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A Battery of Tests for Assessing Cognitive Function in U.S. Chinese Older Adults—Findings From the PINE Study

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Background. Existing methodological challenges in aging research has dampened our assessment of cognitive function among minority older adults. We aim to report the composite scores of five cognitive function tests among U.S. Chinese older adults, and examine the association between cognitive function and key sociodemographic characteristics.

Methods. The Population Study of Chinese Elderly in Chicago Study enrolled an epidemiological cohort of 3,159 community-dwelling Chinese older adults. We administered five cognitive function tests, including the Chinese Mini-Mental State Examination, the immediate and delayed recall of the East Boston Memory Test, the Digit Span Backwards assessment, and the Symbol Digit Modalities Test. We used Spearman correlation coefficients to examine the correlation between cognitive function and sociodemographic variables. Linear regression models were used to report the effect of sociodemographic and health variables including age, sex, education on cognitive function.

Results. Our multivariate analysis suggested that performance in each domain of cognitive function was inversely associated with age and positively related to education. With respect to sex, after adjusted for age, education and all key variables presented in the model, being male was positively related to global cognitive score and working memory. Being married, having fewer children, having been in the United States for fewer years, having been in the community for fewer years, and better self-reported health were positively correlated with all cognitive function domains.

Conclusions. This population-based study of U.S. Chinese older adults is among the first to examine a battery of five cognitive function tests, which in aggregate enables researchers to capture a wide range of cognitive performance.

Key Words: Cognitive function—Chinese aging—PINE study.

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WITH the rapid growth of the global aging population, especially the oldest old, cognitive impairment has become a pervasive public health issue. In the United States, population-based studies suggest that age-related cognitive impairment affects 17%–34% of community-dwelling older adults (1). The demographic shift will likely increase the prevalence of age-related cognitive impairment, place considerable demands on the U.S. health care system, and impose physical, psychological, and financial stress on patients, their caregivers, and family members (2).

U.S. Chinese aging population is one of the fastest growing subpopulations of older adults in the country. The life expectancy of U.S. Chinese older adults is in the mid 80s (3). Given the prevalence of cognitive impairment increasing with age, we can expect a growing demand for geriatric care in Chinese Americans. However, the prevalence of cognitive impairment is relatively underresearched among U.S. Chinese older adults due to the lack of large scale population-based studies examining the prevalence of cognitive impairment and related clinical diagnosis including dementia or Alzheimer's disease. Despite the data gap, research suggests that there is evidence to believe that Asian Americans should have the same rates or even higher than that of Caucasian older adults (4,5).

In addition, some methodological challenges may have dampened our systematic assessment of cognitive function among Chinese older adults and to make sensible comparisons with other racial/ethnic populations. First, there was a lack of population-based studies which administered a cognitive battery of tests to measure cognitive function and change in different cognitive abilities among Chinese older adults. Cognitive impairment of older adults is not limited to memory, but reflects a host of different definitions, including impairments in language, visual, or spatial awareness, and attention. Multiple measures of each ability may be valuable in reporting different cognitive abilities.

Second, since individual differences found at baseline are likely to become more pronounced over time, forming composite cognitive measures allows researchers to combine tests of various difficulty levels to reflect a wider range of cognitive performance (6,7). The use of standard score, or *z* score, has the statistical advantage of increasing power by reducing random variability present within different tests that accommodate a wide range of cognitive function performance, and has been widely reported in population-based epidemiological studies of U.S. older adults (6,8). Whereas recent studies have further identified the use of composite scores to better demonstrate performance characteristics in studies of cognitive impairment compared with other scoring methods (9), such reports remain scare among Chinese American older adults.

Third, the paucity of data on cognitive impairment can largely be attributed to the absence of culturally and linguistically sensitive instruments to screen and diagnose cognitive impairment among this population (10). There existed a number of measure developed and adapted for use in different cultures and for multiple languages, such as the Cognitive Abilities Screening Instrument (11) or the Cross-Cultural Neuropsychological Battery (12). Despite these tests have been piloted among groups of Chinese Americans, the sample size was small, and the majority of items were taken from a few screening scale which may be limited to measure a wide range of cognitive performances.

Apart from existing methodological challenges, culturally specific perceptions, beliefs, and negative affects relating to cognitive impairment further present challenges to engaging Chinese American older adults to research studies (13), leaving Chinese older adults underrepresented in clinical studies, especially studies of cognitive impairment (14). As a result, we have incomplete knowledge on the scope of cognitive impairment and the effect of sociodemographic characteristics on the cognitive function among community-dwelling U.S. Chinese older adults, which is critical in informing culturally sensitive prevention strategies in the aging population.

