The Income-Related Distribution of Cognitive Function And Its Mobility Among The Chinese Elderly Over 14 Years

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Abstract

Background:

With population aging, cognitive function among the elderly has been growing public health concern in China. This study aimed to investigate the trend of income-related inequality in cognitive function, and to track the health-related income mobility among the Chinese elderly.

Methods:

The data were drawn from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) in 2005, 2008, 2011, 2014 and 2018, with a sample of 10203 Chinese aged 65 and older. The cognitive function was evaluated by the Mini-Mental State Examination (MMSE). The cross-sectional and longitudinal concentration indices were used to measure the magnitudes of inequalities at different length of time. The mobility index was used to capture the discrepancy between the short-term and long-term measures. The contribution of determinants to mobility was estimated by decomposition analysis.

Results:

The results showed that, the cognitive function among the Chinese elderly scored 21.13 at the baseline. Men, activities, daily living ability, education, marriage status, income, community service, vision and hearing condition were positively associated with cognitive function, whereas age, negative well-being and drinking were negatively associated with cognitive function. The cross-sectional concentration index was positive and significant only at the baseline. In the long run, however, the concentration indices were all positive and became larger over time. After five waves, the mobility reached -4.84. The largest negative contributor to the mobility index was daily living ability, followed by relaxing activity, domestic activity and hearing condition. The two largest positive contributors were negative well-being and income.

Conclusion:

Our study found that, as a whole, the cognitive function was not performed well among the Chinese elderly. In the long term, the weighted cross-sectional concentration indices underestimated the inequality in cognitive function and good cognitive performance was concentrated more among the rich. When formulating intervention measures, the Chinese government could give priority to vulnerable groups, especially the elderly who are poor or downwardly income mobile.

Background

Generally speaking, cognitive function is associated with aging and cognitive impairment occurs more frequently in the elderly [1, 2]. With population aging, there will be a large proportion of people at risk of cognitive impairment in China. The elderly with mild cognitive impairment (MCI) perform poorly in at least one cognitive domain, such as memory, attention, executive function, visuospatial skills and language [3]. While those with severe cognitive impairment may develop dementia, one of the most common types of which is Alzheimer's disease (AD). A large-sample survey (46011 participants) between 2015–2018 showed that, the overall prevalence of MCI was 15·5% and of dementia was 6·0% in Chinese adults aged 60 years or older, with 38·77 million MCI patients and 15·07 million dementia patients respectively [4]. Cognitive function among the elderly has been a public health concern in China.

There is no denying that cognitive impairment has many adverse effects. On the one hand, cognitive impairment is not conducive to physical and mental health both for patients and caregivers. On the other hand, cognitive impairment will aggravate the financial burden to family and society. Take AD for example. In 2015, the average cost per AD patient per year in China was US $19144.36, and the total socioeconomic costs of Chinese AD patients reached US $167.74 billion [5]. Accordingly, we should pay more attention to cognitive function in the elderly.

It is estimated that 66% of people with dementia will come from low- and middle-income countries in 2030, the proportion rising to 71% by 2050[6]. This makes us think about what is the distribution of cognitive function among different income groups. China has experienced dramatic economic growth in recent years, however, there has been still wider disparity in health between the rich and the poor. The health inequality in cognitive function will increase the difficulty of preventing and alleviating cognitive impairment. The elderly with low incomes are more likely to be exposed to a multitude of risk factors. Moreover, if bad cognitive function is more concentrated on the poor, there is greater inequality disadvantaged the poor in physical condition and socioeconomic status, aggravating the phenomenon of poverty caused by illness and returning to poverty due to illness. Therefore, it is of great significance to study the distribution of cognitive function between the rich and the poor so that more targeted interventions can be proposed.

Growing evidence suggests that cognitive function was unequally distributed across income groups [7–10]. People with higher income tend to have better cognitive performance, and vice versa. Nevertheless, the researches measuring the extent of income-related inequality in cognitive function are extremely limited. Using the cross-sectional data, a study of children in Indonesia further decomposed the pro-rich inequality in cognitive function and found that the largest contributor was inequality in per capita expenditure in both 2000 and 2007 [11]. However, evidences from this design may be less accuracy and robustness than longitudinal design. Attention must be paid to the change in income-related inequality as the period of measurement lengthens, which can be quantified by health-related income mobility [12]. So far, there is still a blank in the research on measuring the magnitude of income-related inequality and investigating its mobility, with regard to the cognitive function of elderly.

Accordingly, our study aimed to explore three questions. Firstly, to track the distribution of cognitive function scores in Chinese elderly over 14 years and identify its determinants. Secondly, to investigate income-related inequality in cognitive function, and quantify its change with the longitudinal perspective. Furthermore, to decompose mobility of income-related inequality in cognitive function into the contributions of determinants to the gap between the short-term and long-term measures. This study will extend current insights in the income-related inequality in cognitive function and its change over years. In addition, this study may provide a reference for the government to draw public health policies to eliminate or alleviate income-related inequality.

