Effect of living arrangements on cognitive function in Chinese elders: a longitudinal observational study

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ABSTRACT

Objective To examine how living arrangement as a social contextual factor can affect Chinese elders’ cognitive function.

Setting and participants Our sample consists of 2486 Chinese elders from two waves (2014 and 2018) of the Chinese Longitudinal Healthy Longevity Survey (CLHLS) that was administered in 22 of China’s 31 provinces using a multi-stage, disproportionate, purposive random sampling method. The CLHLS aims to better understand the determinants of healthy longevity in China and collects extensive data on a large population of fragile elders aged 80–112 in China.

Outcome measures Cognitive function was measured by the Mini-Mental State Examination (MMSE). Living arrangement was divided into living in an institution, living alone and living with household members. Generalised linear regressions were carried out to examine the associations between baseline characteristics and cognitive function, while controlling age, gender and residential area.

Results A total of 2486 participants were included in the study at baseline in 2014. Of these, 1162 (46.7%) were men and 1324 (53.3%) were women. The mean age at baseline was 75.07 (±8.31) years. The mean years of schooling were 2.86 (±3.68). The number (proportion) of the three living arrangements (lived in institutions, lived alone and lived with household members) were 93 (3.8%), 463 (18.6%) and 1930 (77.6%), respectively. Among all participants, cognitive function declined over time. Those who lived alone presented with the highest MMSE scores at baseline and showed the lowest decline after 4 years. Living arrangements had significant effects on decreasing cognitive function.

Conclusion Chinese elders living in institutions were most vulnerable to cognitive decline. Living alone was not a risk condition in itself for the elderly in terms of cognitive decline. In addition, the benefits of living with household members to support cognitive function were not found in our study.

INTRODUCTION

People aged 65 years or older accounted for 13.5% of China’s population and numbered approximately 191 million in 2020, citing data from the seventh national population census. It is projected that their number will be more than doubled by 2050, reaching 366 million or 26.1% of the population.1 Given this rapid rate of ageing (one of the fastest among Asian nations) and the fact that declining cognitive function often leads to the onset of dementia (one of the most prevalent mental disorders affecting older adults), it is important to understand the severity of declining cognitive function among the elderly in China.2 3

Among Chinese elders aged 60 or above, the prevalence of mild cognitive impairment without dementia was 20.8% in 2009.3 This mild cognitive impairment had an annual conversion rate to dementia of 15%, but only a 1% conversion to Alzheimer’s disease.4 5 Decline in cognitive function has been recognised as one of the top fears that adults have about the ageing process in many countries,5 since cognitive function decline leads to loss of independence, higher risk of disability and premature deaths.6 7 It is well known that general cognitive function declines with the ageing process, depending on genotype and lifestyle.8 One approach to preventing late-life cognitive impairment is to identify factors associated with the preservation of cognitive function during old age.

The ageing process is accompanied by a gradual decline in cognitive function and the ageing of the central nervous system.9 Previous studies have shown that sociodemographic characteristics, such as age, gender, marital status, economic status, health status and intergenerational support, had

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Use of a 4-year longitudinal study of Chinese elders.
⇒ Valuable evidence on how three main types of living arrangements affect cognitive function.
⇒ Participants with the same living arrangements over the 4-year period were selected.
⇒ Living in institutions was a category of the living arrangements.
⇒ Due to a lack of data, confounding factors cannot be completely ruled out and the sample size was limited, especially for the elders living in institutions.

