


# Relationship between left-behind status and cognitive function in older Chinese adults: a prospective 3-year cohort study

Hong-Guang Zhang,<sup>1,2,3</sup> Fang Fan,<sup>1,2,3</sup> Bao-Liang Zhong ,<sup>1,2,3</sup> Helen Fung-Kum Chiu<sup>4</sup>

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H-GZ and FF contributed equally.

H-GZ and FF are joint first authors.

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<sup>1</sup>Department of Psychiatry, Affiliated Wuhan Mental Health Center, Tongji Medical College of Huazhong University of Science & Technology, Wuhan, Hubei, China

<sup>2</sup>Department of Psychiatry, Wuhan Mental Health Center, Wuhan, Hubei, China

<sup>3</sup>Department of Clinical Psychology, Wuhan Hospital for Psychotherapy, Wuhan, Hubei, China

<sup>4</sup>Department of Psychiatry, The Chinese University of Hong Kong, Hong Kong, China

**Correspondence to**  
Dr Bao-Liang Zhong;  
[haizhilan@gmail.com](mailto:haizhilan@gmail.com)

## ABSTRACT

**Background** Due to the inaccuracy of the traditional geographical distance-based definition of left-behind status, data on the negative effect of left-behind status on cognitive function among older adults are controversial.

**Aims** This study examined the cross-sectional and longitudinal associations of left-behind status with cognitive function in older Chinese adults. The left-behind status definition was based on the frequency of face-to-face parent-child meetings.

**Methods** Data from a nationally representative sample of 8 682 older adults (60+ years) in 2015 (5 658 left behind and 3 024 non-left behind), of which 6 933 completed the follow-up in 2018, were obtained from the China Health and Retirement Longitudinal Study. Left-behind older adults were broadly defined as those aged 60+ years who had living adult children and saw their children less than once per month. The cognitive function was assessed with a composite cognitive test with higher total scores indicating better cognitive function.

**Results** Left-behind older adults had significantly lower cognitive test scores than non-left-behind older adults in both 2015 (11.1 (6.0) vs 13.2 (5.9),  $t=15.863$ ,  $p<0.001$ ) and 2018 (10.0 (6.6) vs 12.4 (6.7),  $t=14.177$ ,  $p<0.001$ ). After adjusting for demographic factors, lifestyle factors, chronic medical conditions and the baseline cognitive test score (in the longitudinal analysis only), on average, the cognitive test score of left-behind older adults was 0.628 lower than their non-left-behind counterparts in 2015 ( $t=5.689$ ,  $p<0.001$ ). This difference in cognitive test scores attenuated to 0.322 but remained significant in 2018 ( $t=2.733$ ,  $p=0.006$ ).

**Conclusions** Left-behind older Chinese adults have a higher risk of poor cognitive function and cognitive decline than their non-left-behind counterparts. Specific efforts targeting left-behind older adults, such as encouraging adult children to visit their parents more regularly, are warranted to maintain or delay the progression of cognitive decline.

## INTRODUCTION

Over the past four decades, from 1980 to 2020, China has undergone significant demographic changes, including rapid urbanisation, large-scale internal migration of young and middle-aged labourers from rural to urban areas, and a growing population of

## WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Left-behind older adults constitute a large, vulnerable subpopulation in China. However, existing data on the risk of cognitive decline in this population are limited and controversial, partly due to the problematic conventional definition of left-behind status used in prior studies.

## WHAT THIS STUDY ADDS

⇒ Using high-quality longitudinal data from the China Health and Retirement Longitudinal Study, we found a significantly elevated risk of cognitive decline in broadly defined left-behind older adults. In contrast, we also found that conventionally defined left-behind older adults were not at higher risk of cognitive decline, likely due to the presence of more protective factors against cognitive impairment in this population.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Public mental health efforts are needed to mitigate the risk of cognitive decline in left-behind older adults in China. Possible measures include encouraging adult children to visit their parents more regularly, organising enjoyable community activities for older adults and providing ageing-friendly primary care services.

older adults. During this time, the percentage of residents living in cities, rural-to-urban migrants, and adults aged 60 years and older in China has increased dramatically, rising from 19.4% to 63.9%, 0% to 20.2% and 6.9% to 18.7%, respectively. As of 2020, the corresponding population sizes of urban residents, internal migrants and older adults were 902.2 million, 285.6 million and 264.0 million, respectively.<sup>1–6</sup> The significant demographic transition in the world's second most populous country has brought substantial challenges to the health and well-being of elderly adults in China.<sup>7–9</sup>

Dementia and other cognitive disorders represent a significant public health

challenge for older adults in modern China, placing growing burdens on the healthcare, public health and social welfare systems.<sup>10–12</sup> Given the sheer size of the older adult population in China, identifying risk factors and developing targeted interventions for high-risk subgroups with cognitive impairment may provide a cost-effective means of reducing the disease burden of dementia in the country.