Methods

Data

Data were drawn from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), a dynamic cohort study designed to investigate the social, behavioral, environmental and biological factors affecting the health of human aging. The baseline survey was conducted in 1998, with seven follow-up surveys at approximate three-year intervals. CLHLS adopted a multi-stage random sampling method, covering 23 provinces in China. This study used five waves in 2005, 2008, 2011, 2014 and 2018. The 15638 participants who engaged in 2005 were initially selected. This study excluded those who aged below 65 years old or without critical information, as well as those who dropped out or lost to follow up due to non-death. Considering that there might be misleading results if the deaths were ignored, this study incorporated deaths into longitudinal analysis, by assigning a zero value of health to deaths. Finally, a sample of 10203 individuals aged 65 and older was enrolled into analysis.

Measures

The Mini-Mental State Examination (MMSE) developed by Folstein et al [13] is widely used to evaluate global cognitive function. In this study, cognitive function was assessed by a modified Chinese version of MMSE, which was adapted to the cultural and socioeconomic conditions of the Chinese elderly. The Chinese MMSE is comprised of 24 items involving five dimensions, that is, orientation, registration, attention and calculation, recall, and language. The question " naming foods " was scored 0–7, with higher scores indicating more kinds of food named. Each of the remaining questions was scored 1 point for correct and 0 for otherwise. The MMSE score ranged from 0 to 30, with higher scores indicating better cognitive performance. The reliability of the Chinese MMSE has been demonstrated in previous study (Cronbach's α= 94) [14].

Based on existing literatures, potential variables that may related to cognitive function were considered in this study, including socioeconomic characteristics, lifestyles, health status and community service[4, 15–19]. Socioeconomic characteristics were comprised of age, gender, place of residence (urban, rural), marriage status (having spouse, without spouse), education level and income. Education attainment level was measured by years of schooling. Income was measured by per capita household income that was constructed from the total annual household income divided by household size. According to income, the sample was equally grouped into 5 categories (poorest, poorer, middle, richer, and richest). Lifestyle factors included smoking (current smoker, ex-smoker, and non-smoker), drinking (current drinker, ex-drinker, and non-drinker) and activities. The selected 10 questions were assigned to five categories of activity, namely domestic, physical, intellectual, relaxing and social activities[20], with each category containing two questions. A score was given to each question based on the frequency: 1 for at least once a week, 0 for less than once a week. The scores of different activities all ranged from 0 to 2. Health status included vision condition (vision impairment, normal), hearing condition (hearing impairment, normal), activities of daily living (ADL) disability, and negative well-being. ADL, as an indicator of functional disability, was derived from the Katz Activities of Daily Living (ADL) Scale. Each item was assigned a value of 1 if respondents were completely dependent, 2 if partially independent, 3 if completely independent. The total score ranged from 6 to 18, with a higher score indicating better daily living ability. Based on three questions preselected in CLHLS, an index was constructed to measure negative well-being, as did previous studies [21–23]. The score of the index ranged from 3 to 15. The higher value of negative well-being indicated worse well-being. Measurements of activities, ADL and negative well-being are fully detailed in Table 1. Community service was defined as "yes" if an individual's community provided any social service, such as personal daily care services, home visits, psychological consulting, daily shopping, social and recreation activities, legal aid, health education and so on.

Table 1
Measurements of Activities, ADL and Negative well-being

Variables	Questions	Measurements	Score Ranges
Domestic activity	Housework (cooking, taking care of kids)	Less than once a week = 0; At least once a week = 1	0−2
	Raise domestic animals	Less than once a week = 0; At least once a week = 1	
Physical activity	Outdoor activities (Tai Ji, square dance, visit and interact with friends, or other outdoor activity)	Less than once a week = 0; At least once a week = 1	0−2
	Exercises	Less than once a week = 0; At least once a week = 1	
Intellectual activity	Read newspapers or books	Less than once a week = 0; At least once a week = 1	0−2
	Play cards or mah-jong	Less than once a week = 0; At least once a week = 1	
Relaxing activity	Garden work	Less than once a week = 0; At least once a week = 1	0−2
	Watch TV or listen to radio	Less than once a week = 0; At least once a week = 1	
Social activity	Social activities (organized)	Less than once a week = 0; At least once a week = 1	0−2
	Tours beyond home city/county	Less than once a week = 0; At least once a week = 1	
ADL	Bathing (either sponge bath, tub bath, shower or washing the body)	Needs assistance in bathing more than one part of the body = 1; Needs assistance in bathing only for part of the body = 2; Without assistance = 3	6−18
	Dressing (gets clothes from closets and drawers, including underwear, outer garments and fasteners)	Completely dependent = 1; Partially independent = 2; Completely independent = 3	

Variables	Questions	Measurements	Score Ranges
	Toilet (going to the toilet; cleaning oneself afterwards)	Completely dependent = 1; Partially independent = 2; Completely independent = 3	
	Indoor Transfer (gets in and out of bed as well as in and out of a chair)	Bedridden = 1; With assistance = 2; Without assistance (may use object for support) = 3	
	Continence (urination and bowel movement)	Supervision helps keep urine or bowel control; catheter is used or elder is incontinent = 1; Has occasional ‘accidents’ = 2; Has complete control = 3	
	Eating	Completely dependent = 1; Partially independent = 2; Completely independent = 3	
Negative well-being	Feel fearful or anxious	Never = 1; Seldom = 2; Sometimes = 3; Often = 4; Always = 5	3–15
	Feel lonely or isolated	Never = 1; Seldom = 2; Sometimes = 3; Often = 4; Always = 5	
	Fell the older you get, the more useless you are	Never = 1; Seldom = 2; Sometimes = 3; Often = 4; Always = 5	

Statistical analyses

Characteristics of participants were presented as numbers and percentages for the categorical variables, and as means and standard deviations (SD) for the continuous variables. Multilevel model for repeated measurement data was performed to explore the determinants of cognitive function, where the specific measurement at a particular time is referred as Level-1 data and nested within a particular research participant which constitutes Level-2 data.