To fill in the knowledge void, in the current study, we adapted a battery of five tests for use with Chinese American older adults. These tests, including the Chinese Mini-Mental State Exam (C-MMSE), East Boston Memory Test (EBMT)-Immediate Recall, EBMT-Delayed Recall, Digit Span Backwards assessment, and Symbol Digit Modalities Test, have been validated and widely used among English-speaking and Spanish-speaking older adults in the United States (6,15). The objectives of this report is to: (i) describe cognitive function in an older U.S. Chinese populations using five cognitive function tests, (ii) explore the sociodemographic and self-reported health correlates of cognitive function, and (iii) describe the effect of key sociodemographic variables including age, sex, education on cognitive function.

Methods

Population and Settings

The Population Study of Chinese Elderly in Chicago (PINE) is a community-engaged, population-based epidemiological study of U.S. Chinese older adults aged 60 and older in the Greater Chicago area. Briefly, the purpose of the PINE study is to collect community-level data of U.S. Chinese older adults to examine the key cultural determinants of health and well-being. The project was initiated by a synergistic community–academic collaboration among the Rush Institute for Healthy Aging, Northwestern University Medical Center, and many community-based social services agencies and organizations throughout the Greater Chicago area. In order to ensure study relevance and enhance community participation, the PINE study implemented extensive culturally and linguistically appropriate community recruitment strategies guided by a community-based participatory research approach (16,17). Eligibility criteria for the PINE study included older adults aged 60 and older, who self-identified as Chinese, and reside in the Greater Chicago Area.

Our research team implemented a targeted community-based recruitment strategy by first engaging community centers as our main recruitment sites throughout the greater Chicago area. We also adopted additional outreach efforts through newspapers advertisement, flyers, educational workshops, and word of mouth. These service centers were not merely social services agencies, but also cultural hubs for Chinese people which draw in Chinese families throughout the area. Out of 3,542 eligible older adults approached in the Greater Chicago area, 3,159 agreed to participate in the study, yielding a response rate of 91.9%. Details of the PINE study have been described elsewhere (18). Participants were surveyed by bilingual research assistants in the participant's preferred language and dialect. Based on available data drawn from the U.S. Census 2010 and a random block census project conducted in the Chinese community in Chicago, the PINE study is representative of the Chinese aging population in the Greater Chicago area, with respect to key attributes including age, sex, education, income, number of children, and country of origin (19). The study was approved by the Institutional Review Board of the Rush University Medical Center.

Measurements

Assessment of cognitive function.—We administered a battery of five cognitive function tests. The MMSE is a 30-item measure of global cognition (20) widely used in epidemiological studies (21,22). In the current study, we administered the C-MMSE scale that has been validated in Chinese aging populations with good reliability and validity (23). Episodic memory was assessed using summarized scores of immediate recall (EBMT-Immediate Recall) and delayed recall (EBMT-Delayed Recall) of brief stories in the EBMT (range 0–24) (24). Executive function was assessed using the oral version of the 11-item Symbol Digit Modalities Test (25). Symbol Digit Modalities Test calls for rapid perceptual comparisons of numbers and symbols during the 90-second duration of the test (range in this study:

0–80). The Digit Span Backwards assessment, drawn from the Wechsler Memory Scale-Revised, was administered to test working memory (26).

To assess global cognitive function with minimal floor and ceiling artifacts, we constructed a composite measure for global cognition based on all five tests. A composite score for global cognitive function was calculated by first transforming a participant's score on each cognitive test to a *z* score based on the mean and standard deviation of the distribution of the scores of all participants on that test, and then averaging *z* scores across tests. This procedure has the advantage of increasing power by reducing random variability present within tests. In addition, it produces a composite score that is approximately normally distributed (27,28).

Adaptation of measures into Chinese.—The original English versions of the instruments were first translated into Chinese by a bilingual research team. Due to the vast linguistic diversity of our study population, the Chinese version was then back translated by bilingual and bicultural investigators fluent in Chinese dialects (eg, Mandarin, Cantonese) to confirm consistency in the meaning of the Chinese version with the original English version. Both traditional and simplified Chinese characters were subsequently examined. An experienced bilingual and bicultural geriatrician then reviewed the wording of the Chinese versions with a group of community stakeholders. In order to ensure validity, community stakeholders met regularly in the project preparation phase to ascertain that the meanings of the items in the instruments were adequately understood by Chinese older adults.