According to the Chinese tradition of filial piety, adult children have a primary duty to care for their elderly parents, including providing financial assistance, daily care and emotional support.<sup>13</sup> However, due to the high population mobility in China's transforming society, such as long-term business travel by urban workers and rural young labourers moving to cities for work, a large number of older Chinese parents are left behind in their home communities, unable to receive adequate daily care and timely emotional support from their adult children who are living elsewhere.<sup>14 15</sup> Numerous studies have demonstrated that left-behind elderly individuals are at a higher risk of chronic physical illnesses, loneliness, and depressive and anxiety symptoms than non-left-behind elderly individuals.<sup>15–17</sup> Because these factors have been linked to an increased risk of cognitive impairment,<sup>18–21</sup> left-behind older adults may have poorer cognitive function than those with nearby family members. However, the limited available studies have reported mixed findings, showing positive, negative or non-significant associations between left-behind status and cognitive impairment in older adults.<sup>16 22–24</sup>

There has been no widely accepted definition for left-behind older adults in the literature.<sup>25–27</sup> While this term generally refers to older adults whose adult children have left their parents' homes, the criteria for operationalising left-behind status vary widely across studies, such as the number of adult children who have migrated out (ie, any vs all), the duration of out-migration (ie, 6 vs 10 months per year), the distance between older parents' homes and adult children's current place of residence (ie, living in different communities vs cities) and the frequency of adult children's visits to their parents (ie,  $\leq 2$  vs  $\leq 4$  times per year).<sup>15–17 22 28 29</sup>

However, the commonly used definition based on out-migration duration and geographical distance may not be accurate. Left-behind status also reflects the lack of adult children's company, timely care and emotional support for older parents. With China's recent transportation infrastructure growth and expansion, such as high-speed rail, highways and rural-road networks,<sup>30</sup> long out-migration duration and far geographical distance are no longer major barriers to home visits by young migrants. For instance, in Wuhan, the capital city of Hubei province, there are many young rural workers from Xiaogan, another city in the same area. However, the distance between the two cities is only a 26 min ride by high-speed train or a 70 min ride by bus, and the ticket prices are affordable for most migrant workers, costing approximately US\$4–US\$5. In the context of filial piety

and Confucian familism, older Chinese adults prefer home care provided by their adult children and adult children should visit their parents in person at least once per month to provide the care needed.<sup>31 32</sup> Therefore, the frequency of face-to-face meetings between older adults and adult children is a more accurate indicator of left-behind status. In some cases, older adults with adult children living in the same communities can also be left behind if their adult children rarely visit and support them. As a result, the mixed findings on the left-behind status–cognition association in older adults in the literature may be attributed to the heterogeneity in left-behind status and the problematic conventional way of defining left-behind status.

It is important to note that rural older adults are not the only ones who can be left behind. Urban older adults may also be left behind if their adult children who have migrated to other areas rarely visit or spend time with them. While there are no official up-to-date statistics, some researchers estimate that there are 40–51 million left-behind older adults in rural China.<sup>17 33</sup> The public health implications would be significant if we could determine the increased risk of cognitive impairment in this large population. This study examined the association between left-behind status and cognitive function in older Chinese adults, both cross-sectionally and longitudinally. Due to the ongoing debate over the definition of left-behind status, we presented our results using two definitions: the conventional definition based on the distance between elderly individuals and their adult children's place of residence, and a broader definition based on the frequency of face-to-face meetings between older adults and their adult children.

