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Preplanned Studies

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Preplanned Studies

Greenness and Asthma in the Middle-Aged and Elderly Population in a Prospective Cohort Study — China, 2011–2018

Jiawei Wang[1]; Teng Yang[1]; Zhihu Xu[1]; Jianbo Jin[1]; Yuxin Wang[1]; Guoxing Li[1,2]; Jing Huang[1,3,#]

Summary

What is already known about this topic?

Greenness, which refers to the density of vegetated land, has been identified as an essential component of a healthy built environment for human health. Residential environment plays a critical role in the progression of early-onset or late-onset asthma.

What is added by this report?

Based on the China Health and Retirement Longitudinal Study from 2011 to 2018, this study indicates a negative association between greenness and asthma in the middle-aged and elderly population.

What are the implications for public health practice?

This study provides further guidance for environmental policymaking in city planning and public health protection to increase greenness in order to counteract the adverse health effects associated with rapid urbanization processes.

Several studies have found greenness to be associated with a lower risk of childhood-onset asthma (*1*). However, limited evidence has been available on the influence of greenness on asthma onset during adulthood, especially in the middle-aged and elderly. Different from childhood-onset asthma, adult-onset asthma is less associated with allergic and atopic diseases. In addition, adult-onset asthma is accompanied by a faster decline in lung function, poorer prognoses, and more severe airflow limitation. Considering the higher risk of asthma-related morbidity and mortality among elderly asthmatics, paying more attention to asthma in older people is critical. Based on the China Health and Retirement Longitudinal Study (CHARLS) from 2011 to 2018, a per 0.1-unit increase in annual normalized difference vegetation index (NDVI) was associated with a hazard ratio (HR) of 0.840 [95% confidence interval (CI): 0.774, 0.991] for asthma in fully adjusted models. The exposure-response curve showed that the HR of asthma decreased with increasing NDVI. These findings have substantial significance for guiding environmental policymaking in city planning and public health protection.

The participants in the study were from CHARLS, which is a nationally representative longitudinal survey of the middle-aged and elderly population (≥45 years old) in China. Further details about CHARLS were detailed elsewhere (*2*). Greenness exposure was measured by NDVI, which calculates the ratio of the difference between the near-infrared region and red visible reflectance to the sum of these two measures, ranging from −1.0 to 1.0, with larger values above zero indicating higher levels of vegetative density. Negative NDVI values are often regarded as blue space or water; values near zero are often bare ground or buildings. The long-term vegetation index dataset of China, SPOT VEGETATION NDVI, which has a spatial resolution of 1 km and a temporal resolution of 10 days, was used to assess greenness (*3*). The estimations for fine particulate matter ($PM_{2.5}$), ozone (O_3), and nitrogen dioxide (NO_2) have been detailed elsewhere (*4*–*6*). Meteorological indicators, including annual average temperature, annual average relative humidity, and annual precipitation, were obtained from the China Meteorological Data Sharing Service System (http://www.nmic.cn/, accessed on June 1, 2021). Annual NDVI, $PM_{2.5}$, O_3, NO_2, and meteorological indicators for individual adults were estimated at participants' residential cities. Gross Domestic Product (GDP) was obtained from the China Statistical Yearbook and assigned to participants according to their residential cities. All participants involved in CHARLS were asked "Have you been diagnosed with asthma by a doctor?" in each interview. Participants with affirmative answers were classified as having asthma.

Time-varying Cox proportional hazards models with time-varying exposures on an annual timescale were used to estimate the associations between greenness and the risk of asthma. The geographic coordinates of the participants were not available due to confidentiality. To verify the reliability of the results, this study used regression calibration to calibrate the measurement error (*7*). The greenness exposure is represented as W=X+U; where W is city-level exposure, X is individual exposure, and U is the additive classic measurement error which is a normal distribution with the mean is 0 and the standard deviation is σ. The NDVI data have the standard deviation within all cities ranging from 0.03 to 0.30 and were used in the regression calibration. Potential effect modification was examined based on covariates. All statistical analyses were performed with R software (version 4.1.0, R Foundation for Statistical Computing, Vienna, Austria). The Cox proportional hazards models with time-varying exposures were conducted with the "survival" package. A two-sided *P*-value <0.05 was considered statistically significant.

A total of 670 new-onset asthma cases from 17,574 adults were observed during a mean of 6 years of follow-up (Table 1). The association between greenness and the risk of asthma is shown in Table 2. The exposure-response curve showed that the HR of asthma decreased with NDVI increasing, and the HR decreased more slowly at higher NDVI (Figure 1A). After regression calibration, the HR decreased with the standard deviation of the measurement error increasing (Supplementary Figure S1, available in http://weekly.chinacdc.cn/). However, at the highest standard deviation of the measurement error, less than a 5% difference between the result of city-level exposure and the regression calibration value was observed. Thus, the results of city-level exposure in this study were convincing and relatively conservative. The associations were significantly stronger in adults with lower household income (*P*-interaction=0.035) and nonsmokers (*P*-interaction=0.049) (Figure 1B).

DISCUSSION

This prospective cohort study among the middle-aged and elderly population suggests that greenness is associated with a lower risk of asthma and the exposure-response curve shows the risk of asthma decreasing monotonically with greenness increasing.

Recently, a large cross-sectional study reported the findings from UK Biobank that higher levels of residential greenness exposure were associated with a lower risk of asthma among adults aged 37 to 73 years (*8*). However, the cross-sectional design restricted the inference of temporal or causal relationships. The findings from this prospective cohort study are more convincing in causal inference, strengthening the evidence on the protective effect of greenness on asthma in adults.

Although less is known about the biological plausibility of the observed association, there are several possible mechanisms. Trees and forests may reduce adverse health effects by reducing air pollution. Moreover, considering the beneficial association between greenness and lower body weight, and the fact that obesity is a risk factor for the development of asthma in adulthood, greenness may reduce the risk of asthma by regulating obesity. In addition, green spaces may host a high diversity of environmental microbiota, which may mediate biodiversity effects on human health, including asthma, through their impact on the immune system. Alongside this, the lower risk of asthma associated with greenness may be mediated by reduced psychological stress, which is increasingly recognized as a risk factor for incident asthma (*9*), since the potential benefits of residential greenness on stress have been identified. Finally, increased access to greenness was associated with a higher likelihood of participating in physical activities, which may further improve human health. Further studies about the underlying mechanisms accounting for the association between greenness and asthma need to be conducted.

Greenness showed a stronger effect among adults with lower household incomes, which may be associated with the socioeconomically disparate situation in China. China has witnessed increasingly rapid urbanization in recent years, which has resulted in an imbalance in the distribution and composition of green spaces. Adults of lower socioeconomic status tend to have more access to green spaces with a high diversity of environmental microbiota. In addition, the effect of greenness on asthma was stronger in nonsmokers. Smoking increases oxidative stress and has pro-inflammatory effects on the lungs, accelerating the normal annual decline in lung function and increasing the risk of airway obstruction, which are changes that predispose the development of asthma. Although greenness was probably a protective factor for asthma, the adverse health effect caused by smoking was so strong that the health benefits from greenness were attenuated greatly.

This study has several strengths. First, this is the first study to investigate the association between greenness and risk of asthma in the middle-aged and elderly

TABLE 1. Descriptive characteristics of the study participants and environmental exposure.

Variables	Descriptive characteristics
Study participants	
Participant counts	17,574
Counts of asthma	670
Total person-year	106,716
Age, ≥60 years, %	41.08
Female, %	51.73
Rural area, %	60.16
BMI, <24 kg/m^2, %	53.06
Illiteracy, %	26.48
Lower income, %	48.35
Disability, %	16.92
Smoking status, %	36.77
Alcohol consumption, %	42.34
Solid cooking fuel, %	51.63
Sleep duration, <7 hours, %	46.17
Environmental exposure	
NDVI, median (IQR)	0.77 (0.08)
$PM_{2.5}$, μg/m^3, median (IQR)	42.69 (30.56)
O_3, μg/m^3, median (IQR)	85.77 (17.24)
NO_2, μg/m^3, median (IQR)	21.12 (8.32)
Annual precipitation, cm, median (IQR)	14.22 (19.35)
Annual average temperature, ℃, median (IQR)	15.83 (5.00)
Annual average relative humidity, %, median (IQR)	70.38 (15.23)

Abbreviation: NDVI=normalized difference vegetation index; IQR=interquartile range; $PM_{2.5}$=fine particulate matter; O_3=ozone; NO_2=nitrogen dioxide; BMI=body mass index.

TABLE 2. Associations between greenness and risk of asthma.

