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Longitudinal relationship between healthy lifestyle and cognitive function mediated by activities of daily living among middle-aged and older Chinese adults

Zheng Ren[1] · Li Cui[2] · Yixuan Liu[2] · Minfu He[2] · Wenjun Li[2] · Ziqiang Chen[2] · Wenjing Zhang[2] · Yachen Wei[2] · Yibing Chen[2] · Ranran Li[2] · Xinyu Gao[2] · Hongjian Liu[3] · Xiumin Zhang[2]

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Abstract

It has been demonstrated that a healthy lifestyle affects cognitive function in middle-aged and older adults, while the role of activities of daily living (ADL) has not been investigated. This study was based on the China Health and Retirement Longitudinal Study (CHARLS) from the first wave (2011) to the third wave (2015), aiming to examine the mediating role of ADL in this relationship. The sample included 13,227 middle-aged and older adults who participated in the three wave surveys. A battery of tests, including episodic memory and executive function, were used to evaluate cognitive function, and ten variables, including BMI, exercise and other variables were employed to construct healthy lifestyle indicators. A cross-lagged model was utilized to confirm the mediating effect of ADL between healthy lifestyle and cognitive function. The results revealed that T1 healthy lifestyle had a significant negative prediction for T2 ADL (β =-0.051, $P<0.001$). T1 ADL significantly negatively predicted T2 health lifestyle (β = -0.052, $P<0.001$). T1 cognitive function significantly negatively predicted T2 ADL (β =-0.032, $P<0.001$). T2 ADL significantly negatively predicted T3 cognitive function (β = -0.103, $P<0.001$). T2 cognitive function significantly negatively predicted T3 ADL (β = -0.003, $P<0.001$). After adjustment for covariates, T2 ADL negatively mediated the association between T1 healthy lifestyle (β = -0.118, $P<0.001$) and T3 cognitive function (β = -0.215, $P<0.001$). The model explained 8.2% of the variance in T3 cognitive function. More healthy lifestyles are the protective factors for cognitive impairment and partially benefit work through better ADL ability.

Keywords Activities of daily living · Cognition function · Healthy lifestyle · Middle-aged and elderly

Introduction

The brain functions gradually decline with the increase of age, which may lead to a large number of elderly people at a high risk of cognitive impairment, featured by the decline of language, attention, memory and other cognitive functions (Gao et al., 2017). One of the characteristics that distinguish people with cognitive decline from other normal older people is that if they do not take timely intervention measures for development, their cognitive state will develop into mild cognitive impairment (MCI) and even dementia, an irreversible neurodegenerative disease. A nationally representative and large-scale survey found that the overall prevalence of dementia and MCI among individuals aged 60 and over was 6.0% and 15.5% in China, respectively (Jia et al., 2020). Moreover, the impaired cognitive function of the elderly significantly increases the risk of disability and dementia, reduces the quality of life, and further brings a huge cost of care and financial burden to families and society (Liang et al., 2022; Winblad et al., 2016). Thus, it is important to identify risk factors for cognitive impairment

Zheng Ren and Li Cui contributed equally to this work.

✉ Xiumin Zhang
xiu_min@jlu.edu.cn; zhangxiumin63@163.com

1 School of Politics and Public Administration, Guangxi Normal University, Guilin 541006, Guangxi, China

2 Department of Social Medicine and Health Management, School of Public Health, Jilin University, Changchun, China

3 Department of Epidemiology and Biostatistics, School of Public Health, Jilin University, Changchun, China

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and early intervention to improve or delay the development of the disease among older adults.

The rate of cognitive decline related to aging varies greatly, which may be explained by many factors, including environmental factors, lifestyle and molecular background of potential brain changes (Aarsland et al., 2020). About 35% of dementia is caused by nine factors: social isolation, smoking, physical inactivity, diabetes, late-life depression, hearing loss, obesity, midlife hypertension, and less education in early life (Livingston et al., 2017). Most of the above factors are related to lifestyle. Individual lifestyle factors are often perceived as modifiable and malleable and have been increasingly targeted to prevent cognitive impairment. According to the Social Determinants of Health model, increasing research is now focusing on the effects of various healthy lifestyles on cognitive function. Numerous studies show that adopting more healthy lifestyles promotes cognitive function, such as participating in social activities (Gorenko et al., 2021), performing moderate physical exercise (Bherer, 2015; Young et al., 2015), moderate sleep duration (Scullin & Bliwise, 2015), ingesting balanced dietary components (Ozawa et al., 2021), keeping moderate gait (Cohen et al., 2016; Gorenko et al., 2021), maintaining weight within the normal range (Dye et al., 2017) and other factors about healthy lifestyles among middle-aged and older adults. However, smoking and alcohol consumption have been found to exert opposite effects on cognitive function: smoking increases the risk of dementia, while moderate drinking (especially red wine) seems to be beneficial in preventing this risk (Nooyens et al., 2008, 2014). Generally speaking, a variety of unhealthy lifestyle changes may help middle-aged and elderly people avoid the rapid development of cognitive impairment.

