Original Article

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How spousal cognitive functioning affects the level of depression in middle-aged and older adults: An instrumental variable study based on CHARLS in China

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SUMMARY A better understanding of the causal relationship between spousal cognitive functioning and depression levels among middle-aged and older adults is vital for effective health policymaking under the globally severe aging challenge. However, the related evidence is often limited by potential omitted-variable bias and reverse causation. This study uses an instrumental variables approach, namely the two-stage least squares (2SLS) method, to examine the impact of spousal cognitive functioning on depression levels among middle-aged and older adults in China. The data were sourced from the China Health and Retirement Longitudinal Study (CHARLS) of 2020, including a total of 3,710 couples aged 45 years and above. Depression levels were measured using the Center for Epidemiologic Studies Depression Scale (CES-D-10), while cognitive functioning was assessed using the Mini-Mental State Examination (MMSE). Spousal social participation was employed as the instrumental variable to address omitted-variable bias and reverse causation. Additionally, an interaction effect test between gender and spousal cognitive functioning was conducted. The results show that for each one-point increase in the spouse's MMSE score, the CES-D-10 score of middle-aged and older adults decreased by 17.1% to 68.2%. The OLS results indicated that women, rural residents, and middle-aged individuals were more sensitive to these changes. The interaction effect test results confirmed that women were more affected by changes in spousal cognitive functioning. However, after a more reliable 2SLS analysis, the results for age groups shifted, showing that middle-aged individuals were more sensitive to these changes, with a decrease in depression levels reaching 70.0%, compared to 60.2% for the elderly group. Nonetheless, given the prevalence of depression among the elderly, the impact of spousal cognitive decline on depression in this group should not be overlooked. Our findings highlight the importance of spousal cognitive health in managing depression among both middle-aged and older adults, with particular attention to women and rural populations.

Keywords depression, cognitive functioning, middle-aged and older adults, instrumental variables, spouse, China

1. Introduction

The Global Burden of Disease study, 2019, shows that depression affects approximately 280 million people worldwide, representing 3.8% of the population, including 5.7% of those aged 60 years and over (*1*). The World Health Organization (WHO) reported that depression imposes a significant economic burden globally, with annual costs approaching US$1 trillion (*2*). The factors that influence depression are complex and varied, involving biological and psychological aspects. Biological factors include genetics, changes in brain chemistry and hormonal imbalances (*3-5*). Psychosocial factors such as loss of a loved one, and social isolation are also recognized as important triggers of depression (*6,7*). Several determinants, including gender, age, education, income, residence, financial support from offspring, and health status, also have been identified as influential factors in the prevalence of depression (*8-12*). According to WHO, the global population aged 60 years and over is projected to rise from 1 billion in 2020 to 1.4 billion by 2030, and further to 2.1 billion by

2050 (*13*). China has 190 million people aged 65 years or older, constituting 13.5% of its total population. The Comprehensive mental health action plan 2013–2030 published by the WHO states that older adults are at high risk for mental health problems (*14*). Depression reduces the likelihood that older people will participate in social or recreational activities, which can have a serious impact on their normal lives (*15*). It also impairs mental and physical functioning, leading to impaired cognitive functioning, increased risk of diseases such as heart disease and stroke, and increased risk of suicide and death in older adults (*16,17*). Additionally, midlife is a special stage in the journey of life. On the one hand, middle-aged people have to face many pressures from society, family and their own development. On the other hand, as they grow older, they may face more health problems, such as chronic diseases and mental health problems (*18*). Middle-aged people are the mainstay of society, but less research has been done on the health of middle-aged people than on other age groups. According to the life course theory, experiences and health in midlife can have a profound effect on the state of affairs in old age (*19*). Some studies have shown that mental stress and physical health in midlife are associated with cognitive ability and risk of depression in old age (*19*). Therefore, health status of middle-aged people should not be ignored, but few studies have focused on midlife. The accelerating aging of the global population highlights age-related cognitive decline as a major public health concern. Based on the status described in the previous section, our study will focus on middle-aged and older adults. Several scholars have researched the impact of cognitive function on depression, but their findings on the causal relationship between the two remain inconclusive.

A study using Longitudinal Ageing Study in India (LASI) reported that older adults with depression were at a higher risk of cognitive impairment compared to their peers through multivariable analyses, but did not confirm the causal relationship (*20*). Chinese researchers who studied 90 outpatients and inpatients with late-life depression from the department of geriatric psychiatry of a hospital, using a longitudinal, cross-lagged model found a unidirectional relationship between depressive symptoms and cognitive decline and, so, depression might be a risk factor for cognitive decline (*21*). Similarly, a study in Korea using data from the Korean Longitudinal Study of Ageing (KLoSA) and a latent growth model (LGM) analysed 1,354 older adults living alone from 2016 to 2020, using the Korean version of the Minimum Mental State Examination (MMSE) scale and depression using the Korean version of the Depression Self-Assessment Scale, and found that initial higher depression levels were linked to lower cognitive function and accelerated cognitive decline (*22*).