## METHODS

### Participants, sampling and procedures

This study is a secondary analysis of data obtained from the China Health and Retirement Longitudinal Study (CHARLS), a nationwide, population-based, longitudinal cohort study that focuses on middle-aged and older adults aged 45 years and above residing in China.<sup>34</sup> It is harmonised with the Health and Retirement Study (HRS) in the USA and is one of the HRS family studies conducted worldwide. The study used stratified multi-stage probability proportional-to-size random sampling methods to obtain a nationally representative sample of around 20 000 individuals from approximately 100 000 households in 450 villages/communities located in 150 counties/districts across 28 provinces in China.<sup>35</sup> The first CHARLS survey took place in 2011–2012, and three follow-up surveys were conducted in 2013, 2015 and 2018. For our analysis, we used data from the third and fourth waves, with 2015 as the baseline for the cross-sectional analysis and 2015–2018 as the follow-up cohort for the longitudinal analysis.

The CHARLS employed undergraduate and graduate students as fieldwork interviewers who underwent

extensive training in interview skills, passed exams and demonstrated proficiency in rehearsal. The study conducted in-person, face-to-face interviews using computer-assisted personal interview (CAPI) programming. In cases where respondents were unable to complete the survey due to physical illness, cognitive disability or other reasons, proxy informants who were knowledgeable about the respondents were interviewed on their behalf. CAPI technology facilitated the easy and immediate detection and correction of any errors made by the interviewers in the field. Experienced supervisors were also assigned to oversee the fieldwork and resolve any issues related to survey implementation. Detailed information about the methodology, survey questionnaire, follow-up procedures and quality control measures has been reported elsewhere.<sup>35 36</sup>

## Measures

### Left-behind status

During the CHARLS questionnaire interview, each participant was asked to report the number of their living children, where each child regularly lived and how often they saw their children if any did not live with them. Based on this information, conventional left-behind older adults were defined as those who were 60 years or older, had adult children who were alive during the interview, and had children living in locations outside of the counties or cities where they resided. Broad left-behind older adults were defined as those who were 60 years or older, had living adult children and saw their children less than once a month. Due to the controversy regarding the number of adult children who migrate out of their parents' areas (whether all or any), we further classified left-behind status into three categories: not left behind, partially left behind and fully left behind. These categories corresponded to no children moving to other counties/cities, some children moving out and all children moving out under the conventional definition. Under the broad definition, the categories corresponded to seeing all children at least once per month, seeing some children less than once per month and seeing all children less than once per month.

### Cognitive function

In accordance with prior studies,<sup>37 38</sup> the CHARLS evaluated cognitive function during the 2015–2018 period using a composite cognitive test. The test comprised five orientation items, serial sevens, copying a drawing of two interlocking pentagons, and immediate and delayed word recall of 10 words. These cognitive tasks were taken from the Mini-Mental State Examination and the Consortium to Establish a Registry for Alzheimer's Disease neuropsychological battery.<sup>39 40</sup> The total score of the cognitive test ranged from 0 to 31, with higher scores indicating better cognitive function. The Cronbach's alpha coefficients for this cognitive test were 0.846 and 0.902 in the 2015 and 2018 waves, respectively.

### Covariates

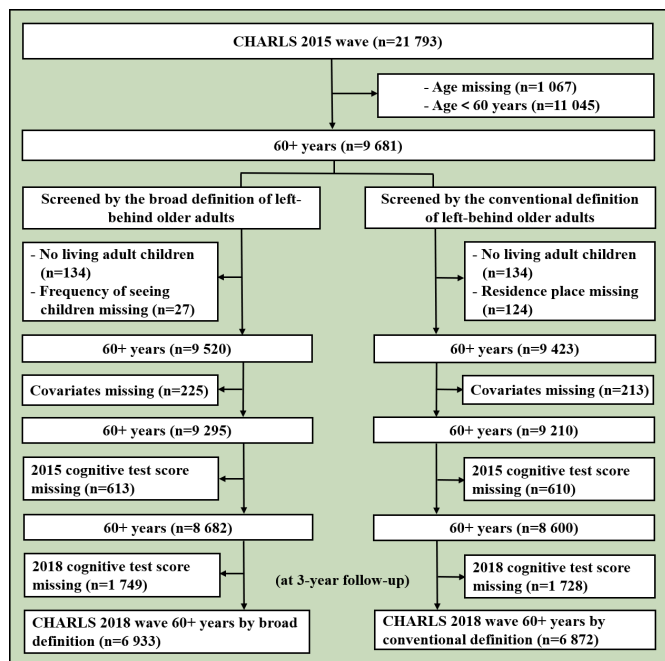
To minimise the likelihood that the left-behind-cognition association is caused by a possible confounding variable, our analysis included several well-established factors associated with cognitive function as covariates. These factors included age, sex, current place of residence (urban or rural), education level (illiterate, not graduated from primary school, primary school, middle school and above), marital status (currently married or cohabiting, never married, separated, divorced or widowed), smoking status (never, former or current), frequency of alcohol consumption in the past year (never, less than once a month or more than once a month), participation in social activities in the previous month (yes or no), physician-diagnosed hypertension and physician-diagnosed diabetes. The question of social participation contained 11 social activities, such as visiting friends, playing games, helping family or neighbours, attending a fitness club and participating in non-governmental organisation activities.