NDVI	Number of events	Model a		Model b		Model c	
		HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Continuous NDVI (per 0.1-unit increase)	670	0.88 (0.81, 0.95)	0.001	0.84 (0.77, 0.91)	<0.001	0.86 (0.77, 0.96)	0.005
Quintile 1 (0.167–0.717)	144	1		1		1	
Quintile 2 (0.717–0.757)	104	0.67 (0.52, 0.86)	0.002	0.64 (0.50, 0.83)	0.001	0.67 (0.51, 0.87)	0.002
Quintile 3 (0.757–0.784)	148	0.86 (0.68, 1.08)	0.202	0.78 (0.62, 0.99)	0.040	0.74 (0.57, 0.95)	0.020
Quintile 4 (0.784–0.819)	140	0.79 (0.61, 1.01)	0.056	0.75 (0.58, 0.96)	0.026	0.78 (0.59, 1.03)	0.084
Quintile 5 (0.819–0.878)	134	0.68 (0.52, 0.87)	0.003	0.64 (0.49, 0.83)	0.001	0.65 (0.59, 0.87)	0.004
P trend*			0.008		0.002		0.008

Note: Model a as minimally adjusted model included age, sex, region of residence (urban/rural), and GDP. Model b was a fully adjusted model additionally adjusted for BMI, education level, household income, smoking status, alcohol consumption, cooking fuel, disability, sleep duration, time-varying $PM_{2.5}$, and time-varying annual precipitation. Model c was further adjusting for O_3 and NO_2 based on Model b.
Abbreviation: NDVI=normalized difference vegetation index; HR=hazard ratio; CI=confidence interval; BMI=body mass index; GDP=Gross Domestic Product; $PM_{2.5}$=fine particulate matter; O_3=ozone; NO_2=nitrogen dioxide.
* Test for trend is based on the median value for each quintile.

population worldwide. Furthermore, a prospective cohort design was used, which is more convincing in causal inference. In addition, the study included a large and population-based sample from 125 cities and 28 provincial-level administrative divisions (PLADs) in China, providing nationally representative panel data

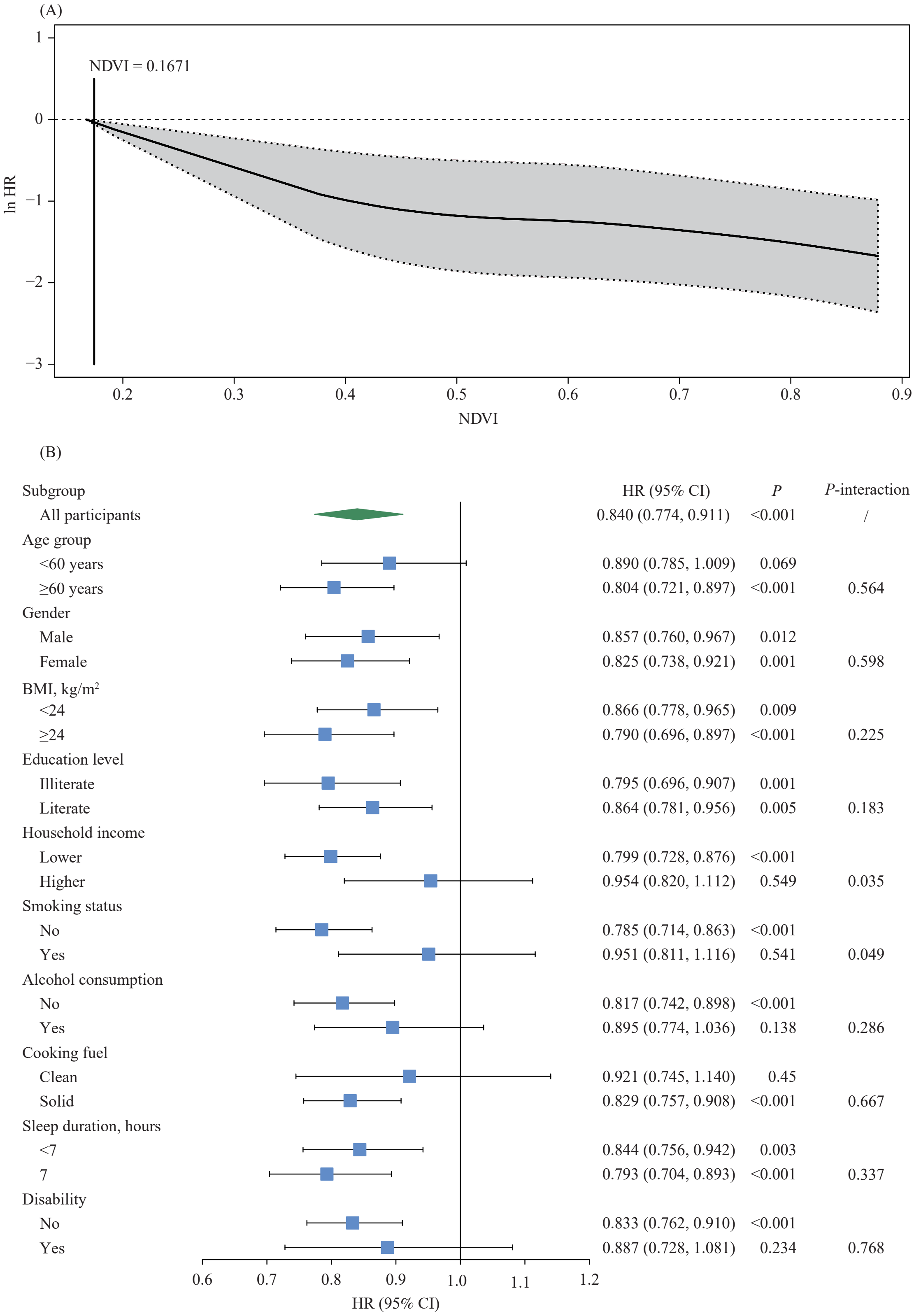

FIGURE 1. Exposure-response curve and subgroup analyses. (A) Exposure-response curve for the association between greenness and risk of asthma. (B) Subgroup analyses of HR (95% CI) for asthma with per 0.1-unit increase in NDVI according to the characteristics at baseline.

Abbreviation: HR=hazard ratio; CI=confidence interval; BMI=body mass index; NDVI=normalized difference vegetation index.

(*2*). Finally, this study included a wide range of individual- and area-level covariates to control for potential confounding.

There are also some limitations to this study. First, since the exact residential addresses of participants are concealed in CHARLS, this study was unable to obtain the precise exposure. City-level measured exposures may introduce misclassification in exposure evaluation. However, such exposure misclassification tends to be non-differential and thus biases the results towards the null. Furthermore, the results of the regression calibration indicated that this study's findings are convincing and relatively conservative. Second, the outcome definition relied on doctor-diagnosed self-reported asthma, lacking more objective definitions, which may underestimate the incidence of asthma in China. Nevertheless, the overall prevalence of asthma between 2011 and 2018 in CHARLS was 6.1%, which is similar to a large cross-sectional study in China, indicating that the quality of investigation for asthma in CHARLS is credible (*10*). Third, greenness was assessed with NDVI, which is unable to distinguish the structure of green spaces, making it difficult to determine whether different types of vegetation have variations in the association between greenness and asthma. Fourth, although a wide range of individual- and area-level covariates were included to control for potential confounding, residual confounding could not be excluded.

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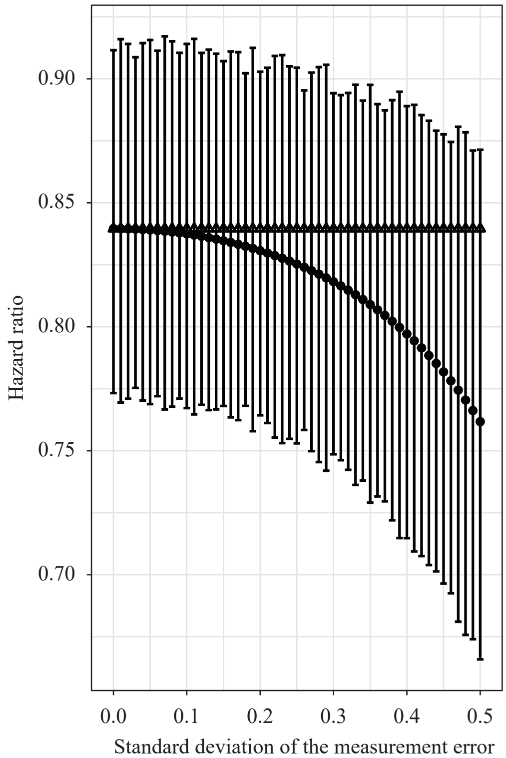

SUPPLEMENTARY FIGURE S1. The hazard ratio of regression calibration under different standard deviations of the measurement error.