Physical and cognitive functions serve as two significant aspects of aging health, and maintaining the two at a high level plays an important role in improving autonomy and achieving success in aging. As one of the important indicators to measure physical function (Cao et al., 2021), activities of daily living (ADL) refers to the basic activities that must be conducted by an individual to survive and adapt to the environment. It is common to see ADL disability in middle-aged and elders because physical and mental functions are progressively decline. The prevalence rate of functional disability in older Chinese adults was estimated to be 26.2% in 2021 (Zheng et al., 2022). Individuals with ADL disability have poor self-care ability and a low degree of social interaction. In this case, their physical functions decline rapidly, which causes the decline of cognitive function. Previous studies have confirmed that ADL disability provides a distinguished contribution to risk for incident dementia (Fauth et al., 2013). Also, the results from a Chinese Longitudinal Healthy Longevity Survey found that baseline ADL limitation strongly predicted the incidence of cognitive impairment in Chinese people over 80 years old, and that a ‘dose-response’ relationship existed (Zheng et al., 2016).

However, a healthy lifestyle may prevent disability for adults, and a series of results indicate that combined changes in lifestyle are likely to help to delay the occurrence of disability or function deterioration in late life (Lee et al., 2013; Lee & Park, 2006). Results from a longitudinal survey have also found taking part in leisure activities, including walking and playing in a ball game, has a connection with a lower risk of ADL disability in middle-aged adults (Monma et al., 2016). The mechanism of this relationship is leisure activities are likely to strengthen social participation and positive emotions, playing an important role in delaying the development of chronic diseases and physical limitations. The ‘use it or lose it’ theory proposes that leading a more active and engaged lifestyle can be cognitively protective (Hultsch et al., 1999). Adelirad et al. (2022) found that maintaining activity participation, particularly high-effort leisure activities, is a part of a healthy lifestyle which is likely to prevent cognitive impairment and imbalance. However, few studies have clarified the role of ADL in the relationship between healthy lifestyle and cognitive function through longitudinal study design. Based on the existing research, it is hypothesized that ADL may play a mediating role in the longitudinal relationship between healthy lifestyle and cognitive function.

Given that cognitive impairment in late life can negatively affect the quality of life of an individual and bring a huge burden to caregivers, it is thought that primary prevention focusing on lifestyle change can contribute much to extending active life expectancy. To sum up, to explore the connection between healthy lifestyle and cognitive function and the mediation effect of ADL, the research derived three-wave longitudinal data on middle-aged and older adults aged 45 and above from the China Health and Retirement Longitudinal Study (CHARLS).

Methods

Study design and sample

This study is based on data from the CHARLS, which is a national and longitudinal survey conducted every 2 years among individuals aged 45 and above in China and provides nationally representative panel data (Zhao et al., 2014). The CHARLS used a multistage probability sampling approach to select a nationally representative sample, and the baseline survey was conducted in 2011. This study screened participants aged 45 and above from CHARLS 2011–2015 datasets, which considered the preset key variables.

Participants received home interviews in the 2011 wave, 2013 wave, and 2015 wave. There were 17,708 participants in the 2011 wave. By the 2013 wave, 2509 subjects were lost or died. During the follow-up period of the 2015 wave, 1614 subjects were lost or died. Ultimately, after excluding participants under the age of 45 in the 2011 wave, 13,227 participants were included in this study. The reasons for dropout and the structure of the analytical sample included in each measurement wave are illustrated in Fig. 1. All participants provided written informed consent, and the Biomedical Ethics Review Committee of Peking University approved CHARLS (IRB00001052-11015).

Measures

Healthy lifestyle

Ten variables, including smoking, alcohol consumption, night sleep duration, nap duration, moderate-intensity physical activity, high-intensity physical activity, social activity, waist-to-height ratio, waist circumference, and body mass index (BMI), were included in this study as indicators of healthy lifestyle. The number of healthy lifestyles (range: 0–10) was analyzed as continuous variables. Mild-intensity physical activity was not included because it had a missing value of 60% or more.

Participants were regarded as smokers if they still used tobacco or had quit smoking, and those who never smoked cigarettes/cigars were regarded as non-smokers, whereas non-smokers were considered participants who had a healthy lifestyle (Ding et al., 2020). Participants were