To cite: Lin Y, Zhang Q, Wang T, et αl. BMJ Open 2022;12:e050410. doi:10.1136/bmjopen-2021-050410
significant impacts on the cognitive function of older adults.\textsuperscript{7} \textsuperscript{8} \textsuperscript{10}–\textsuperscript{12} In addition, a balanced nutritional status and advanced participation in activities of daily living had a positive influence on cognitive function.\textsuperscript{9} \textsuperscript{13}–\textsuperscript{16} However, living arrangements are rarely studied as regards Chinese elders’ cognitive function, despite the fact that China is experiencing a dramatic change in social norms given its economic development and other social movements, such as the one-child policy and domestic migration.\textsuperscript{17}

Living arrangements as a social contextual factor affect the health of the elderly in many ways. Different living arrangements represent different lifestyles and are closely related to the physical and mental health of the elderly.\textsuperscript{18} The transition in living arrangement from living with family to living alone or in institutions is a critical event in many elders’ life-cycle.\textsuperscript{19} Mainly due to population ageing, widowhood, urbanisation, transitions of culture, individual values, and the availability of social services, the number of older people living alone is rising in most countries.\textsuperscript{20} In light of this, empirical studies have measured the impact of living arrangements on cognitive function among the elderly. For example, a study found the association between living arrangements and cognitive decline among people over 65 years in European countries depended on the geographical area and the starting level of cognitive function.\textsuperscript{20} A study of 2200 Japanese elders aged 60 or above showed that functional status played a role in living arrangement transitions.\textsuperscript{21} A recent survey of 2548 adults aged 60 or older in Singapore found that older adults living in multigenerational households seemed to be disadvantaged in their cognitive function.\textsuperscript{22} These studies have shown that the elders’ cognitive function was associated with their living arrangements, although the findings on the relationship between these two factors were still mixed.\textsuperscript{20}

Some studies have found that living alone is associated with higher levels of cognitive impairments,\textsuperscript{18} \textsuperscript{23} while others have found that living alone had some health advantages.\textsuperscript{24} \textsuperscript{25} The studies that examined the effect of living with others on the elderly’s cognitive function were more elusive in their conclusions.\textsuperscript{20} Little of this research has examined specifically how living arrangements affect the cognitive function of Chinese elders. Therefore, this study aims to address that issue by taking advantage of a longitudinal study conducted between 2014 and 2018. The results can provide new evidence for stakeholders to create a more supportive environment to prevent cognitive function decline in Chinese elders.

**METHODS**

**Sources of data**

We used data from two waves (2014 and 2018) of the Chinese Longitudinal Healthy Longevity Survey (CLHLS), an ongoing longitudinal socioeconomic and health survey of the middle-age and old-age populations that is conducted by the Peking University Center for Healthy Aging and Family Studies and the China Mainland Information Group. The CLHLS aims to better understand the determinants of healthy longevity in China. It collects extensive data on a large population of fragile elders aged 80–112, including health, disability, demographic, family, socioeconomic, and behavioural risk factors for mortality and healthy longevity.\textsuperscript{26}

CLHLS was administered in 22 of China’s 31 provinces in 1998 using a multi-stage, disproportionate, purposive random sampling method. The first eight waves (1998, 2000, 2002, 2005, 2008, 2011, 2014 and 2018) have been completed. At each wave, survivors from the previous wave were reinterviewed, and the deceased participants were replaced with new ones. In 2014, 7192 elders aged over 65 were interviewed face-to-face. The 2018 wave included 15,874 elders, with 3,463 of the participants having been interviewed in 2014. The same living arrangement-related variables were presented in the data of 2018 and 2014. To minimise the potential for selection bias and confounding effects from survivors,\textsuperscript{25} we selected participants with the same living arrangements over the 4-year period from the samples interviewed in both 2014 and 2018. We excluded 261 participants (51 participants in the 2014 wave and 214 participants in the 2018 wave, 4 of which were missing in both waves) whose living arrangements were missing and 716 samples whose living arrangements were inconsistent in two waves. The missing living arrangements was completely missing at random that was better for deleting the missing samples directly. See details in figure 1. The final study sample included 2,486 Chinese elders.