In China, most of the middle-aged and older adults over 45 years primarily live with their spouses. Most patients with cognitive impairments receive home-based health management and are cared for by family caregivers. The National Health Commission of the PRC has issued a notice on promoting the prevention and treatment of Alzheimer's disease through the "Alzheimer's Disease Prevention and Promotion Action Plan (2023-2025)", which emphasizes the importance of specialized training to enhance caregivers' skills, alleviate their caregiving stress, and boost their confidence (*23*). This reflects China's national-level attention to the psychological well-being of patients' families. Despite the influence of cognitive functioning on depression has been recognized, most studies on cognitive decline and depression focus predominantly on individuals. Few studies have considered the influence of spousal cognitive function on depression among middle-aged and older adults, and there are also some controversies in these conclusions. A study using data from the National Alliance for Caregiving and the American Association of Retired Persons containing 1,509 ethnically diverse study participants, utilizing multivariate regression analyses, concluded that dementia caregivers are more affected when caring for cognitively impaired individuals with dementia compared to non-dementia caregivers (*24*). This conclusion highlights that family dynamics, in particular spousal interactions, play a significant role in affecting mental health among the elderly. Some researchers have suggested that spousal cognitive function could influence the other spouse's mental health. A study involving 2,486 couples analyzed the interrelation between emotional and cognitive health for individuals and spouses with dyadic regression models confirming the previous point (*25*). Furthermore, Monin using the Actor-Partner Interdependence Model (APIM) with data from the Cardiovascular Health Study (CHS), found that one partner's depressive symptoms could predict cognitive decline of the other, but not vice versa (*26*). Contrarily, research using APIM and the data from the China Health and Retirement Longitudinal Study (CHARLS), 2011 to 2018 waves, indicated that lower cognitive functioning of one spouse was associated with more depressive symptoms in the other without a reciprocal relationship (*10*). These inconsistent results highlight the necessity for further research to elucidate the influence of spousal cognitive functioning on depression among middle-aged and older adults.

Actor-Partner Interdependence Models can reveal interactions between individuals and is essentially a correlation-based analysis. However, due to the presence of potential confounding variables and uncontrollable factors, APIM cannot determine whether such changes are causal. Therefore, it is necessary to select an appropriate research method to explore the causal relationships. The Instrumental Variables (IV) method is appropriate to overcome endogeneity bias and reveals underlying causality in the scenario mentioned before. Based on the aforementioned current state of

depression and the advantages of the instrumental variables approach over other research methods, our study employed CHARLS 2020 wave and IV method to explore whether lower spousal cognitive functioning is a cause of depression in middle-aged and older adults to further test causality and add the latest research evidence.

2. Materials and Methods

2.1. Data source

The data of our study came from the CHARLS, a representative longitudinal survey targeting middle-aged and elderly populations across China. We conducted a cross-sectional study using CHARLS 2020 data released in November 2023. All participants provided written informed consent and this study was approved by the ethics committee of Peking University (approval code: IRB00001052-11015). CHARLS 2020 includes the information pertaining to 19,395 individuals from 11,412 households across 28 provinces, autonomous regions, and municipalities. Selection criteria for our sample was guided by the study's objectives and previous research on depression, required that: *i*) both members of the couple are 45 years old or above, *ii*) both complete The Center for Epidemiological Studies Depression Scale short form (CES-D-10), *iii*) both undergo the MMSE, and *iv*) both have complete and available baseline data. Based on these criteria, we selected a final sample of 7,420 participants, comprising 3,710 heterosexual couples aged 45 years and above. The flowchart for sample selection is presented in Figure 1.

2.2. Variables and measurement

2.2.1. Explained variable

The explained variable for this study was the level of depression, which was quantified in CHARLS by the CES-D-10 scale. The scale, which has high internal reliability and internal consistency analysis revealed that the Cronbach's alpha coefficient for the CES-D-10 scale in this study was 0.7955. The questions in CES-D-10 scale include a) I am annoyed by small things, b) I have a hard time concentrating when I do things, c) I feel depressed, d) I feel like it is a lot of work to do everything, e) I am hopeful about the future, f) I am scared, g) my sleep is not good, h) I am pleasant, i) I feel lonely, and j) I don't think I can go on with my life. The options of each question were categorized into four levels: 1 = rarely or not at all (< 1 day), 2 = not too much (1-2 days), 3 = sometimes or half the time (3–4 days), and 4 = most of the time (5–7 days). Depression scores were calculated based on established criteria, assigning scores of "0", "1", "2", and "3" to the four levels. Notably, items e) and h) were reverse scored. The total possible score was 30, with higher scores indicating