The cross-sectional concentration index CI^t, firstly introduced by Kakwani [24] and Wagstaff et al.[25], was used to measure income-related inequality in cognitive function in short run. It ranges from − 1 to 1, with the higher absolute value indicating the more pro-poor or pro-rich distribution inequality. However, there is a limitation that the association between health and income that individuals may experience over time cannot be revealed by cross-sectional concentration index. Therefore, a longitudinal concentration index CI^T was adopted and it could be written down as the sum of two terms, as did previous study [26]:

$$CI^T = \frac{2}{\bar{\bar{y}}^T} cov({y_i}^T, {R_i}^T) = \sum_t \frac{\bar{y}^t}{T\bar{\bar{y}}^T} CI_t - \frac{2}{NT\bar{\bar{y}}^T} \times \sum_i \sum_t (y_{it} - \bar{y}^t)({R_i}^t - {R_i}^T)$$

Where y_{it} and ${y_i}^T$ are the health status of individual i at time t and average health of individual i after T periods, respectively. $\bar{y}^t$ and $\bar{\bar{y}}^T$ are the average health status at time t and in T periods, respectively. ${R_i}^t$ and ${R_i}^T$ are the relative rank of individual i in the distribution of N incomes at time t and of average incomes after T periods, respectively. Term 1 is the weighted sum of cross-sectional concentration indices for each period. Term 2 is the difference between income ranks of a specific period and ranks for mean income over all periods and their association with health.

It is worth noting that whether there is the difference between the results obtained from long-term perspective and that from short-term perspective. Following Shorrocks's concept of income mobility, Jones et al. developed a measurement tool, health-related income mobility M^T, for the gap between cross-sectional and longitudinal income-related health inequalities, and they broke it down into its explanatory attributes based on econometric model[26], which can be written as following:

$$M^T = \frac{2}{N\sum_t \bar{y}_t CI_t} \times \sum_i \sum_t (y_{it} - \bar{y}^t)({R_i}^t - {R_i}^T) = \sum_{k=1}^{k} \hat{\beta}_k \frac{\sum_t {\bar{x}_k}^t {CI^t}_{xk}}{\sum_t \bar{y}^t CI^t} {M^T}_{xk} + \varepsilon$$

Where $\hat{\beta}_k$ is the estimated coefficient for kth independent variable. ${CI^t}_{xk}$ and ${M^T}_{xk}$ are the kth independent variable's concentration index at time t and mobility index after T period, respectively. The positive (negative) value of M^T indicates that the weighted sum of the cross-sectional concentration indices overestimates (underestimates) the degree of long-term inequality. This study followed the methods proposed by Jones et al. to capture the health-related income mobility and perform decomposition analysis based on multilevel model[26].

All statistical analyses were performed by the STATA 16.0, with a significant level of 0.05.

Results

Table 2 shows characteristics of the study population at the baseline. The study sample at baseline consisted of 10203 participants with the mean (standard deviation, SD) age of 87.23 (11.55) years old, including 4350 (42.63%) men and 5853 (57.37%) women. About 64% never smoked or drank. Among the five types of activities, the most frequent one was physical activity, while the most infrequent one was social activity, with mean scores of 0.77 (0.79) and 0.09 (0.32), respectively. The mean ADL score was 16.84 (2.55) and mean negative well-being score was 6.9 (2.23).

Table 2
Characteristics of respondents at baseline

Characteristics	All (N = 10203)
Age, years	
Mean (SD)	87.23 ± 11.55
Gender	
Men, n (%)	4350 (42.63)
Women, n (%)	5853 (57.37)
Place of residence	
urban, n (%)	3933(38.55)
rural, n (%)	6270 (61.45)
Income, RMB thousand yuan	
Mean (SD)	4.53 ± 7.53
Education attainment level, years	
Mean (SD)	1.78 ±3.17
Marital status	
Having spouse, n (%)	3081 (30.20)
Without spouse, n (%)	7122 (69.80)
Smoking status	
Current smokers, n (%)	1974 (19.35)
Ex-smokers, n (%)	1690 (16.56)
Non-smokers, n (%)	6539 (64.09)
Drinking status	
Current drinkers, n (%)	2118 (20.76)
Ex-drinkers n (%)	1466 (14.37)
Non-drinkers, n (%)	6619 (64.87)
Domestic activity	
Mean (SD)	0.66 ± 0.77
Physical activity	
Mean (SD)	0.77 ± 0.79