Significant differences were noted in baseline demographic characteristics between study participants and excluded participants. We found participants excluded had significantly higher ages that might have been too old to follow-up on or had filled in the questionnaire less adequately than the study sample. At the same time, there were more rural participants in the study sample than among the excluded participants (table 1).
Measurement

Outcome: cognitive function

The CLHLS measures the cognitive function of elders with the Mini-Mental State Examination (MMSE). The scale ranges from 0 to 30, with higher scores indicating greater cognitive function. The scale consists of five domains: orientation (10 points), registration (3 points), attention and calculation (5 points), recall (3 points), and language and praxis (9 points). Some studies recommended cut-off point of 23/24 or 24/25 in Western countries, so that a score equal to cut-off point or less indicated cognitive impairment.27 28 However, in China, some researchers found the cut-off points of the MMSE varied according to the respondents’ education attainment. Most studies employed the cut-off points recommended by the Shanghai Mental Health Center: 17/18 for those without formal education, 20/21 for those with 1–6 years of education (primary school) and 24/25 for participants with more than 6 years of education (middle school or higher).29 In our study, 48.6% were illiteracy, 37.5% were with more than 6 years of education (middle school or higher). Taking into account nearly half of the illiteracy rate, we set the cut-off points for cognitive impairment at 18. Due to the lack of two items in the language and praxis domain of the MMSE in this study, we adjusted the scoring criteria accordingly, subtracting the scores of the two missing items (2 points) from the original scores. So the highest score in this study was 28 points, greater than 16 were considered ‘normal’, and those less than 16 were considered ‘cognitive impairment’. And this study did not classify dementia, and the scores of the scale were used for statistical analysis in terms of the cognitive status of elders only. The percentages of missing MMSE scores were moderate (range: 4%–10%). Different from a situation in which scores are missing completely at random, due to which the corresponding data on living arrangements can be directly deleted, the missing MMSE scores in our study were not random, which called for us to fill in the missing data. Mean Imputation is a simple and fast method of handling missing data that will not affect the estimate of the mean of the variable compared with other ways.30 This is how we addressed the missing data from the MMSE scores here.

Explanatory variables

In this study, the key explanatory variable was the ‘living arrangement’ of older adults. In the CLHLS survey, each participating person was asked about coresidence. There were three categories to choose from: living with household members (eg, a spouse or other family members like child, spouse of child, grandchild, spouse of grandchild, great grandchild or spouse of great grandchild, sibling, parent or parent-in-law, housemaid and others), living alone and living in an institution. As we know, living alone or in institutions is marked a critical transition event in elders’ living arrangements. The aims of this study were to know whether their cognitive decline in these arrangements was greater than that of elders in other living arrangements or not. We adopted a classification of the living arrangements of our survey elders into the following three categories: ‘living in an institution’, ‘living alone’, or ‘living with household members (eg, a spouse or other family members like child, spouse of child, grandchild, spouse of grandchild, great grandchild or spouse of great grandchild, sibling, parent or parent-in-law, housemaid and others)’.

Based on the literature, we controlled age, gender, years of schooling and residential areas as confounding variables. Referring to earlier studies about the prevalence of dementia in individuals aged 65 years and older,31 32 we created 5-year age distribution bands. At the same time, considering that China’s average life expectancy is less than 80 years,33 age was categorised into four groups (≥65 and <70; ≥70 and <75; ≥75 and <80; ≥80), gender into two groups (male and female) and residential area into three groups (urban, township and rural).

Table 1 Baseline characteristics of study samples and samples excluded from study

| Characteristic       | Study participants (n=2486) | Participants excluded* (n=4706) | χ²/t value | P value |
|----------------------|----------------------------|--------------------------------|------------|---------|
| Mean age, years±SD   | 75.07±8.308                | 88.75±10.61                    | 54.597     | <0.001  |
| Years of schooling, years±SD | 2.86±3.68                  | 2.41±3.48                      | 5.63       | <0.001  |
| Gender               |                            |                                | 4.249      | 0.041   |
| Males, n (%)         | 1162 (46.7)                | 2080 (44.2)                    |            |         |
| Females, n (%)       | 1324 (53.3)                | 2626 (55.8)                    |            |         |
| Residential, area    |                            |                                | 135.348    | <0.001  |
| Urban, n (%)         | 312 (12.6)                 | 739 (15.7)                     |            |         |
| Town, n (%)          | 502 (20.2)                 | 1459 (31.0)                    |            |         |
| Rural, n (%)         | 1672 (67.3)                | 2508 (53.3)                    |            |         |
| Total                | 2486 (100)                 | 4706 (100)                     |            |         |