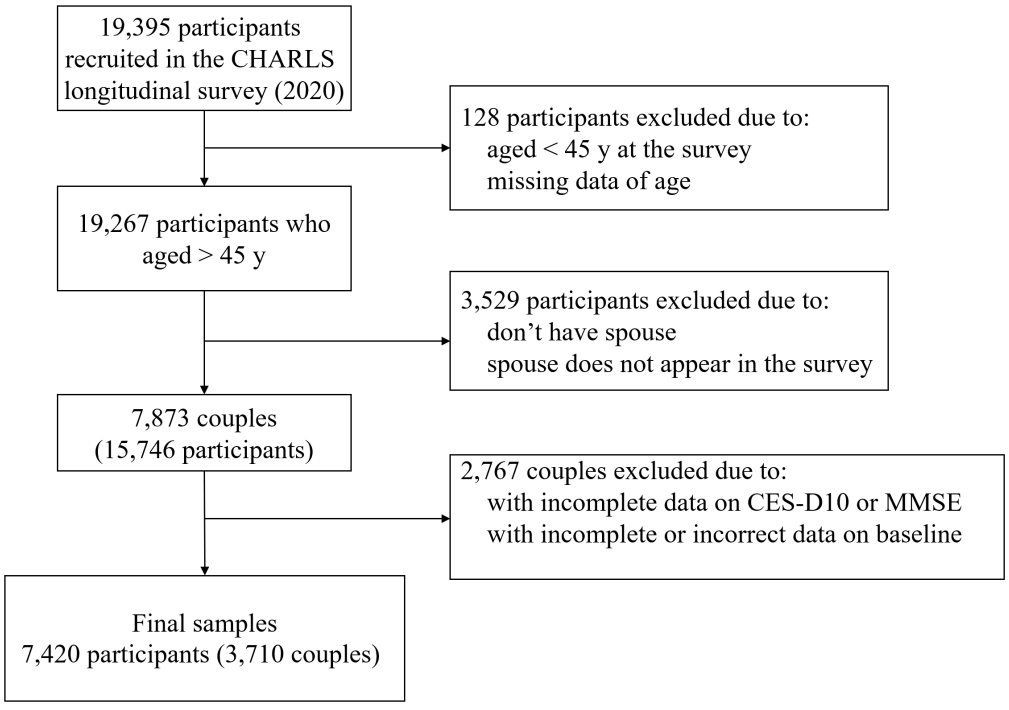

Figure 1. Flow chart of sample selection. This flowchart depicts the selection process of participants from the CHARLS longitudinal survey conducted in 2020. Out of the initial 19,395 participants, 128 were excluded due to being under 45 years of age or missing age data. From the remaining 19,267 participants, 3,529 were excluded because they did not have a spouse or their spouse did not appear in the survey. This resulted in 7,873 couples (15,746 participants) being identified. Further, 2,767 couples were excluded due to incomplete data on CES-D10 or MMSE or incomplete or incorrect baseline data. The final sample included 7,420 participants (3,710 couples).

increased levels of depression.

2.2.2. Explanatory variable

The key explanatory variable in this study is spousal cognitive functioning, which was calculated through the MMSE scale in CHARLS with a total score of 21. Higher scores represent better cognitive functioning of the respondents. Cognitive functioning consists of two components: state of mind and situational memory. A total score of 11 was obtained from the tests of date recognition, numeracy, and drawing function, while a total score of 10 was obtained from the test of situational memory using word recall.

2.2.3. Control variables

Control variables selected in this study are based on previous research on depression, including gender, age, education, annual household income, self-rated health, financial support from offspring, and residence. These factors are hypothesized to influence depression among middle-aged and older adults.

2.2.4. Instrumental variable

Instrumental variables must correlate with endogenous explanatory variables. Extensive evidence has explored the link between social participation and cognitive function. For instance, a longitudinal study in the United States from 1982–1994 found that individuals without social ties had a 137% increased risk of cognitive decline compared to their socially engaged counterparts, after adjusting for control variables (*27*). Additionally, a study in Taiwan from 1989–2000 found that older adults engaged in one to two social activities were 13% less likely to fail cognitive tests (*28*). And compared to those uninvolved in social activities, engagement in three or more activities reduced the likelihood of failing these tests by 33%. A previous study, using Health, Aging, and Retirement in Europe (SHARE), identified a strong positive correlation between various types of social participation and cognitive functioning in older adults (*29*). Therefore, we imported the spousal social participation as an instrumental variable, because it aligns with the principle that instrumental variables should correlate with endogenous explanatory variables. In this context, social participation is linked to their cognitive function, which may subsequently affect spousal depression through its impact on their own cognitive functioning. This selection also meets the exclusivity criterion because the control variables in this study are unaffected by spousal social participation. In conclusion, choosing spousal social participation as the instrumental variable in this study is reliable.

To enhance data comparability, we standardized spousal social participation and obtained a standardized score. First, we calculated the score derived by assigning one point for each of the eight different social activities in which spouses participated. The standardized score was then calculated by subtracting the mean score from the total score and dividing the result by the standard deviation.

The detailed measurement of the variables used in this study are presented in Table 1.

The variables and their relationships involved in this study are shown in Figure 2. Standardized score of spouses' social participation serves as an instrumental variable, influencing depression levels indirectly through its effect on spousal cognitive functioning. Control

Table 1. Variables and their measurements

Variable	Variable type	Measurement
Explained variable		
Depression level	continuous	CES-D-10 scale score out of 30, the higher the score the higher the level of depression.
Explanatory variable		
Spousal cognitive functioning	continuous	Spouse's MMSE scale score out of 21, with higher scores associated with better cognitive functioning.
Control variables		
Gender	binary	1= male, 0 = female.
Age	continuous	One full year of life.
Education	ordered categorical	1 = below primary school, 2 = primary school, 3 = middle school, 4 = High school and above.
Annual household income	continuous	RMB, in logarithms.
Self-rated health	ordered categorical	1 = poor, 2 = rather poor, 3 = average, 4 = good, 5 = excellent.
Financial support from offspring	binary	0 = no, 1 = yes.
Residence	binary	0 = urban, 1 = rural.
Instrumental variable		
Standardised score of spousal social participation	continuous	Each participation in one of the 8 social activities counts as 1 point. The score is calculated as (total score - mean)/standard deviation. 8 social activities include: visiting, playing mahjong, offering help, dancing, club activities, volunteer activities, going to school or training, other socialising.