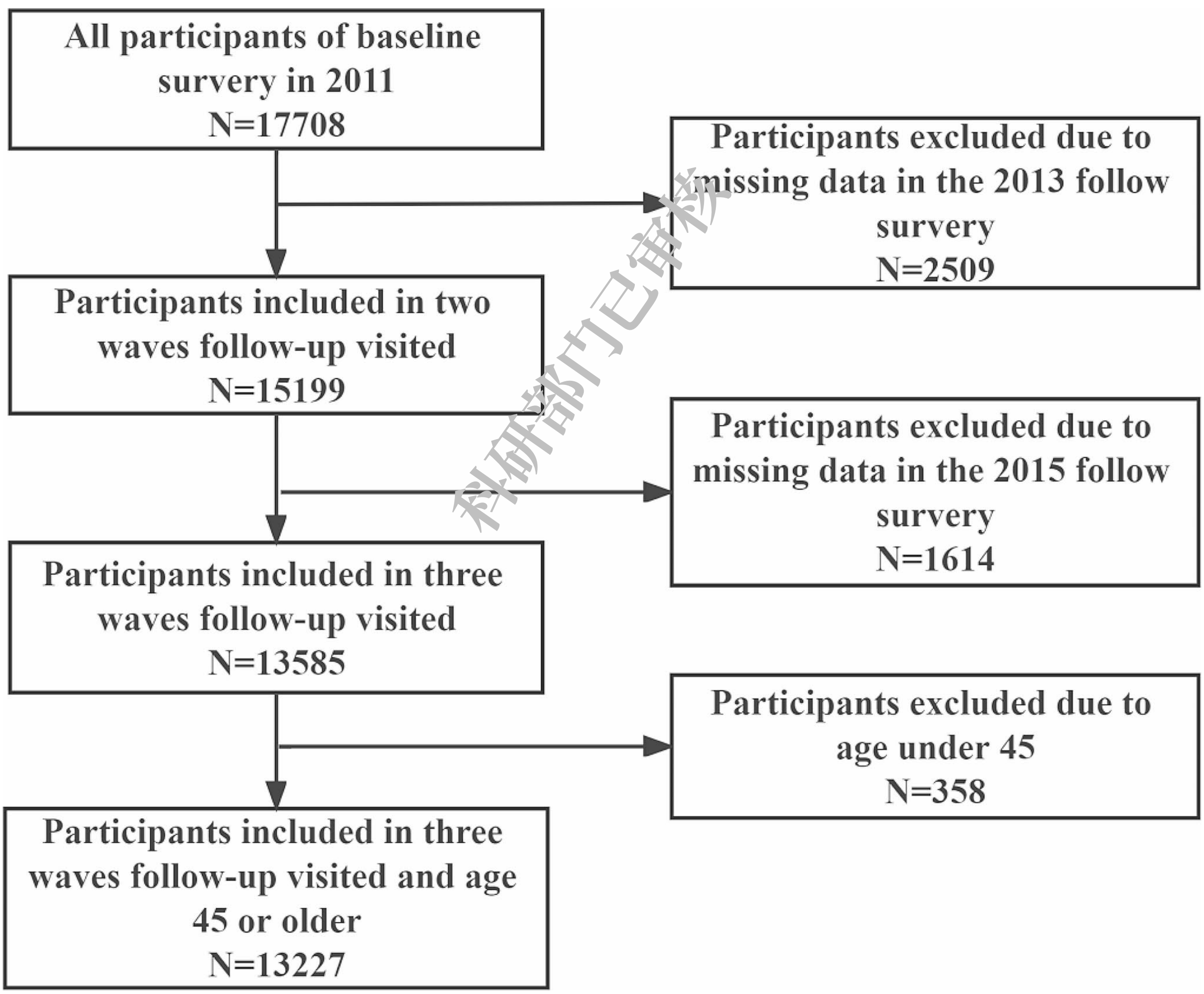

Fig. 1 Detailed steps for selecting the study observations

thought of as drinkers if they drank in the past year, and those who did not drink were regarded as non-drinkers, whereas non-drinkers were considered participants who had a healthy lifestyle. The question "How many hours (average hours) did you sleep at night in the past month?" was used to calculate night sleep duration. Sleeping at night for 7–9 h was regarded as a healthy lifestyle (Garcia-Perdomo et al., 2019). The question "How long did you take a nap after lunch in the past month?" was utilized to calculate nap duration. Napping for ≤ 60 min was regarded as a healthy lifestyle (Wang et al., 2020). Participants who participated in high-intensity and moderate-intensity physical activities for at least 10 min continuously were considered a healthy lifestyle. Participants who participated in any social activity were considered to participate in social activities, otherwise, they were thought not to participate in social activities, where participation in social activities was considered a healthy lifestyle.

Body mass index (BMI) is obtained by dividing the kilograms of weight by the square of meters in height. Normal BMI (18.5 $kg/m^2 \leq$ BMI $<$ 24.0 kg/m^2) was thought as a healthy lifestyle (Jia et al., 2010). A healthy lifestyle was considered if the waist circumference of male participants was less than 85 cm and that of female participants was less than 80 cm (Ashwell & Gibson, 2014). Normal waist-to-height ratio (WHtR $\leq$ 0.5) was considered a healthy lifestyle (Lu et al., 2021).

Cognitive function

A questionnaire was designed by CHARLS to assess two measures of cognitive function, namely executive function and episodic memory. Executive function was measured according to the mental status components from the Telephone Interview of Cognitive Status (TICS). The TICS components consisted of today's date, day of the week and serially subtraction of 7 from 100 (5 times). In figure drawing, participants were asked to redraw a picture from one painting. We calculated executive function as the total score from TICS and figure drawing, ranging from 0 to 11. Episodic memory is based on the ability to immediately repeat in any order ten Chinese nouns (immediate word recall) and recall the same list of words a few minutes later (delayed recall). We form an episodic memory measure as the average of immediate and delayed recall scores. The cognitive function score was the sum of episodic memory and executive function, with a higher score indicating a better cognitive function (range: 0–21) (Li et al., 2022).