*Subjects who lost to follow-up or had missing, inconsistent living arrangement data. SD, standard deviation.
Descriptive statistics (mean, SD, range and percentage) were used to characterise the sample. We compared baseline characteristics between participants with different living arrangements using cross-tabulations and χ² tests. T-tests were employed to test the differences in cognitive function from 2014 to 2018. Significance was set at p<0.05. A generalised linear model (GLM) was carried out to examine the associations between baseline characteristics and cognitive function between the two waves, while controlling the confounding factors (age, gender, years of schooling and residence). After stratification by living arrangement, with-in-subjects effects and betwee-subjects effects on the outcome of cognitive function and its domains were tested to examine whether the living arrangement at baseline was associated with the decline in functional capacity after 4 years. The Bonferroni method was used for pairwise comparison of living arrangement.

**Patient and public involvement**

Our analysis is based on secondary data, and all data are publicly available. No patient was directly involved.

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**RESULTS**

**Characteristics of the participants**

A total of 2486 participants were included in the study at baseline in 2014, with 1162 (46.7%) men and 1324 (53.3%) women (table 2). The mean age (±SD) was 75.07 (±8.308) years and the mean years of schooling were 2.86 (±3.68) in total. The characteristics of participants that were classified in terms of their living arrangements at baseline were summarised. The number (proportion) of the three living arrangements (lived in institutions, lived alone and lived with household members) were 93 (3.8%), 463 (18.6%) and 1930 (77.6%), respectively. The participants who lived in institutions were older than the other two groups. Moreover, the residential area of the three living arrangements was significantly different.

**Cognitive function by living arrangement**

The participants’ scores on the MMSE and its domains in 2014 and 2018 are shown in table 3. In general, cognitive function declined over time, all of which were statistically significant. Participants who lived alone presented the highest MMSE scores (24.99±4.05) and the lowest percentage of cognitive impairment (4.1%) at baseline, and their decline in cognitive function after 4 years was the lowest. On the other side, those who lived in institutions showed the lowest baseline scores (23.56±5.82) and the highest percentage of cognitive impairment (8.6%), and their decline in cognitive function after 4 years was the highest, with the larger declines in the domains of orientation, language and praxis.

**Effect of living arrangement on the cognitive function of the elderly**

Table 4 presents the effects of older persons’ baseline living arrangements on their cognitive function transition by using the GLM. After controlling for age, gender, years of schooling and residential area, living arrangement had significant effects on the decline in cognitive function. In terms of tests of within-subject effects, statistically significant differences were detected at different time points in total cognitive function and its domains (p<0.001). Furthermore, except for the domains of orientation (p=0.680), attention and calculation (p=0.120) and recall (p=0.223), interactions between time and living
Lin Y, et al. BMJ Open 2022;12:e050410. doi:10.1136/bmjopen-2021-050410

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... which meant different living arrangements had an impact on the trends in cognitive function. As regards between-subjects effects, significant differences were detected between the groups according to their living arrangements. Among the controlling variables, age had significant effects on the decrease of cognitive function no matter which aspect was considered. Except in the domain of recall, years of schooling had significant effects on the decrease of cognitive function, but interactions between time and years of schooling were not significantly different in the domain of registration, recall, language and praxis, which meant years of schooling had no effect on the trends in these respects. Interactions between time and gender showed significant differences in the domains of attention and calculation (p=0.036) and recall (p=0.039), and the cognitive functions of different genders were significantly different. A similar situation prevailed in the variable of residential area.