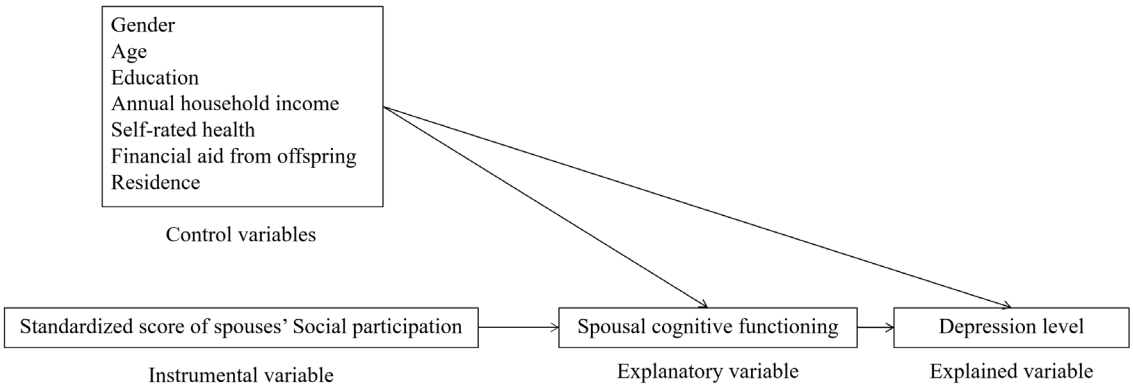

Figure 2. Causal diagram of this research. This figure illustrates the conceptual framework used to examine the impact of spousal cognitive functioning on depression levels, incorporating both control and instrumental variables. The standardized score of spouses' social participation is utilized as the instrumental variable to explain spousal cognitive functioning, which is the key explanatory variable in the model. The control variables include gender, age, education, annual household income, self-rated health, financial aid from offspring, and residence. These factors are controlled for in the analysis to isolate the effect of spousal cognitive functioning on depression levels, which is the primary explained variable.

variables, including gender, age, education, annual household income, self-rated health, financial aid from offspring, and residence, are incorporated to adjust for confounding factors that may affect the relationship between spousal cognitive functioning and depression levels.

2.3. Statistical analysis

2.3.1. Descriptive statistics

Descriptive statistics were used to characterize the sample. We calculated means or proportion of each variable for the overall sample and stratified by gender, residence, and age groups (< 60 years and ≥ 60 years). Depending on the variable type, differences between groups were assessed using either chi-square (χ^2) tests or *t*-tests, with *p*-values reported to determine statistical significance.

2.3.2. Ordinary least squares

The association between the cognitive abilities of spouses in middle-aged and older populations and their respective depression levels were analyzed using an Ordinary Least Squares (OLS) regression model. The model is defined as follows:

$$Depression_i=\beta_0+\beta_1 s\_c_i+\beta_2 X_i+\varepsilon_i \quad (1)$$

where, *s_c* is the abbreviation for *spouse_congnition* and $Depression_i$ represents the depression degree of individual *i*, and s_c_i represents the cognitive ability of individual *i*'s spouse. The variable X_i includes additional covariates, such as gender, age, and education, that could potentially influence the depression degree. The model also features β_0 as the intercept, β_1 as the coefficient for the explanatory variable, β_2 as the coefficient for the control variable and ε_i to account for residual errors. This model structure allows for analysis of how spousal cognitive functioning impacts an individual's depression while controlling for other significant demographic and personal factors. To address potential heteroskedasticity issues within the dataset, the regression model was enhanced with the robust option. Additionally, the OLS regression was conducted stratified by gender, region, and age groups to explore responses to different demographic populations to changes of spousal cognitive functioning.

Because men and women may exhibit different behavioural patterns in caring for their cognitively impaired spouses during their lives, it was necessary to explore whether there was an interaction effect between gender and spousal cognitive functioning. In conducting OLS regression analyses, we specifically conducted an OLS regression in the overall sample that included an interaction term between gender and spousal cognitive functioning in order to explore whether the effect of spousal cognitive functioning on depression differed significantly between genders, and thus to clarify which gender was more sensitive to this effect.

2.3.3. Instrumental variable

Endogeneity of explanatory variables presents a significant challenge for OLS. Two primary factors contribute to the endogeneity of spousal cognitive functioning. The first is the presence of omitted variables such as couple's rapport, lifestyle habits, and genetics. These factors are difficult to measure but may influence both depression and spousal cognitive ability. Second, the other source of endogeneity is the issue of reverse causality, which means depression could potentially affect spousal cognitive functioning. To address these issues and derive more robust regression outcomes, the instrumental variable method was employed to better

ascertain the causal relationships between the variables.

In this study, the two-stage least squares (2SLS) approach within the instrumental variable framework was used. Reliability of the 2SLS estimates is based on validity of the chosen instrumental variable. The first-stage model is as follows:

$$s\_c_i=\alpha_0+\alpha_1 s\_\ scfsp_i+\alpha_2 X_i+\upsilon_i \quad (2)$$

where *s_scfsp* stands for spouse_ standardised score for social participation and $s\_\ scfsp_i$ is the instrumental variable of our research. X_i encompasses covariates influencing depression as mentioned in Equation (1). In the second stage of 2SLS, the predicted value s_c_i of Equation (2) is used to replace s_c_i of Equation (1). And then, using OLS Equation (1), the regression coefficients determined by 2SLS can be obtained. 2SLS also introduces the robust option and performs stratified analysis.

When implementing 2SLS, the statistically significant coefficient for the instrumental variables in the first-stage regression indicate a correlation with the endogenous explanatory variable. Additionally, the validity of instrumental variable is further supported by specific test statistics such as the Cragg-Donald Wald F value, the Kleibergen-Paap rk Wald F value for the weak identification test, and the Kleibergen-Paap rk LM value for the under identification test. In addition, to quantitatively validate the exogeneity of the instrumental variable, we employed the Union of Confidence Intervals (UCI) method proposed by Conley *et al*., setting the gmin value to -1 and the gmax value to 1 (*30*).

Following the preparation of data and methods, the study's parameters were estimated using Stata 17.0 software, ensuring rigorous and precise analysis results.

3. Results

3.1. Summary statistics

Descriptive statistics for each variable are presented in Table 2, with additional details available in Supplemental Tables S1-S3 (*https://www.biosciencetrends.com/action/getSupplementalData.php?ID=212*) of the Appendix. The mean of the CES-D-10 score in the overall sample is 7.63, suggesting a mild level of depression. Statistically significant differences in depression levels were observed between genders, residential areas, and age groups.