Note: The hollow triangles represent the results of city-level and the solid dots represent the results of regression calibration.

Preplanned Studies

Association Between Physical Activity and Physical Fitness Among Adults Aged 40 to 79 Years — Beijing, China, 2020–2021

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Summary

What is already known about this topic?

Physical fitness is well documented to be associated with physical activity among adults in the United States. In China, research on this association places a heavier emphasis on the populations of children and adolescents.

What is added by this report?

Physical fitness was shown to be positively associated with physical activity among adults aged 40 to 79 years in China. In populations with lower levels of physical fitness, this association was stronger. The coefficients of the log-transformed metabolic equivalent value of physical activity (logPA) in quantile regression models at the 25th, 50th, 75th, and 90th percentile of the physical fitness indicators were 1.14, 1.04, 0.89, and 0.84, respectively.

What are the implications for public health practice?

Effective measures should be implemented to promote physical activity among adults ages 40 and older, such as providing sufficient space for physical activity, especially for communities with low levels of physical fitness.

The ability to maintain or improve physical fitness has been demonstrated to be associated with an improved quality of life and reduced all-cause and cardiovascular disease mortality (*1*). However, physical fitness has declined steadily among Chinese adults over the past two decades (*2*). A study conducted among adult males in the United States showed that many lifestyle habits, such as sedentary lifestyle and smoking habit, are associated with changes in physical fitness. Additionally, physical activity is likely one of the important factors to explain physical fitness change (*1*). While there is evidence to support the connection between quality of life and physical fitness, in China, the studies on the association between physical fitness and physical activity have mostly focused on child and adolescent populations (*3*–*4*). Few studies have investigated the connection in adult populations, particularly the association between different levels of physical fitness and physical activity. This study aims to explore the association between different levels of physical fitness and physical activity in adults over the age of 40 in Beijing, China.

Data were drawn from the Survey on Physical Activity and Healthy Behavior of Middle-aged and Older Adults, a community-based cross-sectional study conducted from October 2020 to January 2021 in Beijing, China. The sample was selected using judgment sampling from middle-aged adults and older residents from six communities in Yanyuan Subdistrict and Dahongmen Subdistrict to promote sampling diversity. In total, 1,319 participants who met the age criteria (between 40 and 79 years old) and were functionally independent in activities of daily living (ADL) were recruited for the study. The survey was guided by a structured questionnaire and used interviews conducted by trained staff to ensure consistent quality. Among the entire sample population, 308 individuals were randomly selected to complete the physical fitness tests and were ultimately the subjects for this study. This study was approved by the Ethics Committee at the School of Psychological and Cognitive Sciences, Peking University (protocol number#2019-08-04).

The survey collected basic sociodemographic characteristics (gender, age, education, marital status, living arrangement, and monthly personal income), health risk behaviors (smoking and alcohol consumption), and chronic disease status (with or without chronic diseases). The physical activity data were collected using the International Physical Activity Questionnaire-Long Form (IPAQ-LF), including leisure-time, occupational, transport-related, and domestic physical activity. Physical fitness was measured by trained staff using the same equipment in accordance with the methods and procedures specified in the Manual of Standards for National Physical Fitness Measurement (*5*–*6*). The test items for adults aged 40 to 59 years included weight-for-height (WH, an assessment of body shape), forced vital capacity (FVC, an assessment of pulmonary function), step-test index (STI, an assessment of cardiorespiratory fitness), hand grip strength (HGS, an assessment of muscular strength), sit-and-reach (SR, an assessment of flexibility), choice reaction time (CRT, an assessment of psychomotor speed), and standing on one leg with eyes closed test (SOL, an assessment of balance). Each item stated above was scored according to the corresponding range from 1 to 5 (*6*). Different from the middle-aged adults, the measurement for the older adults (aged 60 years and older) included six test items, excluding the STI (*5*).

The scores from all the test items were aggregated to a composite physical fitness indicator (PFI) score which was then classified into 3 levels — excellent (score >26 for adults ages 40 to 59; score >23 for adults over 60), good (24≤score≤26 for adults ages 40 to 59; 21≤score≤23 for adults over 60), and poor (score <24 for adults ages 40 to 59; score <21 for adults over 60), according to the Manual of Standards for National Physical Fitness Measurement (*5*–*6*). Participants were categorized as middle-aged adults (aged between 40 and 59 years) and older adults (aged 60 years and older). Subjects were also categorized by education level into three groups — low (without high school diploma), middle (high school diploma), and high (high school diploma and some college). Subjects were then categorized by monthly personal income into three levels — lower than 3,000 CNY, 3,000–6,000 CNY, and higher than 6,000 CNY. The results of IPAQ-LF were summarized as a continuous variable metabolic equivalents (MET)-minutes per week. The MET value was calculated by weighting each type of physical activity by its METs to yield a total score, according to guidelines for data processing and analysis of the IPAQ (*7*). A density plot was used to depict the distribution of PFI by subgroup including age group, gender, educational attainment, and monthly personal income. A radar chart was then used to show the mean score of each test item among the two age groups. The random forest algorithm was used to identify and validate the most influential correlations for physical fitness (*8*). The random forest feature importance scores used were based on the mean decrease of the Gini index to rank these correlations. Lastly, the quantile regression model was used to analyze the association between the different levels of physical fitness and physical activity and was adjusted for possible confounding variables obtained by the random forest algorithm. Considering the large range of MET, physical activity was log-transformed (with a base of 2, written as logPA) before performing the regression analysis. All *P*-values <0.05 were considered statistically significant. All analyses were performed using R software (version 4.0.2, R Development Core Team, Vienna, Austria).

The PFI distribution of the middle-aged population appeared shifted to the right of the elderly population distribution, indicating that overall PFI among the middle-aged population was higher than among the older adult population in this study. Similarly, overall PFI was higher among females, people with higher education, and people with higher incomes (Figure 1).

As shown in the radar charts, overall, the group with higher PFIs performed better than the group with lower PFIs on all components of physical fitness among both the middle-aged and elderly populations. All the middle-aged adults across the three groups of PFI (excellent, good, and poor) had the best performance in WH among seven components of physical fitness. The poor group of PFI got the lowest mean score on the STI. Overall, the older adults across the three groups of PFI had better performance on WH and CRT among the six components of physical fitness measured. The performance of the poor group of PFI was relatively balanced in six components of physical fitness among the elderly (Figure 2).

As shown in the variable importance plot of correlations for physical fitness, the most important correlation for all groups was physical activity (importance score: 0.27), followed by education level (0.15), monthly personal income (0.13), living arrangement (0.08), chronic disease status (0.08), and age (0.08) (Figure 3).

After adjusting for educational level, monthly personal income, living arrangement, chronic disease status, and age, the coefficient of logPA in the quantile regression model at the 25th percentile was 1.14 [95% confidence interval (CI): 0.57 to 1.31, *P*<0.001], indicating that PFI increased by 1.14 per 100% increase in physical activity. Absence of multicollinearity between these variables was confirmed by testing variance inflation factors. The coefficients of logPA in the models at the 50th, 75th, and 90th percentile were 1.04 (95% CI: 0.53 to 1.46, *P*<0.01), 0.89 (95% CI: 0.40 to 1.30, *P*<0.05), and 0.84 (95% CI: 0.61 to 1.25, *P*<0.05), respectively (Figure 4).