Characteristics	All (N = 10203)
Intellectual activity	
Mean (SD)	0.21 ± 0.47
Relaxing activity	
Mean (SD)	0.60 ± 0.63
Social activity	
Mean (SD)	0.09 ± 0.32
Vision condition	
Vision impairment, n (%)	4216 (41.32)
Normal, n (%)	5987 (58.68)
Hearing condition	
Hearing impairment, n (%)	3487 (34.18)
Normal, n (%)	6716 (65.82)
Activities of daily life disability	
Mean (SD)	16.84 ± 2.55
Negative well-being	
Mean (SD)	6.90 ± 2.23
Community service	
No, n (%)	7050 (69.10)
Yes, n (%)	3153 (30.90)

The mean scores of cognitive function by years are presented in the Fig. 1. The total sample scored 21.13 at the baseline, with the richest having the highest score of 22.10 while the poorest having the lowest score of 19.59. Over time, the mean scores of cognitive functions had a downward trend, sharply dropping to 3.07 in 2018.

Table 3 presents the association between cognitive function and its determinates. The multi-level random intercept model revealed that gender, activities, ADL score, education, marriage status, income, community service, vision and hearing condition were positively related to cognitive function. Conversely, age, negative well-being and drinking had negative effect on cognitive function.

Table 3
Association between cognitive function and its determinants

Variables	**Estimate**	**Std. Error**	**t**	***p***
Place of residence				
Rural (ref)				
Urban	0.006	0.045	0.13	0.898
Age (years)	-0.040	0.003	-15.62	< .0001
Gender				
Women (ref)				
Men	0.325	0.058	5.62	< .0001
Negative well-being	-0.141	0.012	-11.33	< .0001
Smoking status				
Current smokers (ref)				
Ex-smokers	-0.019	0.065	-0.29	0.774
Non-smokers	-0.116	0.068	-1.71	0.087
Drinking status				
Current drinkers (ref)				
Ex-drinkers	-0.138	0.064	-2.17	0.030
Non-drinkers	-0.191	0.062	-3.10	0.002
Domestic activity	1.731	0.046	37.85	< .0001
Physical activity	0.991	0.044	22.51	< .0001
Intellectual activity	1.602	0.072	22.23	< .0001
Relaxing activity	2.042	0.057	36.12	< .0001
Social activity	0.387	0.097	3.98	< .0001
ADL disability	1.060	0.007	158.42	< .0001
Education attainment level (years)	0.026	0.008	3.29	0.001
Marital status				
Without spouse (ref)				
Having spouse	0.131	0.058	2.27	0.023
Income (RMB thousand yuan)	0.005	0.001	3.32	0.001

Variables	Estimate	Std. Error	t	*p*
Community service				
No (ref)				
Yes	0.259	0.045	5.76	< .0001
Vision condition				
Vision impairment (ref)				
Normal	0.460	0.047	9.72	< .0001
Hearing condition				
Hearing impairment (ref)				
Normal	2.529	0.051	49.96	< .0001

The concentration and mobility indices are shown in the Table 4. The CI^t column reports the cross-sectional concentration indices of cognitive function. The index was positive in 2005 and negative in 2011, statistically significant only in these two years. The CI^T column reports longitudinal concentration indices of cognitive function using one, two, etc. periods. In the long run, the concentration indices were all significantly positive and increased from 0.0248 to 0.0369, illustrating that good cognitive function was concentrated on the rich. Term 1 reports the weight average of the cross-sectional concentration indices up to the corresponding wave. The discrepancy between the short-term and long-term measures is vividly presented in Fig. 2. Long-term concentration indices were larger than short-term concentration indices, with the former having an upward trend while the latter on the contrary. Term 2 reports the difference between the short-term and long-term measures. The estimates in term 2 column were all negative and absolute values increased as the time window over, which contributed to the increase in the longitudinal concentration indices. The health-related income mobility indices reported in the M^T column were all negative and reached − 4.8408 after fourteen years, indicating that the weighted cross-sectional concentration indices underestimated the degree of longitudinal inequality by 484.08% in the long run.

Table 4
Concentration and mobility indices for cognitive function by year

Year	CI^t	Term 1	Term 2	CI^T	M^T
2005	0.0248	0.0248	0.0000	0.0248	0.0000
2008	0.0106	0.0198	-0.0108	0.0306	-0.5482
2011	-0.0270	0.0112	-0.0217	0.0329	-1.9281
2014	-0.0178	0.0081	-0.0266	0.0347	-3.2911
2018	-0.0198	0.0063	-0.0306	0.0369	-4.8408

Table 5 shows the contributions of determinants to mobility index by decomposition analysis. The first column reports longitudinal concentration indices of characteristics after five periods. Except age, ex-drinkers and marriage, the unequal distributions in other characteristics between income groups were all statistically significant. The second column reports the characteristics-related income mobility indices. The positive indices of age, negative well-being, current smokers, domestic activity, ADL, income revealed that weighted average of cross-sectional indices overestimated the degree of income-related inequality with long-term perspective. Whereas the mobility indices of the other characteristics were all negative, which implied the weighted average underestimated the long-term inequality. It is worth noting that the mobility index of 1.52 for ADL was larger than one. This revealed that better ADL was actually pro-rich unequally distributed in long term, while it showed a pro-poor distribution suggested by cross-sectional measures. The third and fourth column show the contributions of determinants on the concentration indices of cognitive function and the percentages of contributions. Obviously, ADL made the largest contribution to the mobility index of -3.5446, accounting for 73.22% of the cognitive function mobility index. It played a major role in making good cognitive function more concentrated on the rich. Relaxing activity, domestic activity and hearing condition also made large negative contributions of -0.3243, -0.2830 and – 0.1878. The two biggest positive contributors that detracted from the mobility index were negative well-being and income, which contributed the pro-rich inequality decreased of 17.05% and 2.29%, respectively.