Education was also considered a proxy measure of socioeconomic status since the income and occupation variables in the CHARLS dataset had high rates of missing values. When evaluating the link between health and socioeconomic status, education is a more accurate measure of socioeconomic status than income and occupation.<sup>4</sup>

### Statistical analysis

We used one-way analysis of variance (ANOVA) to compare cognitive test scores across three categories of left-behind status. Once the ANOVA detected a statistically significant difference overall, we performed the least significant difference test to examine further which specific pairs of means were different. Given that very small differences could be statistically significant in studies with a large sample size, we also calculated Cohen's *d* values to quantify the magnitude of differences between subgroups of left-behind status. Values of 0.20–0.49, 0.50–0.79 and  $\geq 0.80$  suggest small, medium and large practical differences, respectively.<sup>41–43</sup> In subsequent linear regression analyses, the decision to merge the partially left-behind category with either the fully left-behind category or the not left-behind category depended on Cohen's *d* value of the comparison between partially left behind and not left behind/fully left behind. If the difference was very small (Cohen's *d*  $< 0.20$ ), the two categories were merged together as one category, regardless of the level of statistical significance. To compare continuous variables between non-left-behind and left-behind groups, we used independent-sample *t*-tests. For categorical variables, we used  $\chi^2$  tests.

To investigate the independent cross-sectional association between left-behind status and cognition, we conducted a multiple linear regression analysis. The main predictor was left-behind status, while demographic factors, lifestyle factors and chronic medical conditions were entered as covariates. Cognitive test score was used



**Figure 1** Flowchart of participants' inclusion from CHARLS, 2015–2018. CHARLS, China Health and Retirement Longitudinal Study.

as the outcome variable. We used a similar approach to examine the longitudinal left behind–cognition association, which included the 2015 cognitive test score as an additional covariate and the 2018 cognitive test score as the outcome variable. We quantified the left behind–cognition association using the crude regression coefficient (beta). We conducted all statistical analyses using SPSS V.25.0 and assumed a two-sided test at the 0.05 level of statistical significance.

## RESULTS

**Figure 1** illustrates the inclusion and follow-up process of study participants from the CHARLS 2015 wave. We generated two final samples for the current analyses: the conventional and broad samples. Based on the conventional definition of left behind, the conventional sample consisted of 8 600 participants in 2015, with 6 872 completing the follow-up in 2018. Based on the broad definition of left behind, the broad sample consisted of 8 682 participants in 2015, with 6 933 completing the follow-up in 2018.

The average ages of both samples were 67.9 years (SD 6.5, range 60–101) in 2015. Women accounted for 50.7% of the conventional sample and 50.6% of the broad sample. For detailed sociodemographic and lifestyle characteristics, as well as chronic illnesses of the two samples and their subsequent follow-up cohorts, please refer to [table 1](#).

### Results from the conventional sample

In the conventional sample, partially and fully left-behind older adults accounted for 36.7% and 9.5% of the total

sample, respectively ([table 1](#)). Fully left-behind older adults had significantly higher cognitive test scores than both not and partially left-behind older adults in both 2015 and 2018 ( $t=3.634-7.058$ ,  $p<0.001$ ). The cognitive test scores were also significantly higher in left-behind than non-left-behind (not+partially) older adults in both 2015 and 2018 ( $t=4.456-6.715$ ,  $p<0.001$ ) ([table 2](#)).

After adjusting for demographic factors, lifestyle factors, chronic medical conditions and the baseline cognitive test score (in the longitudinal analysis only), the positive association between left-behind status and cognitive test score remained statistically significant in the cross-sectional cohort (beta=0.579,  $p=0.001$ ) but was not statistically significant in the longitudinal cohort (beta=0.221,  $p=0.226$ ) ([table 3](#)).