Activities of daily living

Daily living skills were measured using the Katz index, including the following series of questions: controlling urination and defecation, using the toilet, getting into or out of bed, eating, bathing or showering, and dressing. The response scale contained four options: (1) No, I don't have any difficulty; (2) I have difficulty but can still do it; (3) Yes, I have difficulty and need help; and (4) I cannot do it. Participants classified as ADL independent had the ability to complete all the activities without difficulty, while those with difficulty on any of the above items were considered to have ADL disability (Ferrucci et al., 1996).

Covariates

Covariates included age (45–59 or $\geq$60), gender (male or female), marital status (have a spouse or no spouse), educational level (illiterate or non-illiterate), income (have income or no income), medical insurance participation (yes or no), self-rated health (healthy or unhealthy), hypertension (yes or no), diabetes (yes or no), cardiovascular and cerebrovascular diseases (yes or no), and depressive symptoms (yes or no). The self-rated health (SRH) used two groups, given different sets of response options by two questions "Would you say your health is very good, good, fair, poor or very poor?" and "Would you say your health is extremely good, very good, good, fair or poor?". Both scales were accommodated by quantifying SRH as 1 = excellent, 2 = very good, etc., until 6 = very poor. The values of the two assessments were averaged, followed by creating a dichotomous measure where participants were considered healthy participants when the mean SRH $<$ 4.5 and unhealthy participants when the mean SRH $\geq$ 4.5 (Lu et al., 2021). The participants were asked whether they had been diagnosed with cardiovascular and cerebrovascular diseases, diabetes and hypertension, and those who answered "yes" were considered to have cardiovascular and cerebrovascular diseases, diabetes and hypertension. The 10-item Center for Epidemiologic Studies Depression Scale (CESD-10) was used to measure the depressive symptoms (Andresen et al., 1994). The participants were asked about the number of days they experienced per item in the prior week. The negative effect items were rated from 0 (rarely or never; less than 1 day) to 3 (most or all of the time; 5–7 days), while the positive effect items were reversed. The scores of the CESD-10 range from 0 to 30, in which a higher score indicates a higher level of depressive symptoms. In this study, participants with a CESD-10 score of at least 10 can be considered as having depressive symptoms (Guo et al., 2017).

Data analysis

After the collinearity test, it was found that all the variables were not collinear. The internal relationship among the variables was investigated using Pearson correlation analysis. After adjustment for covariates, the mediation of ADL between healthy lifestyle and cognitive function was explored by using the cross-lagged panel model. The SPSS macro program PROCESS was utilized to verify the intermediary effect analysis of ADL between healthy lifestyle and cognitive function. All *P*-values were two-sided, and $P < 0.05$ revealed statistical significance. Statistical Product and Service Solutions (SPSS) version 24.0 (IBM Corp, Armonk, New York, USA) and Mplus version 8.0 were employed for all the analyses.

Results

Sample characteristics and cognitive impairment

Table 1 shows the descriptive analysis of each variable. There were a total of 13,227 participants, of whom 53.1% were females, more than a quarter (27.9%) were illiterate and less than 20% reported that they had income. Among these participants, most participated in medical insurance, and more than 70% said that they were in good self-rated health. In addition, 23.6% were diagnosed with hypertension, 5.5% were diagnosed with diabetes, and 11.6% were diagnosed with cardiovascular and cerebrovascular diseases. In this study, the overall proportion of participants with depressive symptoms was 37.1%, 32.3% and 35.6% in the 2011 wave, 2013 wave and 2015 wave, respectively. Table 1 presents other information.

Correlations among study variables

Three waves of healthy lifestyle, ADL and cognitive function were all positively related to other waves (*r* is from 0.30 to 0.92, $P < 0.001$). T1-T3 healthy lifestyle was negatively related to T1-T3 ADL (*r* is from −0.28 to -0.05, $P < 0.001$), T1-T3 healthy lifestyle was positively related to T1-T3 cognitive function (*r* is from 0.04 to 0.28, $P < 0.001$), and T1-T3 ADL was negatively related to T1-T3 cognitive function (*r* is from −0.21 to -0.13, $P < 0.001$). Details are given in Table 2.