The average cognitive function score for the study sample was 13.11. Females scored higher on average (13.35) compared to males (12.87). Urban middle-aged and elderly individuals (13.77) also exhibited higher cognitive function scores than their rural counterparts (12.54). Furthermore, individuals aged < 60 years (13.66) displayed higher cognitive scores than those aged ≥ 60 years (12.50). Given that the main explanatory variable of this study is spousal cognitive functioning, that information is represented in Table 2. The spousal cognitive function score for men was calculated based on the cognitive scores of females, and vice versa for women, as presented in Supplemental Table S1-S3 (*https://www.biosciencetrends.com/action/getSupplementalData.php?ID=212*). The standardized score for spousal social participation was found to be higher among urban and individuals aged < 60 years compared to rural and older adults aged ≥ 60 years, and no significant differences were observed between genders.

3.2. Ordinary least squares regression

The outcomes of the OLS regression analysis conducted in this study are presented in Table 3. Model (1) from Table 3 indicates that the regression coefficient for spousal cognitive functioning is significantly negative. Specifically, for each one-point increase of spousal cognitive functioning, the depression scores of middle-aged and older adults decreased by 17.1%. Further analysis in models (2) and (3) reveals that depression of females is more sensitive to changes in spousal cognitive functioning: a one-point increase in spousal cognitive functioning results in a 20.8% decrease of depression scores, compared to a 15.1% decrease for males. According to model (4) and (5), older adults show more

Table 2. Summary of statistics

Variable	Overall, *n* = 7,420
Explained variables	
CES-D-10 Depression Scale Score, Mean (SD)	7.63 (6.084)
Explanatory variable	
Spousal cognitive functioning, Mean (SD)	13.11 (3.13)
Control variables	
Gender, *n* (%)	
Male	3,710 (50.00)
Female	3,710 (50.00)
Age, Mean (SD)	60.33 (8.19)
Education, *n* (%)	
Below primary school	1,192 (26.85)
Primary school	1,819 (24.51)
Middle school	2,246 (30.27)
High school and above	1,363 (18.37)
Logarithm of annual household income, Mean (SD)	8.58 (3.98)
Self-rated health, *n* (%)	
Poor	372 (5.01)
Rather poor	1,173 (15.81)
General	3,917 (52.79)
Good	1,007 (13.57)
Excellent	951 (12.82)
Financial support from offspring, *n* (%)	
Yes	6,028 (81.24)
No	1,392 (18.76)
Residence, *n* (%)	
Rural	3,980 (53.64)
Urban	3,440 (46.36)
Instrumental variable	
Standardised score of spousal social participation, Mean (SD)	0.00 (1.00)

Table 3. Ordinary least squares regression result

Variable	Overall (1)	Female (2)	Male (3)	< 60 years (4)	≥ 60 years (5)	Urban (6)	Rural (7)
Spousal cognitive functioning	-0.171***	-0.208***	-0.151***	-0.150***	-0.178***	-0.149***	-0.191***
	(0.022)	(0.033)	(0.027)	(0.032)	(0.031)	(0.032)	(0.031)
Gender	-1.522***	/	/	-1.535***	-1.541***	-1.233***	-1.807***
	(0.129)			(0.172)	(0.196)	(0.173)	(0.191)
Age	-0.008	-0.0176	-0.000	0.062*	-0.027	-0.029*	0.009
	(0.009)	(0.013)	(0.011)	(0.026)	(0.018)	(0.012)	(0.013)
Education							
Primary school	-0.912***	-1.165***	-0.365	-1.121***	-0.710**	-1.326***	-0.574*
	(0.189)	(0.246)	(0.263)	(0.278)	(0.265)	(0.302)	(0.244)
Middle school	-1.443***	-1.860***	-0.775**	-1.859***	-1.049***	-1.407***	-1.467***
	(0.181)	(0.250)	(0.252)	(0.262)	(0.260)	(0.280)	(0.243)
High school and above	-1.778***	-2.234***	-1.144***	-2.040***	-1.692***	-1.957***	-1.600***
	(0.200)	(0.319)	(0.279)	(0.304)	(0.277)	(0.284)	(0.314)
Self-rated health							
Rather poor self-reported health	-3.250***	-3.140***	-3.388***	-3.738***	-2.821***	-3.822***	-2.918***
	(0.422)	(0.452)	(0.449)	(0.632)	(0.564)	(0.751)	(0.514)
General self-reported health	-6.194***	-6.028***	-6.335***	-6.476***	-5.896***	-6.718***	-5.830***
	(0.392)	(0.419)	(0.406)	(0.579)	(0.531)	(0.709)	(0.474)
Good self-reported health	-8.482***	-8.646***	-8.366***	-8.819***	-8.042***	-8.985***	-8.148***
	(0.408)	(0.488)	(0.446)	(0.593)	(0.569)	(0.720)	(0.512)
Excellent self-reported health	-9.251***	-9.470***	-9.061***	-9.494***	-9.040***	-9.729***	-8.924***
	(0.408)	(0.483)	(0.450)	(0.596)	(0.561)	(0.723)	(0.503)
Logarithm of annual household income	-0.020	-0.034	-0.008	-0.077**	0.001	-0.011	-0.058
	(0.017)	(0.025)	(0.022)	(0.027)	(0.022)	(0.021)	(0.028)
Residence	0.956***	1.023***	0.853***	0.701***	1.176***	/	/
	(0.132)	(0.199)	(0.179)	(0.179)	(0.200)		
Financial support for children	-0.011	0.194	-0.227	0.068	-0.287	-0.187	0.265
	(0.158)	(0.237)	(0.210)	(0.196)	(0.270)	(0.208)	(0.244)
_cons	17.904**	19.035*	15.294**	15.025*	18.761**	19.396***	17.901***
	(0.823)	(1.162)	(1.185)	(1.653)	(1.483)	(1.245)	(1.092)
R^2	0.228	0.216	0.193	0.234	0.224	0.205	0.214
Obs	7,420	3,710	3,710	3,862	3,558	3,440	3,980