Compared with the non-left-behind group, the left-behind group had significantly higher proportions of men, participants aged 60–69 years, respondents with an educational attainment of middle school and above, participants with a marital status of ‘currently married/cohabiting’, current smokers, drinkers, interviewees who participated in social activities and participants without hypertension ( $\chi^2=5.281-93.563$ ,  $p\leq 0.022$ ) ([table 4](#)).

### Results from the broad sample

In the broad sample, 42.8% and 22.4% of the total sample were partially and fully left-behind older adults, respectively ([table 1](#)). Both fully and partially left-behind older adults had significantly lower cognitive test scores than not left-behind older adults in both 2015 and 2018 ( $t=9.903-16.138$ ,  $p<0.001$ ). The cognitive test scores were also significantly lower in left-behind (partially+fully) older adults than non-left-behind (not left-behind) older adults in both 2015 and 2018 ( $t=14.177-15.863$ ,  $p<0.001$ ) ([table 2](#)).

After adjusting for demographic factors, lifestyle factors, chronic medical conditions and the baseline cognitive test score (in the longitudinal analysis only), the negative association between left-behind status and cognitive test score remained statistically significant in both the cross-sectional cohort (beta=-0.628,  $p<0.001$ ) and the longitudinal cohort (beta=-0.322,  $p=0.006$ ) ([table 3](#)).

Compared with the non-left-behind group, the left-behind group was significantly more likely to be older and to live in rural regions, have a lower level of educational attainment, be never-married/separated/divorced/widowed, currently smoked, did not participate in social activities, and did not have hypertension and diabetes ( $\chi^2=6.870-588.822$ ,  $p\leq 0.032$ ) ([table 4](#)).

## DISCUSSION

### Main findings

This study investigated the cross-sectional and longitudinal associations between left-behind status and cognition in older Chinese adults. Surprisingly, opposite cross-sectional and inconsistent longitudinal associations between left-behind status and cognition were

**Table 1** Characteristics of conventional and broad samples and their subsequent follow-up cohorts

Variable	Conventional sample				Broad sample			
	2015 older adults (n=8 600)		2018 follow-up cohort (n=6 872)		2015 older adults (n=8 682)		2018 follow-up cohort (n=6 933)	
	n	%	n	%	n	%	n	%
Sex								
Male	4 242	49.3	3 400	49.5	4 290	49.4	3 433	49.5
Female	4 358	50.7	3 472	50.5	4 392	50.6	3 500	50.5
Age group (years)								
60–69	5 602	65.1	4 796	69.8	5 663	65.2	4 844	69.9
70–79	2 456	28.6	1 820	26.5	2 471	28.5	1 830	26.4
80+	542	6.3	256	3.7	548	6.3	259	3.7
Current residence place								
Urban	1 707	19.8	1 323	19.3	1 719	19.8	1 330	19.2
Rural	6 893	80.2	5 549	80.7	6 963	80.2	5 603	80.8
Education								
Illiterate	2 808	32.7	2 059	30.0	2 834	32.6	2 075	29.9
Not graduated from primary school	1 992	23.2	1 676	24.4	2 015	23.2	1 697	24.5
Primary school	2 003	23.3	1 649	24.0	2 022	23.3	1 665	24.0
Middle school and above	1 797	20.9	1 488	21.7	1 811	20.9	1 496	21.6
Marital status								
Currently married/cohabiting	6 939	80.7	5 684	82.7	6 996	80.6	5 729	82.6
Never married/separated/divorced/widowed	1 661	19.3	1 188	17.3	1 686	19.4	1 204	17.4
Smoking status								
Currently smoking	2 335	27.2	1 899	27.6	2 363	27.2	1 916	27.6
Quit smoking	1 397	16.2	1 092	15.9	1 411	16.3	1 104	15.9
Never smoked	4 868	56.6	3 881	56.5	4 908	56.5	3 913	56.4
Frequency of drinking alcohol								
>Once per month	2 164	25.2	1 786	26.0	2 189	25.2	1 803	26.0
<Once per month	622	7.2	525	7.6	627	7.2	528	7.6
Never	5 814	67.6	4 561	66.4	5 866	67.6	4 602	66.4
Social participation								
No	4 334	50.4	3 376	49.1	4 370	50.3	3 402	49.1
Yes	4 266	49.6	3 496	50.9	4 312	49.7	3 531	50.9
Hypertension								
No	6 153	71.5	4 960	72.2	6 210	71.5	5 006	72.2
Yes	2 447	28.5	1 912	27.8	2 472	28.5	1 927	27.8
Diabetes								
No	7 974	92.7	6 386	92.9	8 054	92.8	6 445	93.0
Yes	626	7.3	486	7.1	628	7.2	488	7.0
Left-behind status								
Not left behind	4 631	53.8	3 700	53.8	3 024	34.8	2 431	35.1
Partially left behind	3 153	36.7	2 492	36.3	3 716	42.8	2 922	42.1
Fully left behind	816	9.5	680	9.9	1 942	22.4	1 580	22.8