Sociodemographic characteristics.—Sociodemographic profile characteristics included age, education, personal annual income, marital status, number of children, living arrangement, language preference, country of origin, years in the United States, and years in the community. Overall health status was measured by asking participants, "In general, how would you rate your health?" on a four-point scale. Quality of life was assessed by asking, "In general, how would you rate your quality of life?" on a four-point scale. Health changes over the last year was measured with the question, "Compared to one year ago, how would you rate your health now?" on a three-point scale.

Data analysis.—Descriptive characteristics were provided for the total cohort. We then calculated the mean and standard deviation of each of the five cognitive function tests. Spearman correlation coefficients were calculated to determine the relationships between sociodemographic and health-related variables with the continuous and composite score of each cognitive test. Based on the results of bivariate analysis, we then preformed multivariate analysis using linear regression models to report the effect of sociodemographic and health-related variables on composite measure of function by cognitive domain. We used SAS, Version 9.2 for all statistical analyses (SAS Institute Inc., Cary, NC).

Results

Participants

Of the 3,159 participants enrolled in the PINE study, 58.9% were female. Participants had a mean age of 72.8 (*SD* ± 8.3), with age ranging from 60 to 105 years old. The mean years of education completed was 8.7 (*SD* ± 5.1). Participants resided in the United States an average of 20.0 years (*SD* ± 13.2) and the majority emigrated from Mainland China (92.8%). With respect to language preferences, 75.7% of the participants preferred to speak in Cantonese or Toishanese dialects, 22.4% preferred Mandarin, and 2.2% preferred English.

Mean and Standard Deviation of Each Test

The mean and standard deviation of each cognitive function test used in the analyses are presented in Table 1. The mean score for C-MMSE was 22.8 (*SD* ± 5.4). The mean scores for EBMT-Immediate Recall and EBMT-Delayed Recall were 7.4 (*SD* ± 2.7) and 7.0 (*SD* ± 3.0), respectively. The mean score for DB was 5.0 (*SD* ± 2.4), and 29.6 (*SD* ± 12.1) for Symbol Digit Modalities Test. C-MMSE had a negative skewed distribution; the remaining four were roughly symmetric.

Summary Measures of Each Test

Summary measures for various domains of cognitive function are listed in Table 2. Summary measures of each of the five tests were formed by converting raw scores on each component test to *z* scores using the mean and standard deviation of the score, and then averaging the *z* scores of the tests in each domain (29,30). None of the participants achieved the minimum or the maximum possible composite score on the five composite domain measures, indicating that the measures can accommodate wide individual differences in ability. All composite scores were approximately normally distributed. We further constructed a composite

Table 1. Domains of Cognitive Testing in a Community-Dwelling Population of U.S. Chinese Older Adults

Cognitive Test	Total Number	Mean	*SD*	Skew
C-MMSE	3,116	22.8	5.4	−1.3
EBMT	3,108	7.4	2.7	−0.7
EBDR	3,092	7.0	3.0	−0.8
DB	3,111	5.0	2.4	0.6
SDMT	2,555	29.6	12.1	0.2

Notes: C-MMSE = Chinese Mini-Mental State Exam; DB = Digit Span Backwards; EBDR = East Boston Memory Test-Delayed Recall; EBMT = East Boston Memory Test-Immediate Recall; SDMT = Symbol Digit Modalities Test.

Table 2. Characteristics of Cognitive Domains in a Community-Dwelling Population of U.S. Chinese Older Adults

Cognitive Domain	Mean	*SD*	Score Range	Skew
Global cognitive score	−0.002	0.86	−2.8 to 2.0	−0.6
Episodic memory	−0.005	0.97	−2.7 to 1.3	−0.7
Working memory	0.00	1.00	−2.1 to 2.9	0.55
Perceptual speed	0.00	1.00	−2.4 to 4.2	0.17

Note: Each cognitive function test is the mean of the *z* scores.

measure for global cognition based on all five tests. The composite measure ranged between −2.8 and 2.0 in the current study sample.

Correlation Between Domains of Cognitive Function, Sociodemographic and Health Variables

Specifically, younger age ($r = -.33$, $p < .001$), being male ($r = -.14$, $p < .001$), higher levels of education ($r = .59$, $p < .001$), higher levels of income ($r = .05$, $p < .01$), being married ($r = .23$, $p < .001$), living with more household members ($r = .07$, $p < .001$), having fewer children ($r = -.37$, $p < .001$), having been in the United States for fewer years ($r = -.12$, $p < .01$), and having been in the community for fewer years ($r = -.12$, $p < .01$) were significantly correlated with higher global cognitive function scores (Table 3). Similar trends were observed with respect to specific cognitive function domains, although the correlation between working memory (Digit Backwards Span) and income and between working memory and living arrangement were not statistically significant.