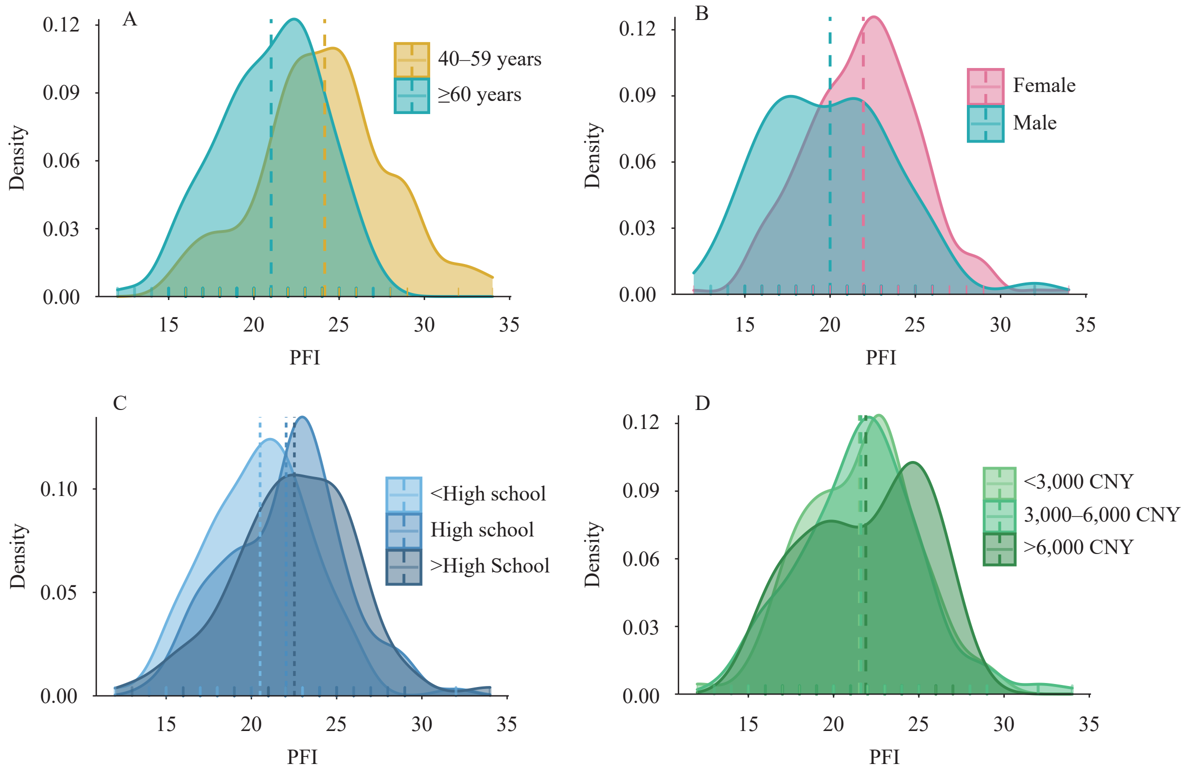

FIGURE 1. Distribution of PFI by (A) age group, (B) gender, (C) education level, and (D) monthly personal income.
Note: Scores from all test items of physical fitness are aggregated to form a summary PFI.
Abbreviation: PFI=physical fitness indicator.

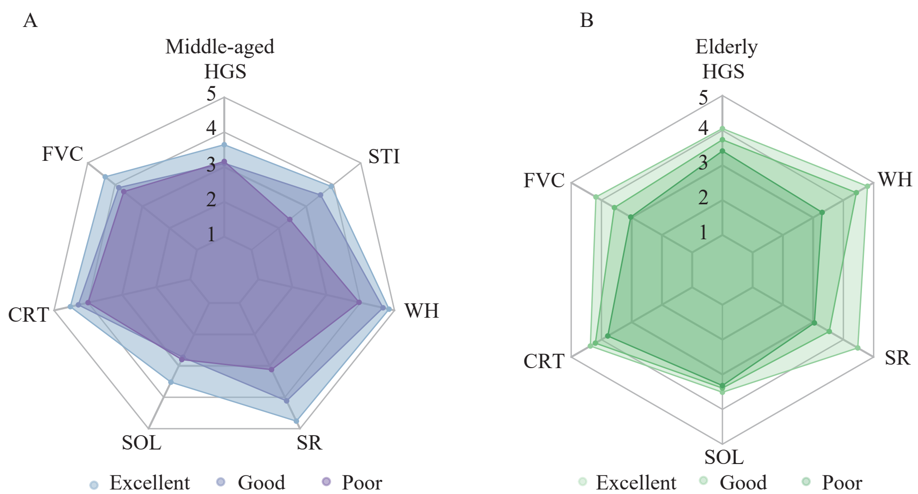

FIGURE 2. Radar chart of mean score of every test item by group of PFI among (A) middle-aged adults and (B) the elderly.
Abbreviation: PFI=physical fitness indicator; WH=weight-for-height; FVC=forced vital capacity; STI=step-test index; HGS=hand grip strength; SR=sit-and-reach; CRT=choice reaction time; SOL=standing on one leg with eyes closed test.

DISCUSSION

To our knowledge, this is the first study to explore the association between physical activity and different levels of physical fitness among adults in China. This community-based study found a positive association between physical fitness and physical activity, especially in populations with lower levels of physical fitness. This positive association was also found in a study among older adults in Shaanxi Province, China (*9*). Stronger associations among adults of low physical fitness suggest that interventions to promote physical

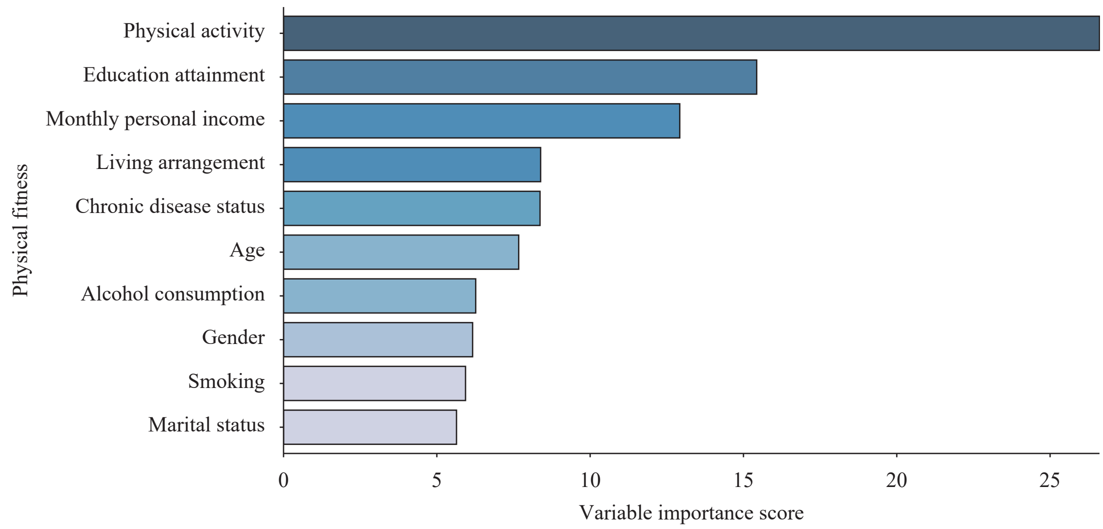

FIGURE 3. Variable importance plots of correlations for physical fitness based on the random forest algorithm.

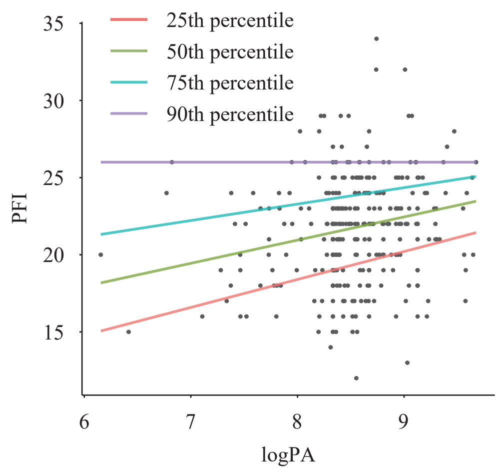

FIGURE 4. Trends of PFI at different percentiles with logPA.

Note: All results from the International Physical Activity Questionnaire-Long Form (IPAQ-LF) were summarized as a continuous variable, MET-minutes per week, which is used to represent physical activity level. Physical activity level was log-transformed (with a base of 2, written as logPA).

Abbreviation: PFI=physical fitness indicator; MET= metabolic equivalents.

activity in the population with a low level of physical fitness may have greater health benefits. Future studies may need to further validate the differences in the association between different levels of physical fitness and physical activity among different populations based on prospective cohort studies in a large sample.

The findings from this study also showed that physical activity was the most important predictor for physical fitness, which was consistent with the previous study (*1*). In addition to physical activity, the results showed that education level and personal income were also important predictors for physical fitness. One meta-analysis showed that there was an association between physical fitness and educational levels, with higher levels of education associated with increased physical fitness (*10*). A study among workers aged 20 to 65 years in Tokyo suggested that those with higher socioeconomic status were more likely to have favorable physical fitness (*11*). The results of this study further contribute to these findings. This study also found that almost all indicators of physical fitness among people with lower PFI were worse than those among people with higher PFI. Two possible explanations for this finding are that 1) most types of exercise improve more than one type of physical fitness, for example, running improves both cardiorespiratory fitness and muscle strength; and 2) people with high physical fitness are more likely to engage in multiple forms of physical activity.