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; robust standard errors in brackets.

sensitive responses with depression scores decreasing by 17.8% for every one-point increase of spousal cognitive functioning. Finally, the comparison between models (6) and (7) demonstrates that the depression scores of rural middle-aged and older adults are more profoundly affected by spousal cognitive functioning, with depression scores decreasing by a 19.1% reduction for each one-point increase of spousal cognitive functioning.

The OLS regression results after adding the interaction terms for gender and spousal cognitive functioning are shown in Table 4. Regression coefficients for the other variables after the addition of the interaction term are in the same direction of sign and have essentially equal values as before the interaction term was added. The regression coefficient with the addition of the interaction is 0.096, with a *p*-value of less than 0.05, and the effect of spousal cognition on depression is significantly different between genders. The regression coefficient of the interaction term is positive, which means that for men, the effect of spousal cognition on depression is weaker and women are more sensitive to this change. Fitted line plot (Figure 3) visualizes this result, with women experiencing a higher decline in depression than men as their spouse's cognitive functioning improves.

3.3. Two-stage least squares regression

To mitigate the effects of potential unknown variables and reverse causality, our study imported the standardized score of spousal social participation as the instrumental variable in the 2SLS analysis. The results affirm that the first-stage instrumental variable was significantly correlated with depression scores in all models, as presented in Table 5. The *p*-value corresponding to Kleibergen-Paap rk LM was below 0.1 and both Kleibergen-Paap rk Wald F and Cragg-Donald Wald F value both were greater than the critical value of 19.93 for the test at the 10% level, thus rejecting that the instrumental variable is the assumption of weak identification (*31,32*). Additionally, in the result of UCI, we found that the robust 95% CI for the coefficient of spousal social participation is (-4.828, 3.285), which includes the coefficient found in Table 5 for the overall sample in the first stage: 0.305. It indicates that the instrumental variable meets the requirement of

Table 4. Ordinary least squares regression with interaction effects: impact of spousal cognitive functioning and gender on depression levels

Variable	Overall
Spousal cognitive functioning	-0.226***
	(0.034)
Gender	-2.793***
	(0.593)
Age	-0.007
	(0.009)
Education	
Primary school	-0.887***
	(0.190)
Middle school	-1.427***
	(0.181)
High school and above	-1.771***
	(0.200)
Self-rated health	
Rather poor self-reported health	-3.249***
	(0.422)
General self-reported health	-6.185***
	(0.392)
Good self-reported health	-8.472***
	(0.408)
Excellent self-reported health	-9.248***
	(0.408)
Logarithm of annual household income	-0.019
	(0.017)
Residence	0.969***
	(0.133)
Financial support for children	-0.010
	(0.158)
Gender*Spousal cognitive functioning	0.096*
	(0.043)
_cons	18.541
	(0.874)
R^2	0.228
Obs	7,420

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; robust standard errors in brackets.

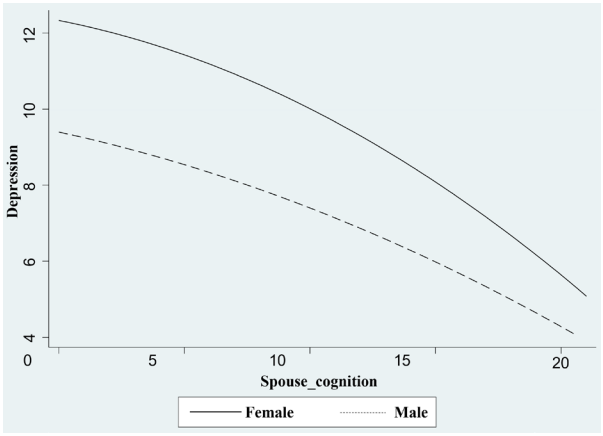

Figure 3. Interaction effect of spousal cognition and gender on depression. This figure illustrates the interaction between spousal cognition and gender on depression levels. The y-axis represents the level of depression, while the x-axis represents spousal cognitive functioning. The solid line corresponds to females, and the dotted line corresponds to males. The graph demonstrates that as spousal cognition increases, depression levels decrease for both genders. However, the effect is more pronounced for females, indicating a stronger negative association between spousal cognition and depression in women compared to men.

exogeneity. These results confirm the adequacy of the standardized score of spousal social participation as an instrumental variable and the reliability of the 2SLS regression results.

The regression coefficient of spousal cognitive functioning on depression levels of middle-aged and older adults were significant in all models and showed a consistent direction with the OLS results, as shown in Table 5. The introduction of the instrumental variable amplified the effect. In the overall sample, each point increase in the spousal cognitive functioning score was associated with a 68.2% decrease in the depression score. The subgroup analysis of 2SLS maintains the relationship between the magnitude of the regression coefficients between genders as well as between urban and rural areas, however, the age groups changed. The absolute value of the explanatory variable's regression coefficients was larger in the middle-aged group than in the older group. The finding from 2SLS, which offers a more robust estimation of causality, indicated that the causality is more pronounced in the middle-aged group.