With respect to self-reported health status, having better overall health status ($r = .14$, $p < .001$) and better quality of life ($r = .10$, $p < .001$) were correlated with higher global cognitive function score. Similar trends were reported for all cognitive domain scores. Health change over the last year was positively correlated with higher composite scores in perceptual speed ($r = .06$, $p < .01$) and working memory ($r = .04$, $p < .05$), but the correlations were not statistically significant with respect to global cognitive score, episodic memory, and C-MMSE composite score. Correlations among five cognitive function domains were statistically significant ($p < .001$).

Effect of Key Sociodemographic and Health Variables on Cognitive Impairment

We then examined the effects of sociodemographic and health variables on cognitive function in multivariate analysis. We included all the above independent variables in a single model that were found to be significant in the bivariate correlation analysis (Table 4). Our results show that age was inversely related to all cognitive function domains. For every 1 year increase in age, the global cognitive function score decreased by 0.030. With respect to specific domains in cognitive function, for every 1 year increase in age, C-MMSE *z* score decreased by 0.038, perceptual speed

Table 3. Spearman Correlations Between Composite Scores of Cognitive Function Domains and Sociodemographic Variables Among Community-Dwelling U.S. Chinese Older Adults

	Age	Sex	Education	Income	MS	Living	Children	Years in United States	Years in Com	Origin	OHS	QOL	HC	GlobCog	SDMTZ	Episodic	DBZ	MMSEZ
GlobCog	−0.33***	−0.14***	0.59***	0.05**	0.23***	0.07***	−0.37***	−0.12***	−0.12***	−0.10***	0.14***	0.10***	0.03	1.0				
SDMTZ	−0.35***	−0.13***	0.55***	0.04*	0.22***	0.07***	−0.37***	−0.13***	−0.12***	−0.11***	0.16***	0.10***	0.06**	0.80***	1.0			
Episodic	−0.28***	−0.08***	0.47***	0.05**	0.18***	0.07***	−0.30***	−0.10***	−0.13***	−0.07***	0.12***	0.11***	0.02	0.92***	0.80***	1.0		
DBZ	−0.22***	−0.20***	0.50***	0.02	0.20***	0.03	−0.28***	−0.10***	−0.06***	−0.09***	0.12***	0.05**	0.04*	0.72***	0.60***	0.46***	1.0	
C-MMSEZ	−0.31***	−0.14***	0.55***	0.07***	0.24***	0.06**	−0.34***	−0.09***	−0.09***	−0.07***	0.13***	0.08***	0.03	0.95***	0.67***	0.91***	0.57***	1.0

Notes: Children = number of children; C-MMSEZ = C-MMSE composite score; DBZ = Digit Backwards composite score; Episodic = East Boston Memory Test and delayed recall score; GlobCog = global cognitive score; HC = health changes over last year; Living = living arrangement; LP-CT = language preference of Cantonese and Taishanese; MS = marital status; OHS = overall health status; Origin = country of origin; QOL = quality of life; SDMTZ = Symbol Digit Modality Test composite score; Years in com = years in the community.

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table 4. Relationship and Estimated Slope Between Sex, Age, Education, and Other Key Sociodemographic Variables on Cognitive Domain Among Community-Dwelling U.S. Chinese Older Adults