Given the association between physical fitness and physical activity, physical fitness can be improved by promoting physical activity among middle-aged and elderly adults. Since physical fitness declines with age, adults over 40 tend to be less physically active. However, physical activity improves physical fitness, so ways to promote physical activity in this older age group should be explored (*12*). Research shows that a lack of physical activity space is the most important non-human factor for physical inactivity in adults (*13*). Therefore, governments should promote the construction of sports grounds and public sports services for middle-aged and elderly adults within communities. In addition, more school and public sports venues should be open to residents under certain conditions.

The strengths of this study were the use of the IPAQ to obtain comprehensive physical activity data and the use of national standards to measure comprehensive physical fitness. This study was also subject to some limitations. Due to limited conditions, participants were recruited without random selection, which may affect the representation of a broader middle-aged and elderly adult population. Lastly, a causal association cannot be established due to the nature of the cross-sectional study design.

This study found that physical fitness is positively associated with physical activity among middle-aged and elderly adults, especially in groups with lower levels of physical fitness. Effective measures should be implemented to promote physical activity among middle-aged and elderly adults, such as providing sufficient physical activity space, especially in areas where people have low physical fitness.

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Preplanned Studies

Changes in Sleep Duration and the Risk of Cognitive Impairment Among Older Adults Aged 65 Years and Over — China, 2014–2019

Yue Wei[1]; Heming Pei[1]; Jinlong Lin[1]; Xiaojin Yan[1]; Gong Chen[1,#]

Summary

What is already known about this topic?

Earlier studies indicated that shorter or excessive sleep duration at baseline was related to cognitive impairment. Yet few studies have been concerned with the association between sleep duration changes and cognitive performance, especially in low- and middle-income countries.

What is added by this report?

A prospective cohort study suggests that maintaining moderate sleep duration may lead to optimal cognitive performance. Either decreasing, increasing, or keeping a longer sleep duration is associated with the risk of cognitive impairment among Chinese elderly aged 65 years and over.

What are the implications for public health practice?

Maintaining a moderate sleep duration may be a protective factor against cognitive impairment. Therefore, we need to pay attention to the seniors' sleep health and prevent or delay the progression of cognitive impairment through sleep therapy.

Cognitive impairment is generally used to refer to an intermediate phase between natural cognitive decline and dementia in the aging process. The prevalence among Chinese aged 60 and over was estimated to be 15.5% in 2018 (*1*). The seventh national census found that there are 264 million Chinese aged 60 and over. It is estimated that about 41 million seniors suffer from cognitive impairment in China. If those older adults go on to develop dementia, there will be a socioeconomic cost of 78 billion USD (*2*). It is therefore vital to identify modifiable factors that can prevent or postpone the onset and development of cognitive impairment.

Growing epidemiological studies indicate that shorter and longer sleep durations assessed at baseline are associated with the risk of subsequent cognitive impairment (*3*). Yet, few studies have addressed changes in sleep duration as a determinant of cognition. This study explored whether sleep duration changes over time were related to subsequent cognitive impairment utilizing data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS).

A prospective cohort study of 2,253 Chinese adults aged 65 years and over was included to evaluate the association. After an average follow-up of 3.79 years, 468 individuals developed cognitive impairment. Analyses were confined to those without cognitive impairment at baseline. Our findings indicated that decreased or increased sleep duration at follow-up or maintaining a longer sleep duration was associated with an increased risk of cognitive impairment. Keeping a moderate sleep duration was beneficial for cognitive function.

These findings suggest that keeping moderate sleep durations may lead to optimal cognitive performance. Therefore, we need to pay high attention to the seniors' sleep pattern and take targeted interventions to maintain stable and moderated sleep duration.

CLHLS is the first large prospective cohort study in China aimed at understanding the determinants of healthy aging. A multistage stratified sampling design was conducted and 631 cities and counties were randomly selected, covering almost 85% of the Chinese population. The initial survey was conducted in 1998 and other 7 subsequent phases were from 2000 to 2019. Details of the study design, sample distribution and collection and quality of data have already been described in a previous study (*4*). The current study used data from Phase 7 (2014) and Phase 8 (2017–2019) as baselines and follow-ups. This study was granted by the Ethics Committee of Peking University, and all respondents signed informed consent.

A total of 3,441 individuals took part in both phases; those who were under 65 years and over 105 years were deleted due to the quality of data. The sample was then restricted to individuals who scored higher than or equal to 24 at baseline Chinese version of Mini-mental State Examination (CMMSE). Not counting the participants with no follow-up cognitive assessment and missing data of key variables, 2,253 eligible participants were included in analysis (Figure 1).

Participants reported their habitual hours of sleep in Phase 7 and Phase 8. The sample was divided into the following five groups based on the sleep duration reported at two time points: sleep less than or equal to 5 h at both phases, reduced sleep duration at follow-up (6 h–8 h or ≥9 h sleep at Phase 7 and ≤5 h or <9 h at Phase 8), sleep 6 h–8 h at both time points (reference group), increased sleep duration at follow-up (≤5 h or 6 h–8 h sleep at Phase 7 and >5 h or ≥9 h at Phase 8), and sleep more than or equal to 9 h at both phases. Cognitive function was assessed at baseline and follow-up using CMMSE, which is a scale of global cognitive function and contains different cognitive domains like orientation, registration, attention and calculation, recall, and language. Total point scores ranged from 0 (worst) to 30 (best), classifying those with less than 24 as having cognitive impairment.

Descriptive data are presented as the mean (standard deviation, SD) for continuous variables and percentages for categorical variables. The baseline characteristics of the sample were tested using t-test or F test for continuous variables and χ^2 tests for categorical variables. Multiple logistic regressions were conducted to explore the association between sleep duration changes and cognitive impairment after adjusting for age, sex, marital status, residence, living arrangement, smoking, drinking, exercise, body mass index (BMI), activities of daily living (ADL), depressive symptoms, and vascular factors (hypertension, diabetes, stroke, and heart disease) at baseline. Analyses were conducted using STATA software (MP version 14.0, Stata Corp, LLC, USA). P<0.05 was regarded as statistically significant.

Among 2,253 participants who were free of cognitive impairment at baseline, the mean (SD) age was 79.44 (7.66) years old, and 53.31% of them were men. After an average follow-up of 3.79 years, 468 cases of cognitive impairment were recorded, accounting for 20.77% of all participants. Table 1 depicts characteristics of the study participants at baseline by grouping of sleep duration changes.

Table 2 shows the association between sleep duration changes and cognitive impairment along with the odds ratio (OR) and 95% confidence interval (CI). After adjusting for demographic, socio-economic, lifestyle behavioral and health status factors, individuals with decreased and increased sleep duration at follow-up had an increased risk of cognitive impairment by 54% (OR=1.54, 95% CI: 1.14–2.08) and 61% (OR=1.61, 95% CI: 1.20–2.17), respectively. And the risk of cognitive impairment was 1.67 (95% CI: 1.11–2.50) times higher for people who slept 9 h or more at both phases. No association was observed between sleeping 5 h or less and cognitive function.

DISCUSSION

This study suggests that any changes, whether a

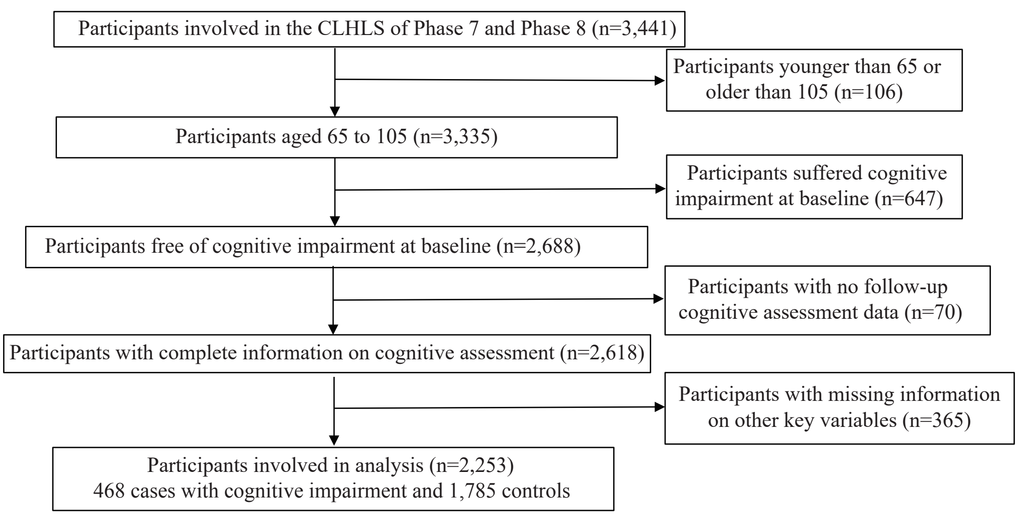

FIGURE 1. Flow chart of sample selection.
Abbreviation: CLHLS=Chinese Longitudinal Healthy Longevity Survey.

