97-1.00). uPDI and hPDI were associated with the risk of cognitive decline, with hPDI showing a HR of 0.99 (95% CI = 0.98-1.00) in univariate analysis and HR = 1.01 (95% CI = 1.00-1.03) in multivariate analysis. Among covariates, age (HR = 1.05; 95% CI = 1.05-1.06) remained significant in both univariate and multivariate analyses. Female, never smoke or drink, education and commercial, service or industrial worker were significant in the univariate analysis, but not in the multivariate analysis (Table 2.). Additionally, a cumulative hazard plot confirmed the applicability of the model (Figure 2).

Table 2. Univariable and multivariable Cox regression analysis

	All	HR (univariable)	HR (multivariable)	HR (final)
Sleep quality				
Very good	840 (14.2)			
Good	3028 (51.2)	1.14 (0.99-1.32, *p*=0.07)	1.10 (0.95-1.28, *p*=0.20)	1.11 (0.95-1.28, *p*=0.18)
Average	1429 (24.2)	1.28 (1.09-1.51, *p*<0.05)	1.25 (1.06-1.48, *p*=0.01)	1.26 (1.06-1.48, *p*=0.01)
Bad	571 (9.7)	1.10 (0.90-1.34, *p*=0.34)	1.28 (1.03-1.58, *p*=0.02)	1.29 (1.04-1.59, *p*=0.02)
Very bad	43 (0.7)	0.92 (0.55-1.55, *p*=0.75)	1.16 (0.68-1.98, *p*=0.59)	1.16 (0.68-1.99, *p*=0.58)
Sleep duration(hours)	7.59 ± 2.4	1.05 (1.03-1.07, *p*<0.001)	1.03 (1.01-1.06, *p*<0.05)	1.03 (1.01-1.05, *p*<0.05)
PDI	34.3 ± 4.8	0.98 (0.97-0.99, *p*<0.001)	0.99 (0.97-1.00, *p*=0.02)	0.99 (0.97-1.00, *p*=0.02)
uPDI	32.7 ± 6.2	1.02 (1.01-1.02, *p*<0.001)	1.02 (1.01-1.03, *p*<0.001)	1.02 (1.01-1.03, *p*<0.001)
hPDI	31.8 ± 4.4	0.99 (0.98-1.00, *p*=0.01)	1.01 (1.00-1.03, *p*=0.03)	1.01 (1.00-1.03, *p*=0.04)
Number of chronic diseases	1.0 ± 1.2	0.99 (0.95-1.02, *p*=0.44)		
Age	79.9 ± 9.8	1.05 (1.05-1.06, *p*<0.001)	1.05 (1.05-1.06, *p*<0.001)	1.05 (1.05-1.06, *p*<0.001)
Sex				
Male	2837 (48.0)			
Female	3074 (52.0)	1.21 (1.10-1.34, *p*<0.001)	1.06 (0.93-1.20, *p*=0.39)	
Ethnic				
Han	5482 (92.7)			
Hui	41 (0.7)	0.86 (0.48-1.56, *p*=0.62)		
Manchu	43 (0.7)	1.07 (0.62-1.84, *p*=0.82)		
Other	56 (0.9)	1.08 (0.65-1.79, *p*=0.77)		
Zhuang	289 (4.9)	1.07 (0.86-1.33, *p*=0.55)		
Smoke				
Current	1415 (23.9)			
Never	3565 (60.3)	1.36 (1.20-1.53, *p*<0.001)	1.14 (0.99-1.31, *p*=0.07)	1.17 (1.03-1.32, *p*=0.01)
Past	931 (15.8)	1.22 (1.03-1.44, *p* =0.02)	1.21 (1.01-1.44, *p*=0.04)	1.17 (0.99-1.39, *p*=0.07)
Drink				
Current	1378 (23.3)			
Never	3769 (63.8)	1.15 (1.02-1.29, *p*=0.02)	0.98 (0.86-1.12, *p*=0.77)	
Past	764 (12.9)	1.04 (0.87-1.23, *p*=0.68)	0.91 (0.76-1.08, *p*=0.29)	
Labor				
Yes	4867 (82.3)			
No	1044 (17.7)	1.01 (0.89-1.15, *p*=0.83)		
Education(years)	3.5 ± 3.9	0.98 (0.96-0.99, *p*<0.001)	1.01 (0.99-1.03, *p*=0.19)	1.01 (1.00-1.03, *p*=0.07)

PDI: plant-based diet index; hPDI: healthful plant-based diet index; uPDI: unhealthful plant-based diet index

Table 2. Univariable and multivariable Cox regression analysis (cont.)