Table 1 Characteristics of all participants from 2011 to 2015 (*N*=13,227)

Variables		2011 wave	2013 wave	2015 wave
		n (%)	*n* (%)	*n* (%)
Demography characteristics				
Gender	Male	6204(46.9)	6204(46.9)	6204(46.9)
	Female	7023(53.1)	7023(53.1)	7023(53.1)
Age (years)	45–59	7508(56.8)	6394(48.3)	5236(39.6)
	≥ 60	5719(43.2)	6833(51.7)	7991(60.4)
Marital status	Have a spouse	11,702(88.5)	11,474(86.8)	11,223(84.8)
	No spouse	1525(11.5)	1728(13.2)	1980(15.2)
Educational level	Illiterate	3684(27.9)	3684(27.9)	3684(27.9)
	Non-illiterate	9543(72.1)	9543(72.1)	9543(72.1)
Income	Have income	2167(16.4)	2555(19.3)	2448(18.5)
	No income	11,060(83.6)	10,672(80.7)	10,779(81.5)
Medical insurance participation	Yes	12,451(94.1)	12,796(96.7)	12,796(96.7)
	No	776(5.9)	431(3.3)	431(3.3)
Health status				
Self-rated health	Healthy	9359(70.8)	9577(72.4)	9527(72.0)
	Unhealthy	3868(29.2)	3650(27.6)	3700(28.0)
Hypertension	Yes	3118(23.6)	3118(23.6)	3118(23.6)
	No	10,109(72.4)	10,109(72.4)	10,109(72.4)
Diabetes	Yes	722(5.5)	722(5.5)	722(5.5)
	No	12,505(94.5)	12,505(94.5)	12,505(94.5)
Cardiovascular and cerebrovascular diseases	Yes	1539(11.6)	1539(11.6)	1539(11.6)
	No	11,688(88.4)	11,688(88.4)	11,688(88.4)
ADL disability	Yes	2721(20.6)	2410(18.2)	2942(22.2)
	No	10,506(79.4)	10,817(81.8)	10,285(77.8)
Depressive symptoms	Yes	4902(37.1)	4273(32.3)	4704(35.6)
	No	8325(62.9)	8954(67.7)	8523(64.4)

Table 2 Correlations between healthy lifestyle, ADL and cognitive function from 2011 to 2015 (N=13,227)

Variables	The number of healthy lifestyles			ADL			Cognitive function		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
The number of healthy lifestyles									
T1	—								
T2	0.42***	—							
T3	0.42***	0.47***	—						
ADL									
T1	-0.28***	-0.11***	-0.11***	—					
T2	-0.14***	-0.07***	-0.08***	0.31***	—				
T3	-0.12***	-0.05***	-0.07***	0.30***	0.92***	—			
Cognitive function									
T1	0.28***	0.05***	0.04***	-0.19***	-0.15***	-0.14***	—		
T2	0.12***	0.06***	0.11***	-0.16***	-0.13***	-0.13***	0.63***	—	
T3	0.23***	0.12***	0.06***	-0.21***	-0.17***	-0.16***	0.67***	0.69***	—

Note: T1: 2011 wave, T2: 2013 wave, T3: 2015 wave, $^{***}P < 0.001$

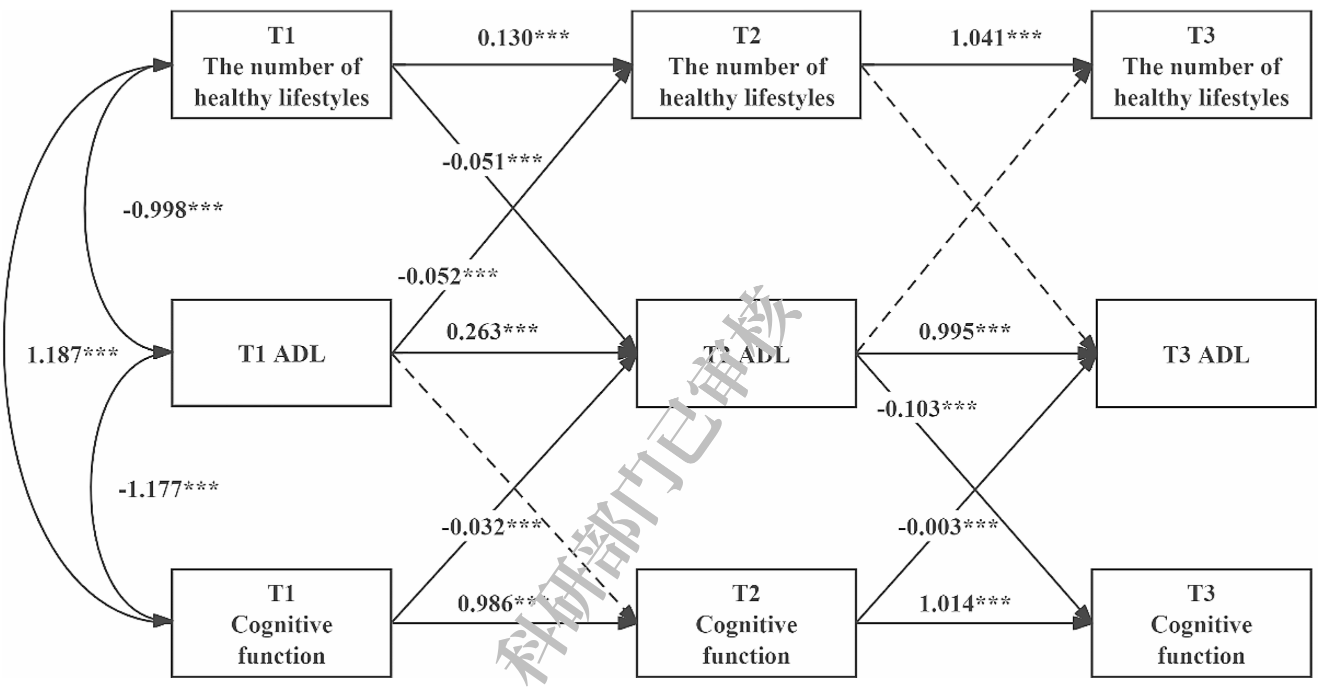

Fig. 2 Cross-lagged model of healthy lifestyle, ADL and cognitive function between T1, T2 and T3. Note: The results adjusted for covariates. T1: 2011 wave, T2: 2013 wave, T3: 2015 wave, $^{***}P < 0.001$