In view of the significant interaction between time and living arrangement on the cognitive function of older adults, we made further pairwise comparisons of estimated marginal means of cognitive function classified by living arrangement. Table 5 presents the results of pairwise comparisons after controlling for age, gender, years of schooling and residence. Cognitive functions of the participants who were living alone were significantly higher than for those living with household members and those living in institutions. Only in the two domains of attention and calculation and of language and praxis were there no differences between the two groups. It is also worth noting that the participants living in institutions had the lowest means of cognitive function in all the domains.

DISCUSSION

This study found that living arrangements were significantly related to the decline in cognitive function in Chinese elderly. Compared with previous studies in China, which only included those living in communities, this study expanded the category of living arrangements to take into account elder living in institutions. Different from many developed countries with joint institutional and family-based long-term care options, China still relies on home-based informal care which suggests that home-based care is the foundation. The results from this study reflect this pattern. Only 3.8% of the older samples lived in institutions, while 23.7% lived alone in the community, with 72.5% living with household members. There was a strong correlation between residential area and cognitive function scores. SD, standard deviation.

Table 3: Cognitive function of participants by living arrangement (n=2486)

|                  | Institutions | Live alone | Live with household members |
|------------------|--------------|------------|-----------------------------|
|                  | 2014 (SD)    | 2018 (SD)  | Difference P value          | 2014 (SD)    | 2018 (SD)  | Difference P value |
| Orientation      | 9.04 (1.83)  | 8.31 (2.57) | -0.73 0.010                 | 9.61 (1.08)  | 9.07 (1.96) | -0.54 <0.001       |
| Registration     | 2.62 (0.87)  | 2.25 (1.19) | -0.36 0.006                 | 2.73 (0.71)  | 2.61 (0.91) | -0.12 0.009       |
| Attention and calculation | 3.91 (1.68)  | 3.25 (2.15) | -0.66 0.004                 | 4.17 (1.56)  | 3.67 (1.91) | -0.50 <0.001       |
| Recall           | 2.20 (1.10)  | 1.83 (1.32) | -0.37 0.010                 | 2.43 (0.99)  | 2.20 (1.18) | -0.24 <0.001       |
| Language and praxis | 5.78 (1.69)  | 4.96 (2.50) | -0.82 0.003                 | 6.05 (1.25)  | 5.68 (1.74) | -0.37 <0.001       |
| Total            | 23.56 (5.82) | 20.62 (8.54) | -2.95 0.001       | 24.99 (4.05) | 23.22 (6.40) | -1.77 <0.001       |
| <16% <16% ('cognitive impairment', %) | 8 (8.6) | 22 (23.7) | 19 (4.1) | 57 (12.3) | 104 (5.4) | 321 (16.6) |
Table 4  Results of general linear model of repeated measures between cognitive function and living arrangement among participants (n=2486)