Estimated Slope (*SE*)	Age	Sex	Education	Income	MS	Living	Children	Years in United States	Years in Com	Origin	OHS	QOL	HC
Global cognitive score (*N* = 3,056)	−0.030	0.059	0.082	0.019	0.055	−0.022	−0.040	0.002	−0.002	−0.078	0.096	0.075	−0.033
	(0.002) ***	(0.025)*	(0.003) ***	(0.011)	(0.090)	(0.007)**	(0.009)***	(0.001)	(0.001)	(0.047)	(0.016)***	(0.019)***	(0.016)*
Perceptual speed (*N* = 2,524)	−0.034	0.045	0.090	0.036	0.054	−0.021	−0.070	0.000	−0.002	−0.152	0.127	0.046	−0.007
	(0.002)***	(0.033)	(0.003) ***	(0.014)*	(0.039)	(0.009)*	(0.012)***	(0.002)	(0.002)	(0.029)*	(0.021)***	(0.025)	(0.022)
Episodic memory (*N* = 3,057)	−0.031	−0.016	0.075	0.017	0.043	−0.011	−0.037	0.004	−0.005	−0.027	0.085	0.111	−0.035
	(0.002)***	(0.032)	(0.003)***	(0.014)	(0.038)	(0.008)	(0.011) **	(0.002)*	(0.002)**	(0.059)	(0.021)***	(0.024)***	(0.021)
Working memory (*N* = 3,064)	−0.020	0.192	0.083	0.013	0.044	−0.035	−0.036	−0.002	0.001	−0.153	0.093	0.041	−0.033
	(0.002)***	(0.033)***	(0.003)***	(0.015)	(0.039)	(0.009)***	(0.012) **	(0.002)	(0.002)	(0.061)**	(0.021)***	(0.024)	(0.022)
C-MMSE *Z* score (*N* = 3,063)	−0.038	0.056	0.087	0.013	0.088	−0.030	−0.031	0.004	−0.001	0.024	0.113	0.068	−0.028
	(0.002)***	(0.031)	(0.003)***	(0.013)	(0.036)*	(0.008)***	(0.011)**	(0.002)*	(0.002)	(0.057)	(0.020)***	(0.023)**	(0.020)

Notes: Adjusted R-squared model fit test statistics are as following: global cognitive score: .438; perpetual speed: .418; episodic memory: .299; working memory: .293; C-MMSE z score: .381. Children = number of children; HC = health changes over last year; Living = living arrangement; MS = marital status; OHS = overall health status; Origin = country of origin; QOL = quality of life; Years in com = years in the community.

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

score decreased by 0.034, episodic memory decreased by 0.031, and working memory decreased by 0.020. In addition, sex (male) was only positively associated with global cognitive score and working memory. The associations between sex (male), perceptual speed composite score, episodic memory score, and C-MMSE composite score, however, did not meet statistical significance.

Education was positively associated with all domains. Global cognitive function score increased by 0.082 for every 1 year increase in education. Moreover, for every 1 year increase in education, perceptual speed composite score increased by 0.090, episodic memory score increased by 0.075, working memory increased by 0.083, and C-MMSE composite score increased by 0.087. Income levels, on the other hand, was only significantly associated with perceptual speed.

With respect to family composition, number of children was significantly associated with all five cognitive function domains; living arrangement was associated with all domains except episodic memory score. Regarding immigration information, episodic memory was the only domain that was associated with both years in the United States and years in the community.

With respect to health variables, only self-reported health status was significantly correlated with all five domains. For every 1 point increase in self-reported health status, global cognitive function score increased by 0.096, perceptual speed composite score increased by 0.127, episodic memory score increased by 0.085, working memory increased by 0.093, and C-MMSE composite score increased by 0.113.

Discussion

In this present population-based study, we used a battery of brief cognitive function tests to measure cognitive impairment among U.S. Chinese older adults. Our report provided composite scores of different domains of cognitive function. Based on the bivariate correlation analysis, age, sex, education, marital status, number of children, years in the United States, years in the community, country of origin, overall health status, and quality of life were significantly correlated with all five cognitive function domains. Income, living arrangement were correlated with all domains except working memory. Health change over the last year were correlated with perceptual speed and working memory. Furthermore, findings from the multivariate analysis suggest that performance in each domain of cognitive function, including perceptual speed, episodic memory, and working memory, was inversely associated with age, and positively related to education level. With respect to sex, after adjusted for age, education and all key variables presented in the model, being male was positively related to global cognitive score and working memory.

This large population-based study of U.S. Chinese older adults in the Greater Chicago area is among the first to examine a battery of five cognitive function tests among a U.S. Chinese aging population. Prior population-based studies assessing cognitive function among Chinese older adults in Mainland China mostly employed a single measure to assess cognitive function and screen for cases of possible cognitive impairment (31). Whereas a brief epidemiological screening instrument such as the MMSE may be easy to administer, it may not capture the wide range of cognitive performance needed to reflect changes among older adults with different initial ability levels. The ability to encompass a wide spectrum of cognitive performance may be particularly valuable in longitudinal studies.

In addition, using composite scores may enable cross-cultural comparisons of cognitive function among white, black, Latino and Chinese older adults (7). Comparing the level of cognitive performance in people of different cultural backgrounds may be challenging, due to the influences of culture-specific factors related to individual test items, language proficiency, and literacy levels, as well as cumulative lifetime socioeconomic position (32). Although it is beyond the focus of this study, future work is needed to compare the performance characteristics of the composite cognitive function measures across different racial/ethnic groups.