The mediation of ADL between healthy lifestyle and cognitive function

To investigate the mediation of ADL between healthy lifestyle and cognitive function from 2011 to 2015, an explicit variable model version of the cross-lagged panel model was implemented. Figure 2 shows the full model results of autoregressive and cross-lagged paths after adjustment for covariates. This model employed the T1, T2 and T3 data of the measured variables. It was found the model had good fit indexes (χ^2/df=30.802, CFI=0.939, TLI=0.923, RMSEA=0.047). Healthy lifestyle, ADL and cognitive function all presented moderate stability at the two-time points, in which autoregressive coefficients ranged from 0.130 to 1.041. In the cross-regression path analysis, it is revealed that T1 healthy lifestyle had a significant negative prediction for T2 ADL (β =-0.051, $P<0.001$). T1 ADL significantly negatively predicted T2 health lifestyle (β = -0.052, $P<0.001$). T1 cognitive function significantly negatively predicted T2 ADL (β =-0.032, $P<0.001$). T2 ADL significantly negatively predicted T3 cognitive function (β = -0.103, $P<0.001$). T2 cognitive function significantly negatively predicted T3 ADL (β = -0.003, $P<0.001$).

A longitudinal mediation model was used to examine whether T2 ADL mediated the association between T1 healthy lifestyle and T3 cognitive function. Table 3 and Fig. 3

Table 3 2013 ADL mediated longitudinally between 2011 healthy lifestyle and 2015 cognitive function after adjustment for covariates ($N = 13,227$)

Model		β	SE	T	95% CI		R^2	F	*P*
					LLCI	ULCI			
M-T2							0.049	56.577	< 0.001
	Constant	7.391	0.224	33.001	6.952	7.830			
	X-T1	-0.118	0.008	-15.147	-0.133	-0.103			
	Age	0.288	0.031	9.310	0.227	0.348			
	Gender	-0.022	0.031	-0.718	-0.083	0.038			
	Education	-0.254	0.035	-7.384	-0.322	-0.187			
	Marital status	0.169	0.046	3.664	0.079	0.259			
	Income	0.141	0.040	3.505	0.062	0.220			
	Medical insurance participation	0.133	0.060	2.196	0.014	0.251			
	Self-rated health	-0.004	0.016	-0.256	-0.034	0.026			
	Hypertension	-0.166	0.035	-4.734	-0.235	-0.097			
	Cardiovascular and cerebrovascular diseases	-0.125	0.064	-1.975	-0.250	-0.001			
	Diabetes	-0.114	0.046	-2.510	-0.204	-0.025			
	Depressive symptoms	-0.031	0.029	-1.044	-0.088	0.027			
Y-T3							0.302	438.862	< 0.001
	Constant	10.558	0.503	20.989	9.572	11.544			
	X-T1	0.285	0.017	16.873	0.252	0.319			
	M-T2	-0.215	0.019	-11.461	-0.252	-0.178			
	Age	-1.039	0.067	-15.521	-1.170	-0.908			
	Gender	-0.372	0.067	-5.583	-0.502	-0.241			
	Education	3.850	0.075	51.644	3.704	3.996			
	Marital status	-0.668	0.100	-6.708	-0.863	-0.473			
	Income	-0.932	0.087	-10.704	-1.102	-0.761			
	Medicare participation	-0.409	0.130	-3.136	-0.664	-0.153			
	Self-rated health	-0.025	0.033	-0.751	-0.091	0.040			
	Hypertension	-0.239	0.076	-3.159	-0.388	-0.091			
	Cardiovascular and cerebrovascular diseases	-0.358	0.137	-2.610	-0.626	-0.089			
	Diabetes	-0.420	0.098	-4.270	-0.613	-0.227			
	Depressive symptoms	0.066	0.063	1.036	-0.058	0.190			

Note: T1: 2011 wave, T2: 2013 wave, T3: 2015 wave. X: The number of healthy lifestyles, M: ADL, Y: Cognitive function