observed in the conventional and broad samples. On average, the cognitive test scores of left-behind older adults in the conventional sample were 0.579 higher than their non-left-behind counterparts in the baseline cohort. However, this difference in cognitive test scores diminished after the 3-year follow-up in this sample. In

contrast, the cognitive test scores of left-behind older adults in the broad sample were 0.628 lower than their non-left-behind counterparts in the baseline cohort. This difference in cognitive test scores attenuated to 0.322 after the 3-year follow-up but remained statistically significant in this sample.

**Table 2** Cognitive test scores of conventional and broad samples and their subsequent follow-up cohorts by category of left-behind status

Sample	2015 cognitive test score		Cohen's d	2018 cognitive test score		Cohen's d
	Score	P value		Score	P value	
<b>Conventional sample</b>						
A: not left behind	11.8 (6.1)	A vs B: 0.045	0.05	10.9 (6.7)	A vs B: 0.006	0.07
B: partially left behind	11.5 (6.0)	B vs C: <0.001	0.28	10.5 (6.7)	B vs C: <0.001	0.22
C: fully left behind	13.2 (6.0)	A vs C: <0.001	0.23	11.9 (6.9)	A vs C: <0.001	0.15
D: not and partially left behind*	11.7 (6.1)	C vs D: <0.001	0.25	10.7 (6.7)	C vs D: <0.001	0.18
<b>Broad sample</b>						
E: not left behind	13.2 (5.9)	E vs F: <0.001	0.40	12.4 (6.7)	E vs F: <0.001	0.37
F: partially left behind	10.8 (6.0)	F vs G: <0.001	0.11	9.9 (5.6)	F vs G: 0.026	0.03
G: fully left behind	11.5 (6.0)	E vs G: <0.001	0.29	10.2 (6.7)	E vs G: <0.001	0.33
H: partially and fully left behind†	11.1 (6.0)	E vs H: <0.001	0.36	10.0 (6.6)	E vs H: <0.001	0.36

\*Due to the very small difference in cognitive test scores between not left-behind and partially left-behind subgroups in 2015 and 2018, not left-behind and partially left-behind were merged together as non-left-behind category in the subsequent linear regression analyses.  
 †Due to the very small difference in cognitive test scores between partially and fully left-behind subgroups in 2015 and 2018, partially and fully left-behind were merged together as left-behind category in the subsequent linear regression analyses.

The out-migration of adult children may have both positive and negative effects on the health of older adults.<sup>23 24</sup> Therefore, the impact of left-behind status on cognitive function among older adults depends on whether the positive effects can outweigh the negative effects. For instance, in Mexico, although older parents with adult children living in the USA had a lower socioeconomic status and more severe depressive symptoms than those with no adult children living in the USA, they were more likely to have more friends in the neighbourhood and

communicate with neighbours more often.<sup>23</sup> As a result, the negative impact of children's out-migration was balanced by the positive effect, and having adult children living in the USA did not increase the likelihood of cognitive impairment in elderly parents.<sup>23</sup>

As shown in table 4, left-behind older adults in the conventional sample exhibited more protective factors for dementia and cognitive impairment, such as younger age, higher levels of education and social participation, while those in the broad sample displayed more risk

**Table 3** Results of multiple linear regression analyses on cross-sectional and longitudinal associations of left-behind status with the cognitive test scores

Sample	Cross-sectional sample in 2015			Longitudinal sample from 2015 to 2018		
	Beta	t	P	Beta	t	P
<b>Conventional sample</b>						
Left-behind status (yes vs no) alone	1.496	6.715	<0.001	1.210	4.456	<0.001
Left-behind status (yes vs no)*	0.588	3.298	0.001	0.556	2.623	0.009
Left-behind status (yes vs no)†	0.579	3.322	0.001	0.612	2.942	0.003
Left-behind status (yes vs no)‡				0.221	1.210	0.226
<b>Broad sample</b>						
Left-behind status (yes vs no) alone	-2.318	15.863	<0.001	-2.368	14.177	<0.001
Left-behind status (yes vs no)*	-0.989	9.020	<0.001	-1.054	7.931	<0.001
Left-behind status (yes vs no)†	-0.628	5.689	<0.001	-0.633	4.708	<0.001
Left-behind status (yes vs no)‡				-0.322	2.733	0.006