Table 5
Decomposition of the mobility index of cognitive function by determinants

Variables	$CI^T(x)$	$M^T(x)$	Elas (x)[a]	Contrib(x)[b]	Percen(%)[c]
Place of residence					
Rural (ref)					
Urban	0.2273	-0.0576	0.0089	-0.0005	0.0106
Age (years)	-0.0005	1.2300	-0.1397	-0.1719	3.5504
Gender					
Women (ref)					
Men	0.0275	-0.1106	0.0566	-0.0063	0.1293
Negative well-being	-0.0173	0.5874	0.2903	0.1705	-3.5227
Smoking status					
Current smokers (ref)					
Ex-smokers	0.0687	-0.0053	-0.0040	0.0000	-0.0004
Non-smokers	-0.0435	0.0261	0.0141	0.0004	-0.0076
Drinking status					
Current drinkers (ref)					
Ex-drinkers	0.0225	-0.0456	-0.0082	0.0004	-0.0077
Non-drinkers	-0.0246	-0.0208	0.0134	-0.0003	0.0057
Domestic activity	-0.0563	0.3661	-0.7731	-0.2830	5.8464
Physical activity	0.0809	-0.5588	0.3075	-0.1718	3.5500
Intellectual activity	0.2760	-0.1637	0.6342	-0.1038	2.1449
Relaxing activity	0.1258	-0.3401	0.9537	-0.3243	6.7003
Social activity	0.3150	-0.1462	0.0803	-0.0117	0.2426
ADL disability	0.0094	1.5200	-2.3320	-3.5446	73.2233
Education attainment level (years)	0.2352	-0.0703	0.1703	-0.0120	0.2472
Marital status					
Without spouse (ref)					
Having spouse	0.0130	-3.7747	0.0015	-0.0058	0.1206

Variables	$CI^T(x)$	$M^T(x)$	Elas (x)[a]	Contrib(x)[b]	Percen(%)[c]
Income (RMB thousand yuan)	0.5207	0.0517	0.4417	0.0229	-0.4720
Community service					
No (ref)					
Yes	0.1079	-0.0549	0.1518	-0.0083	0.1721
Vision condition					
Vision impairment (ref)					
Normal	0.0341	-0.2248	0.1145	-0.0257	0.5316
Hearing condition					
Hearing impairment (ref)					
Normal	0.0280	-0.3679	0.5105	-0.1878	3.8795

Note: [a] represent the elasticity of cognitive function score with respective to independent variables; [b] represents the contribution of independent variables on the concentration indices of cognitive function; [c] represents the percentage contribution of independent variables on the concentration indices of cognitive function

Discussion

With a large sample of CLHLS collected from 2005 to 2018, this study extends prior researches by measuring income-related inequality in cognitive function, capturing and decomposing its mobility among Chinese elderly. Using MMSE as an assessment instrument, our study showed that, the mean cognitive function score of the whole sample was 21.13 at the baseline, and sharply dropped over time, which identified the phenomenon that the cognitive function as a whole was not performed well among the Chinese elderly. The mean score of cognitive function in our study is broadly comparable to Yang's study [27], while far lower than that in Aartsen's and Zhang's study (27.5 and 27.05, respectively) [1, 9]. However, the higher scores of the latter studies might attribute to the potential bias that arose from attrition such as death and resulted in a selection of survivor respondents who had relatively better cognitive performance. By incorporating the dead into long-term analysis, our study provides a more complete picture in terms of global cognitive function. We also found that the richest had the highest mean score, whereas the poorest had the lowest score at the baseline. It reflected that cognitive function was distributed unequally among income groups, which was further identified in the later analysis.

Our study explored the association between the cognitive function and its determinants, and showed that in terms of socioeconomic characteristics, people who were young or had spouse tended to perform cognitive function better, consistent with expectations. The results in our study also revealed that men had better cognitive function than women, which showed similarities with the studies in developing countries [28, 29] but differences from those in developed countries [30, 31]. One possible explanation is related to the patriarchal society where women have disadvantage in nutrition intake, human capital investment, and formation of social network, resulting in the lower cognitive performance in developing countries [14]. Our study suggested a positive role for education in cognitive performance. Better education has a beneficial effect on brain structure, and contributes to the constitution of cerebral reserve capacity [27]. By either enhancing cognitive reserves earlier in life or maintaining cognitive abilities through behavioral interactions over a lifetime, higher education may contribute to better cognitive performance [32].