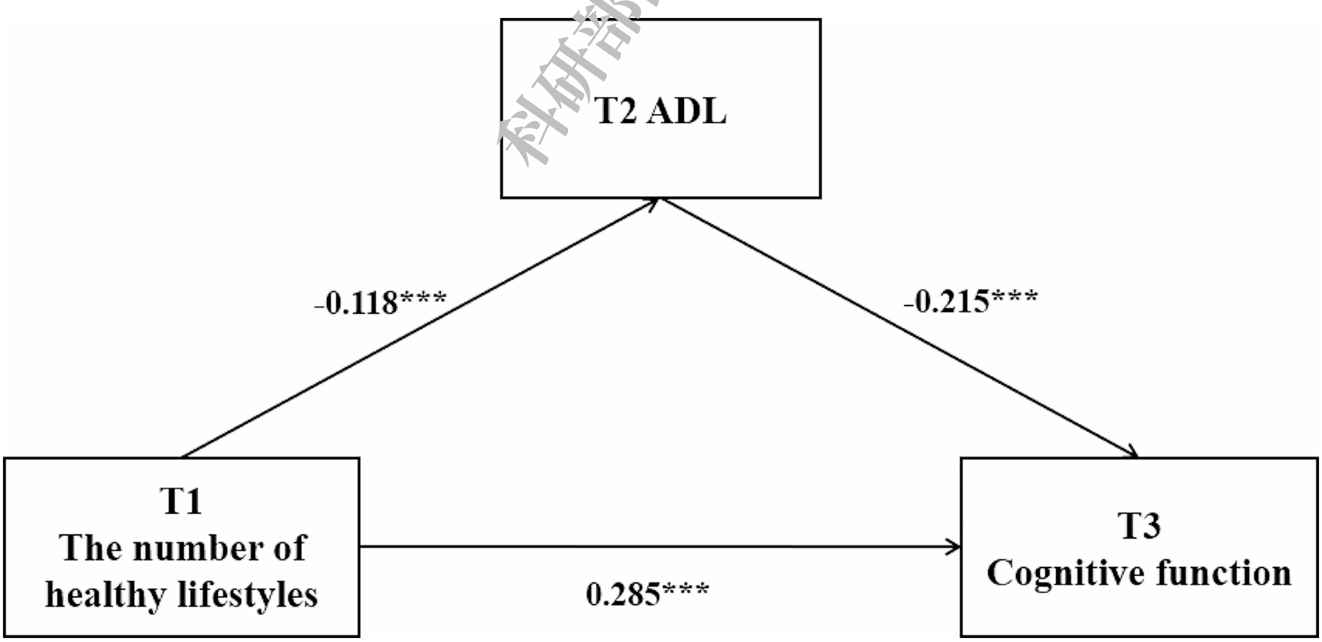

Fig. 3 2013 ADL mediated longitudinally between 2011 healthy lifestyle and 2015 cognitive function. Note: The results adjusted for covariates. T1: 2011 wave, T2: 2013 wave, T3: 2015 wave, ***$P < 0.001$

display the testing results, which show that after adjustment for covariates, T2 ADL negatively mediated the association between T1 healthy lifestyle (β = -0.118, $P<0.001$) and T3 cognitive function (β = -0.215, $P<0.001$). The model explained 8.2% of the variance in T3 cognitive function.

Discussion

This large-scale study estimated the mediating effect of ADL between healthy lifestyle and cognitive function over a 4-year follow-up period. Among middle-aged and older Chinese adults, healthy lifestyle was associated with cognitive function through ADL ability. This finding suggests that increasing the number of healthy lifestyles promotes ADL capacity and improves cognitive function by promoting ADL capacity. Given that China is currently experiencing rapid population aging with increased long-term care costs and the economic burden of ADL disability and dementia, middle-aged and older adults with ADL disability and cognitive impairment need physical rehabilitation and maintain a healthy lifestyle to protect against adverse effects on cognition status. This result may provide a scientific basis for authorities to develop a programme that can promote cognitive function among middle-aged and older adults.

A healthy lifestyle promotes cognitive function in middle-aged and older adults

In this study, the correlation analysis demonstrated that with an increase in the number of healthy lifestyles, the cognitive function of middle-aged and older Chinese adults became better. Some studies have shown that healthy eating habits, outdoor activity (Wang et al., 2021), gait velocity, social engagement (Gorenko et al., 2021) and BMI (Gelber et al., 2012) can mitigate the development of cognitive impairment or reduce its risk. Physical activity can improve the level of cardiorespiratory fitness, reduce some inflammatory cytokines, increase maximal oxygen uptake and neurotrophins, and induce central and peripheral growth factors (Tsai et al., 2019). Siesta (afternoon nap or rest) seems to offer neuroprotective benefits and can help individuals decrease fatigue from exercise and restore energy for engaging in more physical activities. Qian et al. (2020) have also reported that combinations of physical activity and siesta could decrease the cognitive impairment risk to the largest extent. However, an unhealthy lifestyle may exert a negative impact on brain structure, such as increasing oxidative damage, reducing antithrombotic, anti-inflammatory effects, and cerebral blood flow (Anstey et al., 2009; Blondell et al., 2014; Lourida et al., 2019), hence resulting in the decline of cognitive ability and even cognitive impairment of the elderly. For example, smoking can lead to lower hippocampal and dorsolateral prefrontal brain volumes (Schneider et al., 2014), which can affect cognitive function, and drinking can injure the frontal cortex, which is closely related to cognitive ability (Topiwala & Ebmeier, 2018).