|                              | Type III sum of squares | df | Mean square | F value | P value |
|------------------------------|-------------------------|----|-------------|---------|---------|
| **Total cognitive functions**|                         |    |             |         |         |
| **Tests of within-subjects effects** |                         |    |             |         |         |
| Times                        | 464.33                  | 1  | 464.33      | 23.85   | <0.001  |
| Times×Living arrangement     | 139.65                  | 2  | 69.83       | 3.59    | 0.028   |
| Times×Age                    | 2035.59                 | 3  | 678.53      | 38.85   | <0.001  |
| Times×Gender                 | 4.91                    | 1  | 4.91        | 0.252   | 0.616   |
| Times×Residential area       | 19.86                   | 2  | 9.93        | 0.51    | 0.6     |
| Times×Years of schooling     | 93.161                  | 1  | 96.161      | 4.94    | 0.026   |
| **Tests of between-subjects effects** |                         |    |             |         |         |
| Living arrangement           | 751.74                  | 2  | 375.87      | 9.05    | <0.001  |
| Age                          | 1467.34                 | 3  | 489.075     | 117.71  | <0.001  |
| Gender                       | 2328.25                 | 1  | 2328.25     | 56.03   | <0.001  |
| Residential area             | 105.02                  | 2  | 52.51       | 1.26    | 0.283   |
| Years of schooling           | 1251.97                 | 1  | 1251.97     | 30.13   | <0.001  |
| **Orientation**              |                         |    |             |         |         |
| **Tests of within-subjects effects** |                         |    |             |         |         |
| Times                        | 30.94                   | 1  | 30.94       | 14.87   | <0.001  |
| Times×Living arrangement     | 1.26                    | 2  | 0.631       | 0.3     | 0.739   |
| Times×Age                    | 178.48                  | 3  | 59.49       | 28.59   | <0.001  |
| Times×Gender                 | 0.52                    | 1  | 0.52        | 0.25    | 0.616   |
| Times×Residential area       | 4.39                    | 2  | 2.2         | 1.06    | 0.348   |
| Times×Years of schooling     | 9.28                    | 1  | 9.28        | 4.46    | 0.035   |
| **Tests of between-subjects effects** |                         |    |             |         |         |
| Living arrangement           | 71.64                   | 2  | 35.82       | 9.08    | <0.001  |
| Age                          | 879.43                  | 3  | 293.14      | 74.26   | <0.001  |
| Gender                       | 98.14                   | 1  | 98.14       | 24.86   | <0.001  |
| Residential area             | 2.95                    | 2  | 1.47        | 0.37    | 0.689   |
| Years of schooling           | 30.39                   | 1  | 30.39       | 7.7     | 0.006   |
| **Registration**             |                         |    |             |         |         |
| **Tests of within-subjects effects** |                         |    |             |         |         |
| Times                        | 3.21                    | 1  | 3.21        | 5.92    | 0.015   |
| Times×Living arrangement     | 7.57                    | 2  | 3.78        | 6.98    | 0.001   |
| Times×Age                    | 33.02                   | 3  | 11.01       | 20.31   | <0.001  |
| Times×Gender                 | 0.01                    | 1  | 0.01        | 0.03    | 0.862   |
| Times×Residential area       | 1.03                    | 2  | 0.52        | 0.95    | 0.386   |
| Times×Years of schooling     | 0.33                    | 1  | 0.33        | 0.6     | 0.437   |
| **Tests of between-subjects effects** |                         |    |             |         |         |
| Living arrangement           | 9.93                    | 2  | 4.97        | 5.54    | 0.004   |
| Age                          | 208.95                  | 3  | 69.65       | 77.66   | <0.001  |
| Gender                       | 17.3                    | 1  | 17.3        | 19.29   | <0.001  |
| Residential area             | 5.23                    | 2  | 2.61        | 2.92    | 0.054   |
| Years of schooling           | 3.46                    | 1  | 3.46        | 3.86    | 0.05    |
| **Attention and calculation**|                         |    |             |         |         |
| **Tests of within-subjects effects** |                         |    |             |         |         |
| Times                        | 36.71                   | 1  | 36.71       | 20.24   | <0.001  |
| Times×Living arrangement     | 7.33                    | 2  | 3.67        | 2.02    | 0.133   |
elderly living in institutions had the lowest cognitive function. Moreover, cognitive function decline was the smallest in the elderly living alone, especially in terms of their registration function, which was inconsistent with some studies arguing that living alone was associated with higher cognitive impairments. Most studies have concluded that this impairment was due to the social isolation caused by living alone, which causes health issues and cognitive impairment. However, there have been some studies that concluded living alone was not a risk condition, in and of itself, for the elderly, which might indicate that those who live alone are likely to seek contact with others. In the current study, those who lived in institutions had the highest levels of cognitive decline compared with elders in other living arrangements. One hypothesis to explain this finding is 'selection bias', that is, elders living alone may have better cognitive function or healthier lifestyles that maintain cognitive function so their family members are willing to let them live alone, whereas for more fragile elders with worse cognitive