As for lifestyle, drinking was implicated as a risk factor for cognitive function in this study but smoking not. Previous studies showed that smoking might affect cognitive function via vascular pathways [33]. Nevertheless, this study didn't quantify the duration and intensity of smoking, which might lead to the uncorrelation between smoking and cognitive function. Cognitive outcomes following activities were varied in prior studies because theoretical definitions and subsequent operationalizations of activity were highly variable [1, 34, 35]. Our findings suggested that domestic, physical, intellectual, relaxing and social activities had beneficial effect on cognitive function. Among those activities, relaxing activities bestowed relatively large advantages in better cognition function, whereas social activities had relatively limited impacts. Taking part in relaxing activities is an effective way to reduce loneliness and the feeling of social isolation as well as to improve mood that are related to cognitive maintenance. Intellectual activities put forward higher requirements for the elderly in verbal ability, memory, understanding, complex thinking and these abilities are repeatedly strengthened in the process of intellectual activities. One possible mechanism by which physical activities contribute to improving cognitive function is that it can increase neural plasticity and resilience of the brain, which is strongly supported by existing evidence [36]. Participation in social activities contributes to maintaining and expanding the social network, thereby gaining greater access to information and experience of positive emotional. However, social activities may also bring potential risk for psychological stress, such as those caused by personal conflict. Accordingly, it may counteract the positive effect on cognitive function to a certain extent.

As for health status, the elderly with vision or hearing impairment had poorer cognitive performance. In accordance with prior studies, the underlying mechanisms of the associations between visual, auditory and cognitive function remain unclear, but possibly through sensory deprivation that related to social isolation, or information degradation that related to limitation available resources to other cognitive processing due to the compensation of visual or auditory deficits [20, 37, 38]. Consistent with previous evidence, our study manifested that in the elderly, the poorer the daily living ability, the poorer the cognitive function [7, 17]. The elderly with ADL limitations may have an increased demand for assistance, while a gradual decline in physical function and social interaction, resulting in poorer cognitive performance. As previous studies suggested, ADL disability assessments that easily applied to clinical populations, may serve as useful predictors of cognitive impairment [39].

From a longitudinal perspective, our study provided a quite different picture about income-related inequality in cognitive function compared to that obtained from a short-term measure. The cross-sectional concentration indices in this study showed that there was pro-rich inequality in cognitive function at the baseline, but no statistically significant inequality among different income groups in the fourth or fifth wave. Nevertheless, pro-rich inequality existed in the long run and particularly became more serious over time. The short-term measure could not capture individual dynamics in income and health. Specially, the association between changes in the income rank of individuals and systematic differences in cognitive function could not be inferred from cross-sectional information. On average, individuals with downwardly income mobile had poorer cognitive function than those who were upwardly mobile in this study. That explained why this pro-rich inequality exacerbated in the long term. This phenomenon is worthy of social attention. Compared to the rich, the poor are more likely to be exposed to risk factors for cognitive function. People with low income may be poor-educated and have relatively weak awareness of health, making few efforts to prevent and alleviate cognitive decline. In addition, there is evidence that the poor have some problems in accessing health service resources [40]. The poor with severe cognitive impairment need high treatment costs, and even family members to give up jobs to care, resulting in aggravating their poverty conversely and posing significant burdens for society. Therefore, the Chinese government should make more efforts to address the issue of health inequalities in cognitive function, especially among the poor and those with decreasing income.

Further decomposition analysis showed how health-related income mobility can be broken into the contributions of other determinants. Negative well-being and income had positive contributions on the cognitive function mobility. When a longitudinal perspective adopted, negative well-being was less concentrated among the poor and associated with worse health, making cognitive function more concentrated on the poor. Previous cross-sectional studies draw a similar conclusion that income was a relatively larger or even the largest contributor to health inequality [41–44]. However, our study found that, compared to short run, income had less impact on health inequality from a longitudinal perspective. Income had a beneficial effect on cognitive function and was less concentrated among the rich in the long run. As a result, higher income made cognitive function less concentrated among the rich. Whereas ADL score, activities, age, education, vision and hearing condition had negative contributions on the mobility. Daily living ability was the largest contributor to increase the inequality in cognitive function. There was pro-poor inequality in ADL score with cross-sectional data. In the long term, however, this inequality was underestimated and good daily living ability was actually concentrated among the rich. Besides, good daily living ability was beneficial to cognitive performance. Therefore, it made better cognitive function more concentrated among the rich in the long run. Physical, intellectual, relaxing and social activities were all concentrated on the rich and inequalities exacerbated in the long run, while domestic activities were concentrated on the poor and this inequality decreased in the long run. Nevertheless, these five categories of activities were all positively correlated with cognitive function, thus all increasing the pro-rich inequality of cognitive function. The elderly with normal hearing were more likely to perform better cognitive function and this characteristic had greater pro-rich inequality in the long run, contributing to making cognitive function more concentrated among the rich.

Our findings have potential public health significance and provide new evidence for reducing the income-related inequality in cognitive function. When formulating intervention measures, the Chinese government could give priority to vulnerable groups, especially the elderly who are poor or downwardly income mobile. Health education should be carried out to improve their health awareness in order to prevent cognitive decline. The government should reasonably allocate material and human resources so that primary public health services can be popularized in poorer areas. It is of great significance to advocate for greater participation in various activities for the poor to reduce healthy inequality, such as physical, intellectual, relaxing and social activities. The government and society could make efforts to increase the possibility of the elderly in backward areas to participate more in activities, through building fitness function facilities, organizing Tai Chi and square dance and so on. Greater access to hearing aid and hearing rehabilitative treatment for economically disadvantaged individuals may be useful to alleviate health inequality in cognitive function.