4. Discussion

Depression is becoming more common among middle-aged and older adults as the global population ages, so it is critical to determine factors that affect mental health of this population. Concurrently, the growing disease burden associated with low cognitive function in these age groups is influencing the psychological wellbeing of family members, particularly spouses. This study employed the instrumental variable method to confirm the causal relationship between spousal cognitive functioning and depression levels in middle-aged and older adults.

First, the findings reveal that higher spousal cognitive functioning correlates with lower depression levels. Our findings align with previous studies that have explored the relationship between spousal cognitive functioning and depression (*33,34*). However, our study extends these findings by using an instrumental variable approach to address potential endogeneity, providing more robust evidence of causality. Our findings are also inconsistent with the results of some previous studies, a Korean study showing that emotional distress effects spouse's cognitive impairment or that the cognitive ability impacts spouses' emotional distress (*35*). Additionally, the study identified a difference in sensitivity to spousal cognitive functioning's impact on depression between different groups including genders, age groups, and residential areas.

Theories such as emotional contagion and role tension provide valuable frameworks for understanding

Table 5. Two-stage least squares regression

Variable	Overall (1)	Female (2)	Male (3)	< 60 years (4)	≥ 60 years (5)	Urban (6)	Rural (7)
Spousal cognitive functioning	-0.682***	-0.751**	-0.565*	-0.700*	-0.602*	-0.512*	-0.956**
	(0.205)	(0.289)	(0.273)	(0.304)	(0.274)	(0.254)	(0.359)
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Coefficients of regression instrumental variables in the first stage	0.305***	0.305***	0.308***	0.266***	0.360***	0.312***	0.282***
Kleibergen-Paap rk LM	82.742***	49.933***	38.438***	39.601***	43.295***	53.916***	28.745***
Cragg-Donald Wald F	77.952***	46.688***	36.267***	38.237***	40.603***	50.056***	27.840***
Kleibergen-Paap rk Wald F	85.886***	51.744***	39.911***	40.721***	44.900***	56.680***	29.198***
R^2	0.167	0.159	0.143	0.168	0.180	0.172	0.081
Obs	7,420	3,710	3,710	3,862	3,558	3,440	3,980

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; robust standard errors in brackets.

interpersonal dynamics and mental health, in particular in the context of interspousal interactions and their influence on depression (*35,36*). Negative emotions such as depression and frustration often stem from one partner's cognitive dysfunction, which can be transmitted to the other partner. This transmit potentially leads to shared depressive symptoms. Furthermore, the physically healthy spouse may face multiple role tensions that encompass caregiving responsibilities, financial strains, and the balancing of personal emotional needs. The low cognitive functioning of one spouse not only diminishes their quality of life but also imposes a substantial psychological and emotional burden on the caregiver. The physically healthy spouse often shoulders the responsibility of daily care, emotional support, and managing behavioural and emotional changes of the affected partner. These responsibilities will deplete their time and energy, possibly leading to mental health challenges and triggering depression (*34,37,38*).

Moreover, our study found differences in this effect among different groups of middle-aged and older adults. First, in the overall sample, empirical findings of this study indicate that a one-point increase in spousal cognitive functioning scores is associated with a significant reduction in depression levels, ranging from 17.1% to 68.2%. Our study provides causal validation for previous research, while offering a contrast to Monin's conclusions (*10,26*). Typically, a decline in cognitive functioning is paralleled by a deterioration in daily behavioural abilities. Within the Chinese familial structure, physical and mental disease in one spouse frequently necessitates that the other spouse assume caregiving duties. This role not only consumes considerable time and energy but also leads to heightened depression levels. From the perspective of individual-social relationship theory, the influence of spousal cognitive dysfunction on depression in middle-aged and older adults is significant. This reflects the profound impact that social relationships and structures have on individual mental health. In this context, spousal interactions and relationships are critical forms of social capital that significantly affect mental wellbeing. Cognitive dysfunction in a spouse may reduce their capacity to offer emotional and practical support, thereby weakening the overall social support system. The absence or reduction of such support is a crucial factor in the increase of depressive symptoms among middle-aged and older adults (*39*). Moreover, because spouses typically share similar living environments and habits, cognitive dysfunction in one partner may inadvertently impact the other through these shared lifestyle factors (*40*).

In terms of gender-specific differences, females exhibit higher depression levels and are more sensitive to their spouse's cognitive functioning change. Empirical study demonstrated that a one-point increase in their spousal cognitive function is associated with a 20.8–75.1% reduction in depression levels among females, a more substantial decrease compared to the 15.1–56.5% range observed in males. The result of the interaction effects test also support this view. A number of current studies have explored the reasons for this phenomenon. This is consistent with a number of previous studies in which wives' depression was found to be more sensitive to husbands' cognitive functioning (*38,41*). Previous research indicates that women bear a greater burden in caring for their spouses and tend to have lower levels of subjective wellbeing and physical health (*42,43*). Furthermore, the responsibilities of caregiving often diminish the time women can devote to engaging in social activities, which are known to positively influence mental health. Females also tend to experience higher emotional distress and responsibility when dealing with their spouse's cognitive dysfunction, heightening their depression risk. Previous research has corroborated this, indicating that female family caregivers generally suffer more adverse effects on their emotional and mental health compared to their male counterpart (*44*).