\*Adjusted for age group, sex and education.  
 †Adjusted for age group, sex, education, residence place, marital status, smoking status, frequency of drinking, social participation, hypertension and diabetes.  
 ‡Adjusted for age group, sex, education, residence place, marital status, smoking status, frequency of drinking, social participation, hypertension, diabetes and 2015 baseline cognitive test score.

**Table 4** Comparisons of the characteristics of the non-left-behind and left-behind older adults in 2015

Variable	Conventional sample				Broad sample			
	Non-left behind (n=7 784)	Left behind (n=816)	$\chi^2$	P value	Non-left behind (n=3 024)	Left behind (n=5 658)	$\chi^2$	P value
Sex								
Male	3 782 (48.6)	460 (56.4)			1 518 (50.2)	2 772 (49.0)		
Female	4 002 (51.4)	356 (43.6)	17.911	<0.001	1 506 (49.8)	2 886 (51.0)	1.146	0.284
Age group (years)								
60–69	4 947 (63.6)	655 (80.3)			2 093 (69.2)	3 570 (63.1)		
70–79	2 314 (29.7)	142 (17.4)			764 (25.3)	1 707 (30.2)		
80+	523 (6.7)	19 (2.3)	93.563	<0.001	167 (5.5)	381 (6.7)	32.544	<0.001
Current residence place								
Urban	1 560 (20.0)	147 (18.0)			1 028 (34.0)	691 (12.2)		
Rural	6 224 (80.0)	669 (82.0)	1.906	0.167	1 996 (66.0)	4 967 (87.8)	588.822	<0.001
Education								
Illiterate	2 587 (33.2)	221 (27.1)			761 (25.2)	2 073 (36.6)		
Not graduated from primary school	1 792 (23.0)	200 (24.5)			661 (21.9)	1 354 (23.9)		
Primary school	1 813 (23.3)	190 (23.3)			752 (24.9)	1 270 (22.4)		
Middle school and above	1 592 (20.5)	205 (25.1)	16.976	0.001	850 (28.1)	961 (17.0)	204.980	<0.001
Marital status								
Currently married/cohabiting	6 226 (80.0)	713 (87.4)			2 511 (83.0)	4 485 (79.3)		
Never married/separated/divorced/widowed	1 558 (20.0)	103 (12.6)	25.903	<0.001	513 (17.0)	1 173 (20.7)	17.875	<0.001
Smoking status								
Currently smoking	2 071 (26.6)	264 (32.4)			785 (26.0)	1 578 (27.9)		
Quit smoking	1 260 (16.2)	137 (16.8)			528 (17.5)	883 (15.6)		
Never smoked	4 453 (57.2)	415 (50.9)	14.410	0.001	1 711 (56.6)	3 197 (56.5)	6.870	0.032
Frequency of drinking alcohol								
>Once per month	1 922 (24.7)	242 (29.7)			750 (24.8)	1 439 (25.4)		
<Once per month	552 (7.1)	70 (8.6)			222 (7.3)	405 (7.2)		
Never	5 310 (68.2)	504 (61.8)	14.042	0.001	2 052 (67.9)	3 814 (67.4)	0.462	0.794
Social participation								
No	3 954 (50.8)	380 (46.6)			1 419 (46.9)	2 951 (52.2)		
Yes	3 830 (49.2)	436 (53.4)	5.281	0.022	1 605 (53.1)	2 707 (47.8)	21.576	<0.001
Hypertension								
No	5 528 (71.0)	625 (76.6)			2 081 (68.8)	4 129 (73.0)		
Yes	2 256 (29.0)	191 (23.4)	11.279	0.001	943 (31.2)	1 529 (27.0)	16.747	<0.001
Diabetes								
No	7 215 (92.7)	759 (93.0)			2 745 (90.8)	5 309 (93.8)		
Yes	569 (7.3)	57 (7.0)	0.115	0.734	279 (9.2)	349 (6.2)	27.463	<0.001