	All	HR (univariable)	HR (multivariable)	HR (final)
Career				
Agricultural, forestry, pastoral or fishery workers	3645 (61.7)			
Commercial, service or industrial worker	944 (16.0)	0.81 (0.70-0.94, *p*=0.01)	0.96 (0.82-1.12, *p*=0.61)	
Houseworker	415 (7.0)	1.17 (0.99-1.38, *p*=0.07)	1.02 (0.86-1.20, *p*=0.86)	
Other	580 (9.8)	0.86 (0.72-1.03, *p*=0.10)	0.95 (0.79-1.15, *p*=0.63)	
Professional and technical personnel	327 (5.5)	0.94 (0.75-1.18, *p*=0.58)	1.12 (0.86-1.47, *p*=0.39)	
BMI	20.7 ± 4.2	0.97 (0.96-0.98, *p*<0.001)		
Age of primiparity	12.9 ± 4.9	1.00 (0.99-1.01, *p*=0.37)		
Age at last pregnancy	22.1 ± 6.3	1.02 (1.01-1.03, *p*<0.001)	0.99 (0.99-1.00, *p*=0.19)	0.99 (0.99-1.00, *p*=0.13)

PDI: plant-based diet index; hPDI: healthful plant-based diet index; uPDI: unhealthful plant-based diet index

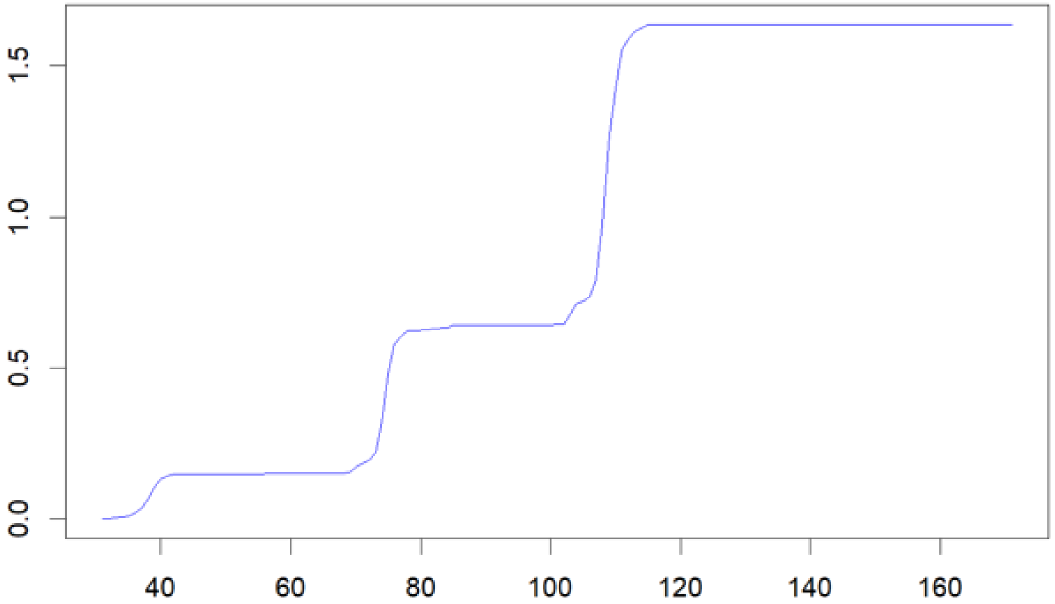

Figure 2. Cumulative hazard plot was used to test the applicability of the cox regression model

Linear regression was used to examine the relationship between plant-based diet and sleep duration, in which uPDI and hPDI had significant effects on sleep duration (p <0.001). Ordinal logistic regression was used to examine the relationship between plant-based diet and sleep quality. hPDI and uPDI had a positive effect on sleep quality (p <0.001) but PDI had a negative effect on sleep quality (p <0.001).