### Table 4 Continued

|                                | Type III sum of squares | df | Mean square | F value | P value |
|--------------------------------|-------------------------|----|-------------|---------|---------|
| Times×Years of schooling       | 4.74                    | 1  | 4.74        | 0.067   |         |
| Language and praxis            |                          |    |             |         |         |
| Tests of within-subjects effects|                         |    |             |         |         |
| Times                           | 28.92                   | 1  | 28.92       | 16.84   | <0.001  |
| Times×Living arrangement       | 14.43                   | 2  | 7.22        | 4.2     | 0.015   |
| Times×Age                       | 130.2                   | 3  | 43.4        | 25.27   | <0.001  |
| Times×Gender                    | 1.02                    | 1  | 1.02        | 0.6     | 0.44    |
| Times×Residential area          | 0.45                    | 2  | 0.22        | 0.13    | 0.879   |
| Times×Years of schooling        | 3.28                    | 1  | 3.28        | 1.91    | 0.167   |
| Tests of between-subjects effects|                         |    |             |         |         |
| Living arrangement              | 47.1                    | 1  | 23.55       | 7.44    | 0.001   |
| Age                             | 961.38                  | 3  | 320.46      | 101.24  | <0.001  |
| Gender                          | 130.66                  | 1  | 130.66      | 41.28   | <0.001  |
| Residential area                | 13.34                   | 2  | 6.67        | 2.11    | 0.122   |
| Years of schooling              | 163.44                  | 1  | 163.44      | 51.64   | <0.001  |
function, their family members may be more likely to send them to institutions given the complexity of the care they require.46 47

In addition, compared with living alone, the benefit of living with household members as a way of maintaining cognitive function was not found in our study. Some studies have suggested that living in a partnership has a positive effect on cognitive function, but the effect of living with adult children was instead more uncertain, with a negative effect being shown.48 Based on our results as well as previous literature, we consider that it may be necessary to distinguish different cognitive impacts depending on the identities of those with whom the elderly are living.

To interpret our finding correctly, a few limitations need to be acknowledged. First, we were unable to break down the question of with whom the elders living in partnership were living. Second, only four confounding variables (age, gender, years of schooling and residence) were controlled due to incomplete data. In other words, if other possible confounding variables were not controlled, an unbalanced distribution of baseline characteristics between groups might exist, which would cause bias in the results and an overestimation of the effect of living arrangements. For example, summarising the relevant literature findings, we thought that marital status, and economic status should also be controlled to eliminate their influence on the results.25 49  We suggest future studies use some statistical techniques to address the bias of unbalanced baselines when limited variables are available in the dataset, such as propensity score matching, etc.

Third, the sample size was limited, and there was a huge difference between living arrangements, especially for elders living in institutions, which would definitely affect the generalisability of the findings. But GLM can handle a non-equilibrium model in which the percentages of categories are different. This was why we chose GLM for our statistical analysis. Finally, the lack of results from two items in the language and praxis domain of the MMSE and the presence of missing values in the cognitive measurement might lead to measurement error and a loss of precision in the resulting estimates.

### Table 5  Pairwise comparisons of estimated marginal means of cognitive function of the participants by living arrangement (n=2486)