factors, such as older age, lower levels of education and no social participation.<sup>20</sup> Therefore, the opposite cross-sectional left behind–cognition associations may be attributed to the distinct characteristics of the two samples of left-behind older adults. This hypothesis is supported by a previous study that found conventionally defined left-behind older adults were significantly younger than non-left-behind older adults, which was linked to better cognitive function in left-behind older adults after a 7-year follow-up.<sup>22</sup> Our study also found that the cognitive advantage of the left-behind group in the longitudinal cohort of the conventional sample decreased after adjusting for baseline cognitive function (table 3), indicating that the superior cognitive function at baseline was associated with the previously higher cognitive function in the left-behind older adults. Therefore, the conventional definition may identify a group of older adults who are left behind but relatively cognitively healthy. In China, one of the conditions for children's out-migration is the ability of their older parents to live independently and have intact cognitive abilities. This is because the central doctrine of Confucianism advocates that 'adult children should not travel far away if their parents are alive'.<sup>44</sup> This 'cognitively healthy selection' could account for the cognitive advantage in conventionally defined left-behind older adults.<sup>45</sup>

In the broad sample, it is reasonable to expect poorer cognitive function in the baseline cohort and faster cognitive decline during the follow-up among left-behind older adults compared with their non-left-behind counterparts. This could be due to the higher number of risk factors for cognitive impairment in left-behind older adults, as well as inadequate cognitive stimuli resulting from less interaction with adult children and reduced participation in social activities.<sup>46 47</sup> Furthermore, the reduced levels of intergenerational support and poorer daily care received by left-behind older adults, compared with non-left-behind counterparts, may contribute to an acceleration of their cognitive decline.<sup>32 48</sup> The broad definition allows for a better understanding of the baseline cognition and underlying mechanisms associated with cognitive impairment in the left-behind elderly. As a result, the findings from the broad sample are reasonable and provide convincing evidence for the elevated risk of cognitive impairment in left-behind older adults.

The present study provides evidence of the presence of cognitively healthy selection bias in the sample of conventionally defined left-behind older Chinese adults and confirms the elevated risk of poor cognitive function and cognitive decline in broadly defined left-behind older adults. This advances our understanding of the adverse effects of left-behind status on the cognitive health of older adults in the context of large-scale rural-to-urban migration in China and other low-income and middle-income countries. However, the study has some limitations.

### Limitations

First, the study did not assess the incidence of dementia, which would be more clinically relevant. Second, the 3-year follow-up duration may not be long enough to assess the long-term changing patterns of cognitive function in left-behind older adults. For example, it is unclear whether conventionally defined left-behind older adults would have poorer cognitive function than non-left-behind older adults if followed up for an additional 3 years. Third, our sensitivity analysis based on age groups indicated a lower crude regression coefficient of left-behind status in the 70+ group compared with the 60+ group. However, given that participants with missing data on baseline covariates were significantly older than those without missing data, we speculate that the negative impact of left-behind status on cognitive function may be even more significant if there were no missing data on covariates. Finally, the study was conducted between 2015 and 2018, before the COVID-19 pandemic. The pandemic's profound negative effect on the mental health of older adults may affect the generalisability of the findings to the postpandemic era.<sup>49 50</sup> Further research is needed to address these limitations.

### Implications

In conclusion, the 3-year longitudinal study using data from CHARLS reveals a significantly higher risk of poor cognitive function and cognitive decline in broadly defined left-behind Chinese older adults. Given the large number of left-behind older adults, the cultural significance of filial piety for the mental health of older adults and the high disease burden of dementia in China, specific interventions targeted towards left-behind older adults are necessary to delay cognitive decline or maintain cognitive function. Possible interventions may include social work services to address the unmet emotional needs of older adults, organising enjoyable community activities for older adults, providing ageing-friendly primary care services and encouraging adult children to visit their parents more regularly.

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#### ORCID iD

Bao-Liang Zhong <http://orcid.org/0000-0002-7229-1519>

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*Hong-Guang Zhang obtained his bachelor's degree in clinical medicine in 2021 from Xinxiang Medical University in Henan Province, China. He is a master's student in psychiatry and mental health at the Affiliated Wuhan Mental Health Center, Tongji Medical College of Huazhong University of Science & Technology in Hubei Province, China. His main research interests include early prevention and clinical management of dementia and other cognitive disorders.*