To assess the total and direct effects of PDI and hPDI on cognitive function in the elderly, as well as the indirect effects mediated by sleep quality and sleep duration, the results of the mediation analysis indicate that both PDI and hPDI have significant total effects on cognitive function, with part of these effects mediated by sleep duration. The proportion of the total effect mediated by intermediate variables was approximately 4.4% (95% CI = 0.009–0.15) and 7.9% (95% CI = 0.03–0.25), both of which were statistically significant (Table 3). Following the application of the Bonferroni correction, the influence of PDI was found to be significant in both the mediation model and the outcome model (p <0.001).

DISCUSSION

A total of 5,911 participants were included in the study, with 52% male and a mean age of 79.9 years. This indicates that the study sample covered a broad age range within the elderly population, with a relatively concentrated age distribution. Sleep quality (average level), sleep duration, PDI, uPDI, and hPDI were all significant in both univariate and multivariate Cox regression analyses. After adjusting for covariates, poor sleep quality was significantly associated with cognitive function in older adults. Additionally, part of the total effect of PDI and hPDI on cognitive function in the elderly was mediated by sleep duration. These findings suggest that a plant-based diet influences cognitive function by affecting sleep quality and duration.

The distribution of sleep quality reveals that most elderly individuals report having a good level of sleep quality (including very good, good, and average), although a certain proportion experience poor sleep quality (including bad and very bad). The average sleep duration was 7.59 hours, which is consistent with the generally recommended sleep duration for older adults.[22] The relationship between sleep quality and cognitive function has been confirmed by a number of studies. Sleep disorders contribute to neurodegeneration by influencing neural pathways, neuroinflammatory factors, and neuroplasticity, ultimately affecting cognitive function.[23,24] The mean values of PDI, hPDI and uPDI show that the intake of plant food in the elderly was 34.3, 31.8 and 32.7, respectively. This suggests that overall plant-based food intake, as measured by PDI, was higher compared to both hPDI and uPDI, which reflected a broader dietary pattern encompassing both healthy and unhealthy plant foods. The slight difference between hPDI and uPDI suggests that although the elderly population in this sample consumed a considerable amount of plant foods, there is a notable proportion of unhealthy plant-based foods in their diet. These findings highlight the complexity of plant-based diets and suggest that future interventions or dietary recommendations should aim to promote healthier plant food choices to optimize the overall diet quality of older adults.

In Cox regression analyses, older adults with average level and bad level of sleep quality showed significantly increased risk of cognitive decline, compared with those with good level or very bad level of sleep quality. The relationship between sleep duration and cognitive function was significant in both univariate and multivariate analyses, with each 1-hour increase in sleep duration associated with a 1.03-fold increased risk of cognitive decline. This is consistent with previous findings,[25] The effect of sleep duration on cognitive function plays a role by influencing memory consolidation and neurotransmitter concentrations,[26] suggesting that sleep quality is a potential risk factor for cognitive decline.

In both univariate and multivariate Cox regression analyses, PDI, uPDI, and hPDI were all associated with the risk of cognitive decline, suggesting that different aspects of a plant-based diet have varying effects on cognitive function. These findings are consistent with the results of previous studies.[27,28] uPDI typically includes plant-based foods that are high in sugar, salt, and fat, such as salted or sugared vegetables, which may negatively impact cognitive health. In contrast, hPDI represents a healthy plant-based diet, emphasizing fresh fruits and vegetables, whole grains, legumes, and other minimally processed or unprocessed plant-based foods. These foods are rich in antioxidants, fiber, and healthy fats, which

Table 3. The mediating effect of sleep duration on the relationship between PDI, hPDI and cognitive function

	Estimate	95%CI lower	95%CI upper	*p* value
PDI				
ACME	-0.0002	-0.0003	0.00	0.01*
ADE	-0.004	-0.006	0.00	<0.05*
Total Effect	-0.004	-0.006	0.00	<0.05*
Prop. Mediated	0.044	0.009	0.15	<0.05*
hPDI				
ACME	-0.0003	-0.0005	0.00	<0.001***
ADE	-0.004	-0.006	0.00	<0.05*
Total Effect	-0.004	-0.006	0.00	<0.05*
Prop. Mediated	0.079	0.03	0.25	<0.05*

PDI: plant-based diet index; hPDI: healthful plant-based diet index; uPDI: unhealthful plant-based diet index

†ACME represents indirect effect, ADE is direct effect, TOTAL effect is total effect, Prop. Mediated is the proportion of indirect effect to total effect.