Several potential limitations should be noted. Firstly, MMSE is not very sensitive to subtle cognitive change. It has been found to have a ceiling effect and a floor effect [45–47]. The latter effect might easily occur among individuals who with poor education or severe cognitive impairment, causing a restricted range of very low scores. However, due to its simplicity and objectivity, MMSE is still a widely-used measure of cognitive function. Secondly, there might be unobserved confounding factors that were not controlled in this study because the data were sourced from existing surveys. Thirdly, measures relied on self-report, which raised concern for potential recall bias. Lastly, the data were collected at multiple points that are pre-determined so that we could not observe whatever happened in between those observation points. Evidence suggests that determinants of cognitive function may differ from those of cognitive decline [48]. There is a strong possibility that contributors to income mobility vary in cognitive function and cognitive decline. The income-related distribution of cognitive decline and its mobility still remain to be studied.

Conclusions

With an aging population, cognitive function, a key factor affecting the life of the elderly, has arisen social attention. Our study showed that, on the whole, the cognitive function of Chinese elderly was not optimistic. Gender, activities, education, marriage status, income, community service, daily living ability, vision and hearing condition were positively related to cognitive function. On the contrary, the elderly who were older, had negative well-being and drank performed poor in cognitive function. With long-term perspective, our study provided a quite different picture about income-related inequality compared to short-term measures. The weighted cross-sectional concentration indices underestimated the pro-rich inequality and good cognitive function was more concentrated among the rich in the long run. Individuals with downwardly income mobile tended to have poorer cognitive function than those who were upwardly mobile. ADL was the largest negative contributor to the health-related income mobility, making good cognitive function more concentrated on the rich in the long run. However, negative well-being and income reduced the pro-rich inequality in the long run, which were the two biggest positive contributors. Our study will shed light on the future policy-making to reduce the health inequality for Chinese government.

Abbreviations

CLHLS: Chinese Longitudinal Healthy Longevity Survey; MMSE: the Mini-Mental State Examination; MCI: mild cognitive impairment; AD: Alzheimer's disease; ADL: activities of daily living; SD: standard deviation

Declarations

Ethics approval and consent to participate

Approval for this study was given by the medical ethics committee of Health Science Center of Xi'an Jiaotong University (approval number 2019-1168). All respondents gave written informed consent prior to data collection.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are available at https://opendata.pku.edu.cn/.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

YJX conceptualized and designed the study; YTZ contributed to data analysis and data interpretation, and wrote the manuscript; YJX, YTZ and LZ performed a critical revision of the manuscript. All authors read and approved the final manuscript.