TABLE 1. Baseline characteristics of participants by changes in sleep duration among Chinese older adults aged 65 years and over, 2014–2019 (N=2,253).

Characteristics	Changes in sleep duration				
	≤5 h at both phases* (n=131) n (%)	Decreased at follow-up† (n=567) n (%)	6 h–8 h at both phases§ (n=831) n (%)	Increased at follow-up¶ (n=534) n (%)	≥9 h at both phases** (n=190) n (%)
Age [years, (mean±SD)]	79.79±6.91	79.29±7.86	78.23±7.37	80.36±7.63	82.33±7.79
Female	79 (60.31)	249 (43.92)	379 (45.61)	263 (49.25)	82 (43.16)
Married	69 (52.67)	322 (56.79)	490 (58.97)	259 (48.50)	91 (47.89)
Rural	74 (56.49)	333 (58.73)	476 (57.28)	252 (47.19)	102 (53.68)
Living alone	35 (26.72)	109 (19.22)	153 (18.41)	110 (20.60)	38 (20.00)
Education [years, (mean±SD)]	2.45±3.52	2.94±3.51	3.45±3.83	2.97±3.65	2.49±3.23
Smoking	15 (11.45)	124 (21.87)	158 (19.01)	104 (19.48)	50 (26.32)
Drinking	18 (13.74)	107 (18.87)	179 (21.54)	105 (19.66)	36 (18.95)
Exercise	47 (35.88)	195 (34.39)	278 (33.45)	204 (38.20)	68 (35.79)
BMI (mean±SD)	23.21±4.75	22.42±4.06	23.18±7.59	22.55±3.83	23.11±5.68
Intact ADL	129 (98.47)	542 (95.59)	792 (95.31)	495 (92.70)	171 (90.00)
Depression (mean±SD)	6.56±3.25	5.98±2.98	5.91±3.00	5.98±2.97	5.33±3.03
Any vascular factors	72 (54.96)	228 (40.21)	330 (39.71)	250 (46.82)	76 (40.00)
CMMSE scores at baseline (mean±SD)	27.98±1.97	28.04±1.79	28.49±1.67	28.26±1.77	27.68±1.88
CMMSE scores at follow-up (mean±SD)	24.95±6.17	25.64±5.63	26.76±4.74	24.96±6.90	24.52±6.46

Abbreviation: SD=standard deviation; BMI=body mass index; ADL=activities of daily living; CMMSE=Chinese version of mini-mental state examination.
* ≤5 h sleep at Phase 7 and ≤5 h at Phase 8;
† 6 h–8 h or ≥9 h sleep at Phase 7 and ≤5 h or <9 h, respectively, at Phase 8;
§ 6 h–8 h sleep at Phase 7 and 6 h–8 h at Phase 8;
¶ ≤5 h or 6 h–8 h sleep at Phase 7 and >5 h or ≥9 h, respectively, at Phase 8;
** ≥9 h sleep at Phase 7 and ≥9 h at Phase 8.

TABLE 2. Association between changes in sleep duration and the risk of cognitive impairment among Chinese older adults aged 65 years and over, 2014–2019. (N=2,253)

Changes in sleep duration	OR (95% CI)	aOR (95% CI)
≤5 h at both phases*	1.78 (1.10–2.83)	1.47 (0.91–2.39)
Decreased at follow-up†	1.66 (1.25–2.21)	1.54 (1.14–2.08)
6 h–8 h at both phases§	Reference	Reference
Increased at follow-up¶	1.91 (1.44–2.54)	1.61 (1.20–2.17)
≥9 h at both phases**	2.29 (1.55–3.35)	1.67 (1.11–2.50)

Note: Multiple logistic regression was adjusted for age, sex, marital status, residence, living arrangement, education, smoking, drinking, exercise, body mass index, activities of daily living, depressive symptoms, and vascular factors at baseline.
Abbreviation: OR=odds ratio; CI=confidence interval; aOR=adjusted odds ratio.
* ≤5 h sleep at Phase 7 and ≤5 h at Phase 8;
† 6 h–8 h or ≥9 h sleep at Phase 7 and ≤5 h or <9 h, respectively, at Phase 8;
§ 6 h–8 h sleep at Phase 7 and 6 h –8 h at Phase 8;
¶ ≤5 h or 6 h –8 h sleep at Phase 7 and >5 h or ≥9 h, respectively, at Phase 8;
** ≥9 h sleep at Phase 7 and ≥9 h at Phase 8.

decrease or an increase, from an intermediate sleep duration, are detrimental to seniors' cognition. Furthermore, keeping a longer sleep duration at both phases is also associated with a higher risk of cognitive impairment. Hence, it's necessary to introduce targeted therapies to maintain an intermediate sleep duration for the elderly's cognitive health.

This study was consistent with the findings of prior studies. A study on behalf of middle-aged office staff in London showed that a move from a moderate sleep duration of 6 h–8 h per night to a shortened or lengthened sleep duration was related to worse cognition (*5*). However, in a small sample of 695 elderly Germans reported 6 h–7 h of sleep duration at baseline, only prolonged sleep duration was observed to be related to cognitive impairment (*6*). Meanwhile, national representative data from Mexico suggested that, among individuals who reported moderate sleep duration at baseline, increased sleep duration at follow-up was detrimental to cognitive performance (*7*). On the other hand, reduced sleep duration was related to a higher incidence of all-cause dementia and Alzheimer's disease in a sample of elderly Swiss (*8*).

Currently, the biological mechanisms of sleep and cognition remain unknown. What is certain is that sleep and cognition are mutually influential (*9*). We restricted our sample to individuals without cognitive impairment at baseline in order to reduce recall bias and minimize the likelihood of reverse causation. First, sleep duration may indirectly affect cognitive function through cardiovascular pathways or other underlying health problems such as depression. In the present study, sleep duration changes and cognitive impairment remained relevant after adjusting for cardiovascular diseases and depressive symptoms. Second, an extreme change of sleep duration may mirror poor sleep quality and thus directly affects the formation and accumulation of amyloid-β in the brain, which is a marker of neurodegenerative diseases (*9*).

This study was subject to some limitations. First, instead of using actigraphy, single-item and self-reported measurement was used to assess the sleep duration changes. Nonetheless, most large cohort studies have obtained sleep-related information through self-reporting because of the high cost of objective measurements. Second, although considerable variables have been included in the analyses, other unmeasured or unknown factors are likely to explain the findings, such as other sleep problems.

In conclusion, this study observed that decreased or increased sleep duration at follow-up or maintaining a longer sleep duration was associated with an increased risk of cognitive impairment. Keeping a moderate sleep duration is beneficial for cognitive function. Therefore, we need to pay attention to the sleep health of the elderly and adopt sleep therapy to prevent and delay the development of cognitive impairments.

Conflicts of interest: No conflicts of interest.

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Vital Surveillances

Trends in the Prevalence of Cognitive Impairment Among Older Adults Aged 65 to 105 Years — China, 2002–2018

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ABSTRACT

Introduction: This study aims to analyze trends and subgroup differences in the prevalence of cognitive impairment among older Chinese adults aged 65–105 years from 2002 to 2018.

Methods: Data were drawn from six waves of the Chinese Longitudinal Healthy Longevity Survey (CLHLS). Cognitive function was measured using the Chinese version of the Mini-Mental State Examination (CMMSE). Cognitive impairment was determined by the total CMMSE score and educational attainment of participants. The generalized estimating equation (GEE) models with a logistic link and binominal distribution were performed to assess the secular trend in the prevalence.

Results: The prevalence of cognitive impairment among older adults aged 65–105 years decreased from 3.44% [95% confidence interval (CI): 3.15%–3.73%] in 2002 to 2.41% (95% CI: 2.17%–2.65%) in 2018 in China. The prevalence was slightly higher in women than in men in 2002 (3.71% *vs*. 3.13%, $P<0.05$), and there was no significant difference between women and men in 2018 (2.60% *vs*. 2.21%, $P=0.12$). Rural older adults had a higher prevalence of cognitive impairment before 2014, but their urban counterparts had a higher prevalence in 2018 (2.75% *vs*. 2.06%, $P<0.05$). The GEE regression model showed that each successive year was associated with a 3% reduction in the odds of the prevalence of cognitive impairment [odds ratio (OR)=0.97; 95% CI: 0.97–0.97; $P<0.05$].