**p*<0.05, ***p*<0.01, ****p*<0.001

have been shown to have positive effects on brain health. Although hPDI is beneficial for overall health, its impact on cognitive function may be more moderate, or its effects may be influenced by other factors such as overall dietary patterns, nutritional balance, and individual differences. It is worth mentioning that age at last pregnancy was significantly associated with cognitive function in the elderly in univariate cox regression analysis, but not in multivariate cox regression analysis.

Age remained significant in both univariate and multivariate analyses, which is consistent with the general perception that cognitive function declines with age.29,30 Female, never smoking or drinking, education level were significant in the univariate analysis but not in the multivariate analysis, the effect of these variables may be masked by other variables, or their relationship with cognitive function is indirect. Studies have shown that postmenopausal women's hormone levels, higher education level, greater knowledge reserve, and good living habits have an impact on cognitive function.[31–33]

Sleep duration plays a mediating role in the relationship between plant-based diet and cognitive function in the elderly. A plant-based diet is rich in antioxidants, fiber, and essential fatty acids, all of which have a positive effect on improving sleep quality. For example, tryptophan, an essential amino acid found in many plant foods, is a precursor to the synthesis of melatonin, a key hormone that regulates sleep. In turn, good sleep quality and adequate sleep duration are crucial for consolidating memory and enhancing cognitive function. The proportion of the effect mediated by sleep quality and sleep duration is small, but it is statistically significant.

Lastly, this study has some limitations. The data were all collected through standardized self-reported measures, which may introduce recall bias and subjectivity, potentially influencing the study's results.

Conclusion

Based on CLHLS data, sleep quality with average level, sleep duration, uPDI and hPDI were all significant in univariate and multivariate Cox regression analysis. Sleep and plant-based diet affects cognitive impairment in the elderly. Meanwhile, sleep duration plays a mediating role in the association between PDI and hPDI and cognitive impairment. In the process of actively facing aging, cognitive function decline in the elderly can be prevented and controlled by adjusting sleep quality, sleep duration and diet structure.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURES

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Supplementary Table 1. Plant-based diet index scoring

Food groups	Frequency	PDI	hPDI	uPDI
Plant-based food				
Healthful				
Whole grain	Yes	5	5	1
	No	1	1	5
Vegetable	Almost everyday	5	5	1
	Except winter	4	4	2
	Occasionally	2	2	4
	Rarely or never	1	1	5
Fresh Fruits	Almost everyday	5	5	1
	Except winter	4	4	2
	Occasionally	2	2	4
	Rarely or never	1	1	5
Legumes	Almost everyday	5	5	1
	Occasionally	3	3	3
	Rarely or never	1	1	5
Tea	Almost everyday	5	5	1
	Occasionally	3	3	3
	Rarely or never	1	1	5
Garlic	Almost everyday	5	5	1
	Occasionally	3	3	3
	Rarely or never	1	1	5
Unhealthful				
Sugar	Almost everyday	5	1	5
	Occasionally	3	3	3
	Rarely or never	1	5	1
Preserved vegetables	Almost everyday	5	1	5
	Occasionally	3	3	3
	Rarely or never	1	5	1
Refined grains	Yes	5	1	5
	No	1	5	1
Animal-based food				
Eggs	Almost everyday	1	1	1
	Occasionally	3	3	3
	Rarely or never	5	5	5
Meat	Almost everyday	1	1	1
	Occasionally	3	3	3
	Rarely or never	5	5	5
Fish	Almost everyday	1	1	1
	Occasionally	3	3	3
	Rarely or never	5	5	5