In this study, it was found that people with better cognitive function instead reduced their healthy lifestyle (data were not shown). The reason for this result may be that middle-aged and older adults with better cognitive function believe that they are in better health than those with poorer cognitive function and are not yet threatened by cognitive impairment or dementia, and thus do not focus on making healthy lifestyle changes. Therefore, it also indicates the necessity of health education among healthy people, which enables them to realize the importance of maintaining healthy lifestyles for disease prevention.

The effect of a healthy lifestyle on cognitive function was mediated by ADL

Previous studies have found that sustaining healthy lifestyles, such as smoking and drinking cessation, healthy weight (Lee et al., 2013), regular aerobic activity, short-term exercise programs (Paterson & Warburton, 2010), keeping domestic animals or pets, and watching TV or listening to the radio (Li et al., 2020), are more likely to maintain ADL function independence. In addition, the number of healthy lifestyles, such as controlling the frequency of smoking and drinking, exercising and maintaining good sleep time, can improve the level of ADL or delay the onset of ADL disability by reducing the risk of chronic diseases.

Previous studies have found that better ADL function is likewise related to better cognitive function. A nest case-control study with a period of 3 years among Chinese adults over 60 years found that the cognitive function scores of older adults with impairment ADL were higher than those of older adults without impairment and that the risk of mild cognitive impairment was higher among older adults with impairment ADL (Yang et al., 2012). A cross-sectional study of Chinese community-dwelling older adults aged 60 years and older revealed that the occurrence of cognitive decline among the elderly was affected by the level of ADL (Xiao et al., 2021). With the decrease in ADL levels, the range of life and activities among the elderly was narrowed, and the opportunities for communication with others were reduced, which led to the reduction of effective stimulation needed by the human brain, thereby accelerating the decline of cognitive function (Zhang et al., 2021). The decline of cognitive function would conversely lead to worse ADL levels by affecting remembering appointments and shopping items, which can cause a vicious circle (Li & Wu, 2022).

In this study, it was found that healthy lifestyle could directly and indirectly affect cognitive function via the mediation of ADL. The "use it or lose it" hypothesis showed that an active lifestyle protects the cognitive function of adults (Hultsch et al., 1999). In the meantime, those who maintained or chose more healthy lifestyles had more possibility to remain physically functionally independent. As for individuals who live in the community, positive lifestyle change, particularly more active participation in exercise or learning activities, can help maintain the functional independence of ADL and also induce neuroplastic changes in the brain countering the age-related cognitive decline (Lee et al., 2013; Arab et al., 2021). Furthermore, individuals with better ADL capacity have a lower risk of cognitive impairment. On the contrary, an unhealthy lifestyle may increase the risk of ADL disability, and further cause middle-aged and older adults to interact less with others by reducing their range of motion and active mobility, which can affect mental health and contribute to developing cognitive impairment.

In middle-aged and older Chinese adults, positive lifestyle changes may help to maintain functional independence, which can promote cognitive function or delay the occurrence of cognitive impairment. A healthy lifestyle is a very efficient intervention measure, which can improve the level of cognitive function and also promote cognitive function by improving the level of ADL, and twofold results can be achieved with half the effort. Given that cognitive impairment poses a significant public health challenge with an aging population, primary prevention that can help older adults choose a healthy lifestyle may contribute to reducing societal and personal costs related to cognitive impairment and even dementia.

The research employed a nationally representative group of community-dwelling middle-aged and older Chinese adults, helping to extrapolate the findings to the population. A prospective design was used to offer more rigorous evidence for causality, and several potential confounding factors were also adjusted. However, there are still some limitations. Firstly, although several important confounding factors were controlled, this study did not consider some factors that affect cognitive function, including genetic factors due to the lack of CHARLS data. Secondly, the results were based on an observational study, and recall bias was inevitable in a questionnaire survey. Thirdly, in the longitudinal model, we utilized covariates in the baseline survey for adjustment, while certain covariates are likely to vary over time. At last, healthy lifestyle, ADL and cognitive function may have feedback loops, and there should be an experimental design to reach more solid evidence for causality in the future.

Conclusions

This retrospective longitudinal study showed that more healthy lifestyles were associated with better cognitive function among middle-aged and older Chinese adults and that the effect of a healthy lifestyle on cognitive function was mediated by ADL. Further development of coordinated interventions for keeping healthy lifestyles may be valuable to improve the cognitive health of older adults and achieve successful aging.

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Authors' contributions Conceptualisation and study design: XMZ and HJL; data acquisition and management: ZR, LC, YXL, MFH, YBC, RRL and XYG; statistical analysis and data analysis: ZR, LC, YXL, MFH, WJL, ZQC, WJZ and YCW; manuscript drafting: ZR and LC; manuscript revision: XMZ, HJL, YXL and MFH; final approval: all authors.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval statement All participants provided written informed consent, and the Biomedical Ethics Review Committee of Peking University approved CHARLS (IRB00001052-11015).

Competing interests The authors declare no conflicts of interest.

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