Conclusions: The prevalence of cognitive impairment among Chinese older adults aged 65–105 years declined slowly from 2002 to 2018. The gender, urban-rural, age, and regional differences in the prevalence of cognitive impairment changed over time.

Dementia is a clinical syndrome characterized by cognitive impairment, which is the leading cause of disability in people aged ≥65 years worldwide (*1*). A recent nationwide survey showed that approximately 15.07 million older adults aged ≥60 years had dementia between March 2015 and December 2018 in China, accounting for nearly a quarter of the world's patients (*2*). Cognitive impairment is a transitional stage between being cognitively unimpaired and having dementia (*2*). It is estimated that 10% to 15% of mild cognitive impairment develops into Alzheimer's disease every year (*3*). Since there is no cure for dementia, government and medical departments seek identification of and intervention for people with cognitive impairment to prevent the progression to dementia (*2*). Therefore, this study aimed to investigate the trends and subgroup differences in the prevalence of cognitive impairment among Chinese older adults aged ≥65 years over the past 20 years based on a large national sample.

METHODS

Data were drawn from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), whose study design has been published previously (*4*). The survey was conducted in a randomly selected half of the cities/counties from 22 provincial-level administrative divisions (PLADs) in China, covering 85% of the national population (*4*). Considering the consistency and credibility of the age range, older adults aged 65–105 years were selected as participants between 2002 and 2018 in this study.

Face-to-face interviews were conducted in the homes of participants by trained interviewers. Sociodemographic information including gender, age, residence area, PLAD, and years of education was collected. The participants were divided into 2 age groups: 65–79 and 80–105 years. The residence area was divided into urban and rural groups. Education was divided into 3 levels: never attended school, primary school or less (≤6 years of education), and secondary school or more. Cognitive function of participants was measured using the Chinese version of the Mini-Mental State Examination (CMMSE), which consists of 24 items and the total score ranges from 0 to 30 points. Cognitive impairment was defined as the total CMMSE score <18 for participants who never attended school, <21 for participants who received 6 years of education or less, and <25 for participants who received more than 6 years of education (*5*).

This study pooled data from 6 waves to obtain 79,103 observations. Of all the observations, 42.3% had validated CMMSE results, 53.0% had partial items missing, and 4.7% had all items missing. The present study excluded observations with all CMMSE items missing, with missing basic sociodemographic information, or with dementia. Finally, a total of 73,672 observations from 43,956 respondents were included in the analysis. Multiple imputation (5 times) for missing CMMSE items data was performed assuming data were missing at random using chained equations (mice package in R). This study also imputed missing values 10, 15, and 20 times to verify the stability of imputation, and the results showed that the distributions of total CMMSE scores were almost consistent. The prevalence of cognitive impairment was weighted to adjust for sampling probability and nonresponses using weights from the database of each wave. The prevalence showed a 95% confidence interval (CI). The age-standardized prevalence of cognitive impairment was also calculated using national data of adults aged ≥65 years from the 2020 China Statistical Yearbook as the standard population. A chi-square test was used to compare the prevalence between subgroups. In order to address the correlation of repeated measurements of the same participants in different waves, the secular trends in the prevalence of cognitive impairment were assessed using generalized estimating equation (GEE) models with a logistic link and binominal distribution. To examine the overall secular trend in the prevalence, the year was used as a continuous variable in the GEE model (*6*). The models were adjusted for gender, residence area, PLAD, age, and years of education. All *P*-values <0.05 were considered statistically significant. All analyses were performed using R software (version 4.1.0, R Development Core Team, Vienna, Austria).

RESULTS

The total number of observations in this study was 73,672. The proportions of adults aged more than 80 years exceeded 60% in all waves. Women, rural residents, and those never attending school took a preponderance of this study's sample across all waves (Table 1).

The prevalence of cognitive impairment among adults aged 65–105 years decreased from 3.44% (95% CI: 3.15%–3.73%) in 2002 to 2.41% (95% CI: 2.17%–2.65%) in 2018 in China. The prevalence of cognitive impairment was slightly higher in women than in men in 2002 (3.71% *vs*. 3.13%, *P*<0.05), with the largest difference between genders in 2011 (5.82% *vs*. 2.47%, *P*<0.05), while there was no significant difference between genders in 2018 (2.60% *vs*. 2.21%, *P*=0.12). The prevalence of cognitive impairment among older adults in rural areas was higher than that in urban areas before 2014, while prevalence among rural older adults was lower than their urban counterparts in 2018 (2.06% *vs*. 2.75%, *P*<0.05). The

TABLE 1. Characteristics of the sample from six waves of CLHLS.

Subgroups	2002 N=15,307	2005 N=13,959	2008 N=14,521	2011 N=8,703	2014 N=6,386	2018 N=14,696
Women, n (%)	8,659 (56.57)	7,745 (55.48)	8,059 (55.50)	4,633 (53.23)	3,355 (52.54)	8,104 (55.14)
Rural, n (%)	8,279 (54.09)	7,771 (55.67)	8,679 (59.77)	4,582 (52.65)	3,487 (54.60)	6,535 (44.47)
80–105 years, n (%)	10,492 (68.54)	9,079 (65.04)	10,296 (70.90)	5,615 (64.52)	4,099 (64.19)	9,414 (64.06)
Regions, n (%)						
Eastern	7,371 (48.15)	6,431 (46.07)	6,696 (46.11)	4,172 (47.94)	3,093 (48.43)	7,321 (49.82)
Central	3,812 (24.90)	3,520 (25.22)	3,957 (27.25)	2,430 (27.92)	1,844 (28.88)	3,696 (25.15)
Western	4,124 (26.94)	4,008 (28.71)	3,868 (26.64)	2,101 (24.14)	1,449 (22.69)	3,679 (25.03)
Education, n (%)						
Never attended school	9,365 (61.18)	8,314 (59.56)	8,820 (60.74)	4,919 (56.52)	3,535 (55.36)	6,484 (44.12)
Primary school or less	4,404 (28.77)	4,120 (29.52)	4,205 (28.96)	2,769 (31.82)	2,100 (32.88)	5,567 (37.88)
Secondary school or more	1,538 (10.05)	1,525 (10.92)	1,496 (10.30)	1,015 (11.66)	751 (11.76)	2,645 (18.00)
Age, $\bar{x} \pm s$	85.83±11.45	84.94±11.33	86.03±11.00	84.72±10.62	84.48±9.67	84.71±11.22

Abbreviation: CLHLS=Chinese Longitudinal Healthy Longevity Survey.

prevalence among adults aged 80–105 years was always higher than that among those aged 65–79 years, and differences between the 2 age groups decreased from 2002 to 2018. The prevalence among older adults in the eastern region was lower than that in the western and central regions in 2002 (2.85% *vs.* 3.54% *vs.* 4.39%, P<0.05), while in 2018, the western was lower than the central and eastern regions (1.74% *vs.* 2.55% *vs.* 2.66%, P<0.05). Trends and subgroup differences in the age-standardized prevalence were similar to those in the crude prevalence (Figures 1–2).

The GEE regression model showed that each successive year was associated with a 3% reduction in the odds of the prevalence of cognitive impairment [odds ratio (OR)=0.97; 95% CI: 0.97–0.97; P<0.05] after adjusting for gender, residence area, PLAD, age, and years of education. The decreasing trends in the prevalence over time were similar across subgroups (Table 2).

DISCUSSION

This study found that the prevalence of cognitive impairment among Chinese older adults aged ≥65 years showed a slow decline from 2002 to 2018, with the prevalence ranging from 2.41% to 4.17%. A study showed a similar decline trend of over 50% among adults aged 65 years and older in the UK from 1991 to 2011 (*7*). However, a study in Brazil has shown an increase in the prevalence of cognitive impairment among people aged 60 years and older from 2000 to 2015 (*8*). The differences in trends of prevalence across countries may be related to their respective social contexts and testing measures, which requires further analysis in future research. One important finding in this study was that the prevalence among older adults aged over 80 years continuously decreased from 2002 to 2018, which may be attributed primarily to generational differences (*9*).