In line with prior studies, findings from our regression analyses suggest that age is inversely related to all domains of cognitive function, and years of education has a significant inverse relationship with prevalence of cognitive impairments. Prior studies of cognitive impairment in global Chinese populations consistently suggest that older age is a highly significant and independent risk factor for mild cognitive impairment and dementia (33,34). However, longitudinal studies are needed to examine how changes in age correspond to cognitive decline in Chinese older adults.

Consistent with previous reports among community-dwelling Chinese older adults (35,36), our findings also suggest the positive association with education and cognitive function across all domains. Whereas researchers have proposed that education likely provide protection against dementia (37), other studies among community-based older adults have reported negative results (38,39). Recent studies further suggest that the protective effect of education may not always be observed, but may depend upon the specific cognitive ability that is measured (40). By examining the association between education and five domains of cognitive function, our data indicate the positive association between education and different cognitive domains, although the magnitude of this association was greater for education and perceptual speed than other domains (0.090). Future studies are needed to investigate the substantial effect of education on various cognitive abilities among U.S. Chinese older adults.

In contrast to age and education, sex appeared to have weaker effect on cognitive performance. Whereas the bivariate correlation between sex and all five tests were statistically significant, the association between perceptual speed, episodic memory, C-MMSE *z* score, and sex did not meet statistical significance. Perceptual speed and episodic memory varied by sex at the bivariate level, but differences disappeared after adjusting for age and education. Although studies consistently suggest that women are disproportionally affected by Alzheimer's disease and dementia, there is also evidence suggesting that older men may have a higher risk for mild cognitive impairment—an intermediate stage between normal aging and dementia (41). One explanation is that men may die of competing causes of death earlier in life, so that only the most resilient men may survive to older ages. In addition, other factors including different structures and functions of the brain may also play an important role in the development and progression of cognitive impairment. Understanding how the prevalence of cognitive impairment may vary by sex and age will contribute to the development of individualized, tailored interventions.

We also examined issues of family composition and immigration experiences in the United States with respect to cognitive performance. Our data suggest that being married and living with more persons in the household are correlated with higher global cognitive scores; however, the number of children was negatively correlated with global cognitive scores. In Chinese culture, which is heavily influenced by Confucianism, traditional multigenerational living arrangements and larger family compositions represent the fulfillment of the cultural ideal of filial piety. Whereas a number of studies indicate that living alone and widowhood may be associated with cognitive impairment, other studies suggest that constructs related to psychological well-being—including diminishing social network, perceived social isolation, and the sense of loneliness—have equally robust associations with impaired cognition over time (42). In addition, a recent report based on a community-dwelling sample of older adults in Shanghai, China, suggests that higher number of children was associated with cognitive impairment (43). Additional research is required to delineate the mechanisms between family structure, support, and cognitive performance of Chinese older adults.

The findings of this study should be interpreted with its limitations in mind. First, participants in this study were all recruited from the Greater Chicago area. Thus, the findings may not be generalizable to Chinese populations in other regions of the United States or in other countries such as Mainland China, Hong Kong, or Taiwan, as they may be subjected to different social and economic influences. Future studies are needed to explore potential geographical variations in cognitive function among older Chinese adults. In addition, this study only uses current annual personal income and years of education as indicators of socioeconomic status. Other potentially important socioeconomic characteristics were not collected, for instance, cities and provinces where older adults emigrated from, previous occupations, literacy levels, and years of education received in the United

States versus in their countries of origin. These factors may also play important roles in estimates of cognitive performance (34), so additional studies are needed to explore these associations. Furthermore, the self-reported health and well-being variables collected in our study are subjected to methodological limitations. In addition, there existed missing data in our study. Last, cognitive assessments may not be as accurate in detecting cognitive impairment as more detailed clinical evaluations. Future studies should consider collecting clinical evaluations, clinical diagnostic assessments, and neuroimaging information.

In summary, our study contributes to the ongoing investigation of age-related cognitive impairment and comprehensive measures that may be useful in detecting changes in cognitive performance in longitudinal studies. Our data support our hypothesis that age is inversely related to all domains of cognitive function and higher educational attainment is positively related to cognitive performance. Findings call for future longitudinal studies to improve our knowledge of risk factors and health outcomes associated with cognitive impairment in global Chinese populations.

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