|                                | Mean difference (I-J) | SE  | P value | 95% CI Lower | 95% CI Upper |
|--------------------------------|-----------------------|-----|---------|--------------|--------------|
| Total cognitive functions      |                       |     |         |              |              |
| Institutions vs live alone     | −2.02                 | 0.53| <0.001  | −3.04        | −0.1         |
| Institutions vs live with household members | −1.58                 | 0.49| 0.01    | −2.53        | −0.62        |
| Live alone vs live with household members | 0.44                  | 0.24| 0.064   | −0.02        | 0.91         |
| Orientation                   |                       |     |         |              |              |
| Institutions vs live alone     | −0.66                 | 0.16| < 0.001 | −0.97        | −0.35        |
| Institutions vs live with household members | −0.5                  | 0.15| 0.001   | −0.79        | −0.21        |
| Live alone vs live with household members | 0.16                  | 0.07| 0.03    | 0.02         | 0.3          |
| Registration                  |                       |     |         |              |              |
| Institutions vs live alone     | −0.23                 | 0.08| 0.002   | −0.39        | −0.08        |
| Institutions vs live with household members | −0.17                 | 0.07| 0.014   | −0.31        | −0.03        |
| Live alone vs live with household members | 0.06                  | 0.03| 0.088   | −0.01        | 0.13         |
| Attention and calculation     |                       |     |         |              |              |
| Institutions vs live alone     | −0.34                 | 0.15| 0.022   | −0.63        | −0.05        |
| Institutions vs live with others | −0.32                 | 0.14| 0.02    | −0.6         | −0.05        |
| Live alone vs live with household members | 0.02                  | 0.07| 0.806   | −0.11        | 0.15         |
| Recall                        |                       |     |         |              |              |
| Institutions vs live alone     | −0.3                  | 0.1 | 0.002   | −0.48        | −0.11        |
| Institutions vs live with household members | −0.2                  | 0.09| 0.028   | −0.37        | −0.02        |
| Live alone vs live with household members | 0.1                   | 0.04| 0.018   | 0.02         | 0.19         |
| Language and praxis           |                       |     |         |              |              |
| Institutions vs live alone     | −0.49                 | 0.14| 0.001   | −0.77        | −0.21        |
| Institutions vs live with household members | −0.39                 | 0.13| 0.003   | −0.65        | −0.13        |
| Live alone vs live with household members | 0.1                   | 0.06| 0.117   | −0.03        | 0.23         |
Our findings revealed that living in an institution significantly decreased cognitive function compared with other living arrangements among the elderly. To improve cognitive function, both material and psychological support programmes are needed in institutions, such as collaboration with local social workers and primary care to provide appropriate healthcare, including mental health support. At the same time, the level of resources required for independent living in the community should be encouraged. On the one hand, technological aids may be provided to elders living alone. One example is ‘Mobile-care’ in Korea, which tracks the phone calls made by the elderly who are living alone and sends a warning signal to a welfare centre if they make no calls for a certain period of time. In addition, various age-friendly physical activity programmes should be encouraged by local governments, such as providing accessible public spaces and transportation enabling older adults to live independently and participate fully in community life.

Acknowledgements The authors thank the Center for Healthy Aging and Development Studies of Peking University for providing the data.

Contributors Conceived and designed the study: YL, QZ, ZZ. Performed the study: YL, ZZ. Analysed the data: YL, TW. Wrote the paper: YL, QZ, ZZ. All authors have read and approved the manuscript. ZZ and YL had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis as guarantors.

Funding This study was supported by the National Natural Science Foundation of China (Grant Number: 71804029), Guangdong Medical Research Fund (Grant Number: C2018081), Doctoral Research Start-up Foundation of Guangdong Medical University in 2019 (B201903), Discipline construction project of Guangdong Medical University (4SG22001G) and the 111 Project (Grant Number B16031) from the Department of Education.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by All procedures involving human subjects/patients of the CLHLS study were approved by Biomedical Ethics Committee of Peking University (IRB00001052-13074). All participants signed a consent form. Participants gave informed consent to have their personal data and/ or images included in a research database. The local ethics review board guarantees that the study procedures are in accordance with the guidelines of the Declaration of Helsinki for epidemiological and other observational research studies involving adults.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement The data, itself, is third party data, and the authors did not produce any of the original data. Interested researchers can apply for access to the data at https://opendata.pku.edu.cn/datavstore/CHADS.

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