The prevalence of cognitive impairment from this study (2.41%–4.17%) was much lower than that of Guo et al. (10.4%–14.7%) and Kuang et al. (7.06%–11.56%) (*10*–*11*). There are three potential reasons. First, cognitive impairment was defined as the CMMSE score <24 by Guo and <18 by Kuang et al. CMMSE score <24 could overestimate the prevalence, and the score <18 could underestimate it, compared with this study. Second, the unweighted sample would overestimate the prevalence due to the oversampling of older adults aged ≥80 years in the CLHLS. Third, there were differences in the data processing. "Unable to answer" in the questionnaire was considered as incorrect answers for CMMSE items so that the total CMMSE score of observations tended to be lower,

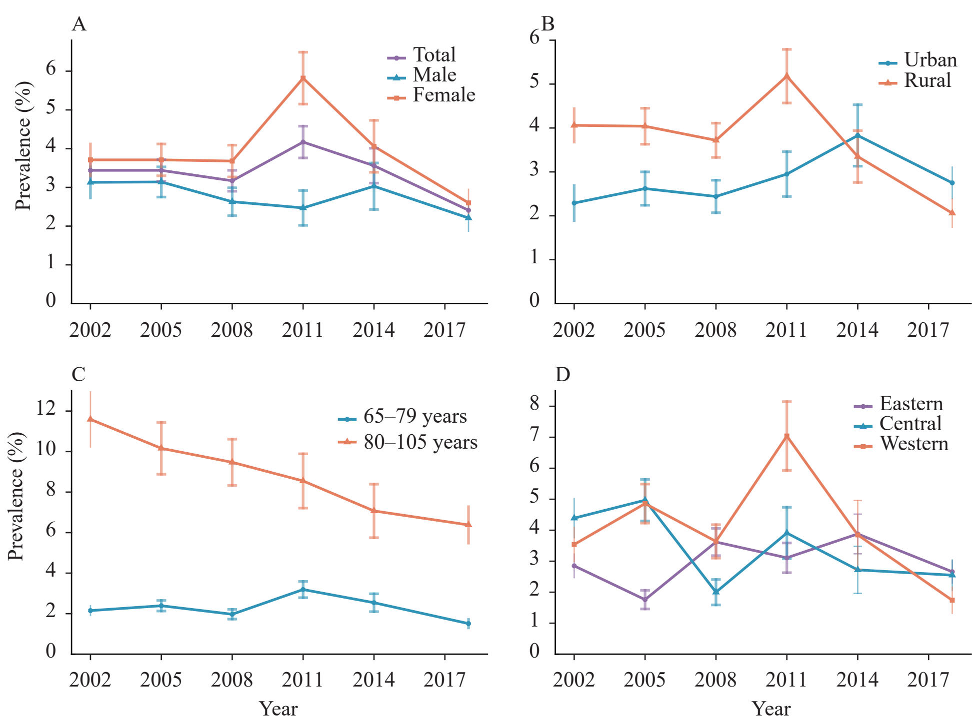

FIGURE 1. Trends in the prevalence of cognitive impairment among Chinese older adults aged 65–105 years by (A) gender, (B) residence area, (C) year group, and (D) region from 2002 to 2018.

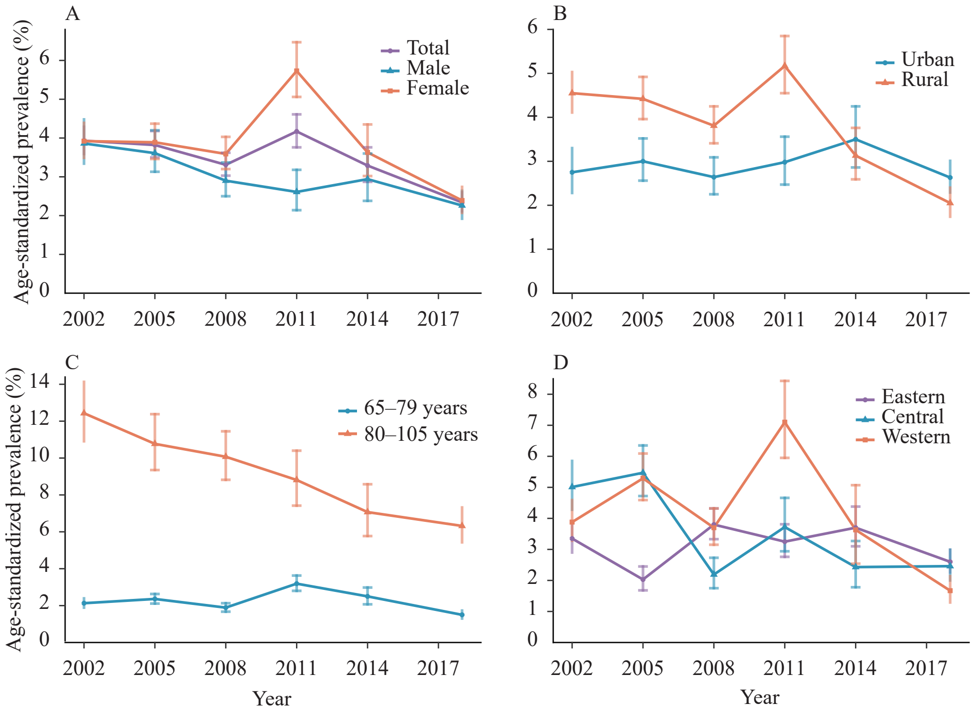

FIGURE 2. Trends in the age-standardized prevalence of cognitive impairment among Chinese older adults aged 65–105 years by (A) gender, (B) residence area, (C) year group, and (D) region from 2002 to 2018.

TABLE 2. OR and 95% CI of cognitive impairment related to year in different subgroups from generalized estimating equation models.

Subgroups	OR (95% CI)	*P* value
Total *	0.97 (0.97–0.97)	<0.001
Gender †		
Male	0.97 (0.97–0.97)	<0.001
Female	0.97 (0.97–0.97)	<0.001
Area §		
Urban	0.98 (0.98–0.98)	<0.001
Rural	0.96 (0.96–0.96)	<0.001
Age group ¶		
65–79 years	0.98 (0.98–0.98)	0.002
80–105 years	0.97 (0.97–0.97)	<0.001
Region **		
Eastern	0.98 (0.98–0.98)	<0.001
Central	0.96 (0.96–0.96)	<0.001
Western	0.96 (0.96–0.96)	<0.001

Abbreviation: OR=odd ratio; CI=confidence interval; PLAD=provincial-level administrative divisions.
* Adjusted for gender, area, age, PLAD, and years of education.
† Adjusted for area, age, PLAD, and years of education.
§ Adjusted for gender, age, PLAD, and years of education.
¶ Adjusted for gender, area, PLAD, and years of education.
** Adjusted for gender, area, age, and years of education.

resulting in an overestimation of the prevalence.

Consistent with a previous study (*12*), this study found that the prevalence of cognitive impairment among women was higher than that among men, possibly related to the lack of estrogen in older women (*13*). In addition, the difference in educational attainment between men and women in the past may also be an important reason for the gender difference in the prevalence of cognitive impairment (*9*). The prevalence among rural older adults was higher than that among urban adults before 2014, which was consistent with a previous study (*12*). Yet the prevalence among urban older adults was higher than that among rural older adults in 2018. The potential reasons need to be explored in future studies. In accordance with previous studies (*12*, *14*), this study also observed that the prevalence among older adults aged 80–105 years was higher than that among those aged 65–79 years — since the incidence of cognitive impairment usually rises with age (*15*). A previous review showed that the prevalence of cognitive impairment among older adults in the western region was higher than that in the eastern region (*12*), which was echoed by this investigation's findings of east-west differences before 2014. Moreover, this study also found a rapid decline in the prevalence in the western region from 2011 to 2018 and thus a higher prevalence in the eastern region than that in the western region in 2018. As only four western provinces were included in analysis, it may not be representative of the older population in the entire western region. The regional differences in the prevalence need further research.

This study has several limitations. First, as mentioned above, the findings from this study may not be representative enough for older adults in the western region, because eight provinces in the western region were not included in the CLHLS. Second, the measurement of cognitive impairment was only screening based on the CMMSE rather than clinical diagnosis, which may overestimate the prevalence of cognitive impairment (*14*). Third, although multiple imputation could be used to provide unbiased estimates with improved efficiency based on the assumption of missing at random (*16*), this study could not ensure that all variables related to missingness were included in the imputation models.

In conclusion, the present study found that the prevalence of cognitive impairment among Chinese older adults aged 65–105 years declined slowly from 2002 to 2018. The gender, urban-rural, age, and regional differences in the prevalence changed over time. However, with an aging population, there are still heavy disease burdens of cognitive impairment in China. How to prevent and intervene in the occurrence and development of cognitive impairment, and improve the life quality of older adults deserves serious consideration by government personnel and researchers.

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