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Figures

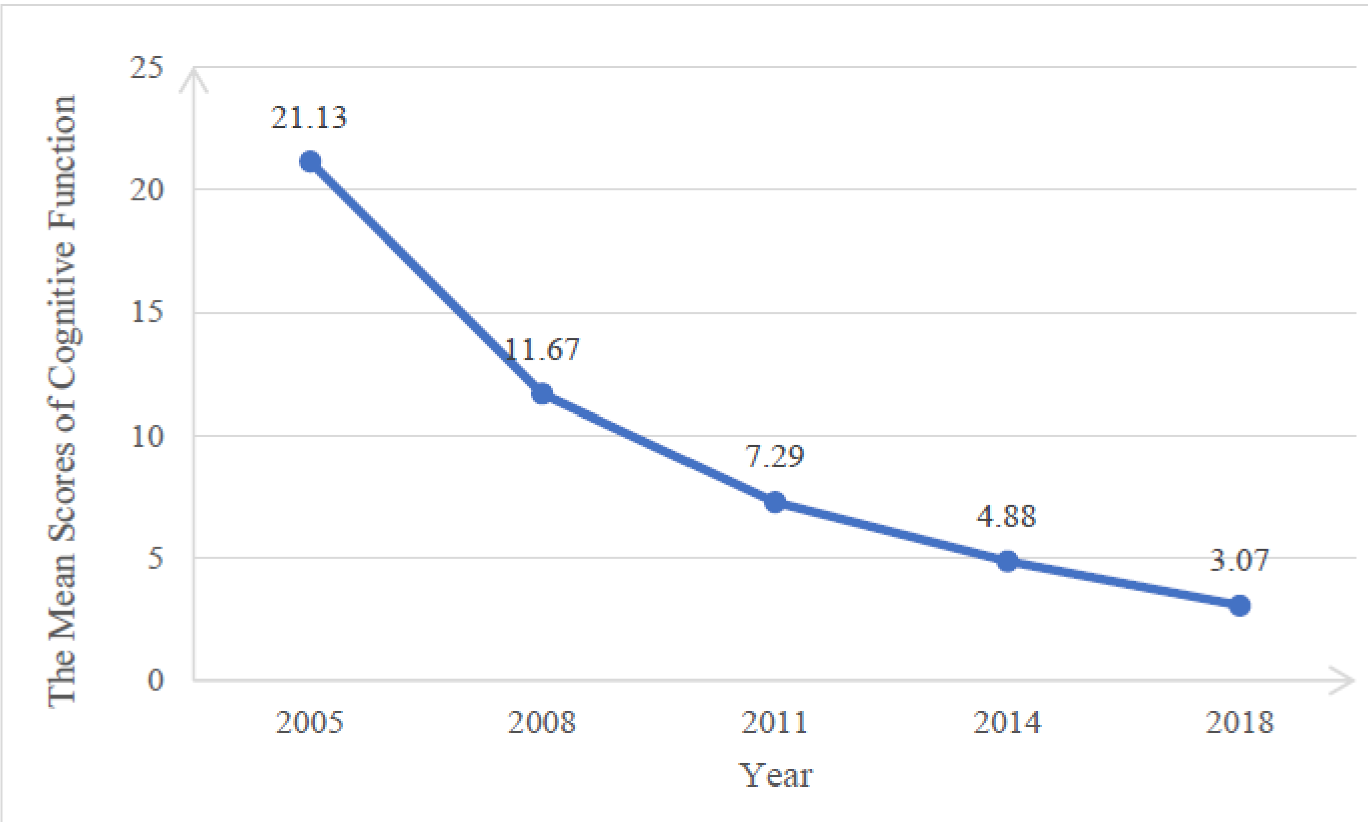

Figure 1

The Mean Scores of Cognitive Function By Years

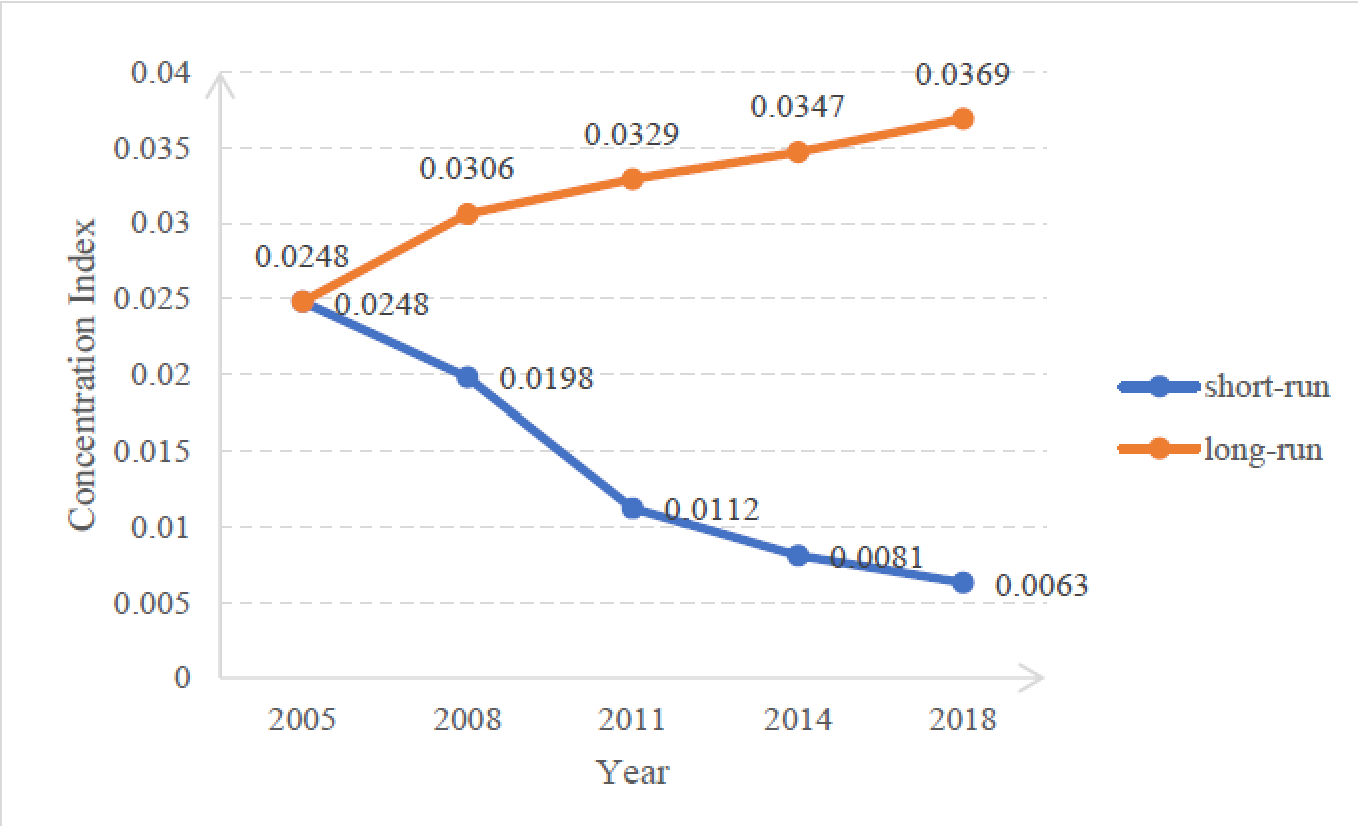

Figure 2

Short run and Long run Concentration Indices for Cognitive Function