Second, in our study, inconsistency exists between the results of OLS and 2SLS in different age groups. In the OLS, depression was more likely to be influenced by spousal cognitive functioning in the middle-aged group, whereas the results were reversed in the 2SLS. In the middle-aged group, endogeneity problems were

more pronounced in this group due to multiple social pressures that may have underestimated the effect of spousal cognitive functioning on depressive symptoms in the OLS. 2SLS corrected for potential endogeneity problems, including possible problems of reverse causation or omitted variables, to provide more reliable causality estimates. According to the 2SLS regression results, the level of depression in middle-aged adults is more significantly impacted by spousal cognitive functioning compared to older adults. A one-point increase in spousal cognitive functioning scores results in a 70.0% reduction in depression levels in middle-aged adults, as opposed to a 60.2% decrease in older adults. Middle-aged adults often face multiple pressures from career development, child-rearing, and elderly care. When the cognitive function of their spouse declines, they are required to undertake additional caregiving responsibilities, increasing their daily life burdens and potentially affecting their mental health. Consequently, the depressive responses of middle-aged adults to their spousal cognitive decline may be more sensitive and complex than those observed in older adults. In contrast, older adults, typically retired, no longer shoulder extensive social and professional responsibilities. Thus, the direct impact of a spousal cognitive functioning decline on their mental health may be less severe. However, while the impact of cognitive decline on the mental health of older adults is less pronounced than in middle-aged individuals, it still warrants attention. Older adults are more prone to physical health issues and tend to have fewer social interactions, spending more time with their spouses daily. Consequently, spousal declining cognitive function is likely to exacerbate their depression. It causes a greater burden of disease in the elderly population than it does in middle-aged people; therefore, for middle-aged people, attention should be paid to detecting early symptoms of cognitive decline and implementing cognitive function training. This not only keeps their own cognitive health strong, but also reduces the psychological burden and depression of their spouses. Community-level psychological counselling services and support groups should also be available to assist them in managing the mental health challenges posed by their spousal cognitive decline. For the elderly, the government should enact policies to establish a robust social support network and provide home care training. This training is designed to teach older adults how to better care for spouses with declining cognitive function and reduce their caregiving burden. Additionally, establishing community service centres focused on the mental health of older adults could provide psychological counselling, emotional support, and other services to help them deal with the psychological stress caused by spousal cognitive decline.

Third, depression in middle-aged and older adults in urban compared to rural areas respond differently to spousal cognitive functioning decline. Our analysis revealed that a one-point increase of spousal cognitive function resulted in a 14.9–51.2% reduction in depression among urban middle-aged and older adults, whereas in rural counterparts, the decrease ranged from 19.1–91.6%. The effect was markedly stronger among the rural middle-aged and older adults. This disparity can likely be attributed to the less-developed social support networks in rural areas, which increase older adults' reliance on family members, in particular spouses. When a spouse's cognitive function declines in these settings, the increased isolation can exacerbate depression risk (*45*). In many rural societies, there is a cultural expectation for middle-aged and elderly individuals, especially women, to care for their ailing spouses. As spousal cognitive functioning deteriorates, the care burden of females increases, leading to increased stress and potential depression due to lack of external support (*42*). The regression coefficients of the OLS regression model (6) and (7) for the gender in our study have also shown evidence of this. Moreover, healthcare resources are often scarce in rural areas, compounding the challenges faced by older adults and their spouses in accessing necessary treatments and support for cognitive impairment or depression (*46*).

Besides, other factors also have an impact on the level of depression in middle-aged and older Adults. The empirical findings of this study highlight several factors that influence depression levels in middle-aged and older adults. Higher education levels are generally associated with improved cognitive processing and problem-solving abilities, which enable individuals to manage stress and challenges more effectively (*47*). Additionally, better-educated individuals often adopt healthier lifestyles, including regular exercise, healthy diet, and smoking cessation (*48*). They may also enjoy higher social status and self-efficacy (*49*). All of the above are associated with reduced depression levels, corroborating previous research findings (*9*). Self-rated health is another critical determinant of depression. Individuals with poorer health ratings are more likely to exhibit depressive symptoms, a conclusion consistent with an analysis using the China Family Panel Studies database (*8*). This association may stem from negative self-perceptions that lead to diminished mood and a reduced sense of self-worth (*50*). Furthermore, the study identified several demographic-specific factors significantly impacting depression levels. Age was a notable influence among the middle-aged and urban populations, and annual household income significantly affected middle-aged and rural populations.

Based on our study and previous studies, certain interventions for spouses of middle-aged and older adults with cognitive decline are necessary. In addition to depressive conditions, spouses of patients with cognitive decline also face problems with their own nutritional status and need to be monitored on an ongoing basis for their mental health and nutritional status (*51*). In

addition, their depression stems in part from the patients' communication deficits, and existing research has shown that improving their communication skills can help improve their psychological status (*52,53*). There are also a number of interventions such as Mindfulness-Based Intervention (MBI), dementia care partner resilience (CP-R) and telephone counselling that have been shown to be effective in improving the psychological status of caregivers with cognitive impairment, and deserve to be further promoted in the future (*54-56*).

Previous research examining the factors influencing depression among couples typically employed the APIM, which can verify correlations between variables but not causality. In contrast, our study employs the instrumental variable method, which can address the challenges posed by unmeasurable potential variables and reverse causation. This approach effectively mitigates endogeneity bias, thereby uncovering underlying causal relationships.

Some limitations also exist in our study. First, depression was assessed by the CES-D-10 scale, and spousal cognitive functioning was measured by MMSE scale scores. Although both scales are extensively used in clinical research, they do not encompass all dimensions of depression or cognitive functioning. Second, our study excluded the non-completion of the scale in the population, who may have lower cognitive functioning and higher risk of depression, which resulted in a study sample that did not fully reflect the actual situation of the middle-aged and elderly population and caused some underestimation. Additionally, these scale scores are derived from individual self-reports and may be subject to subjective bias. Despite efforts to control for a variety of variables through the study design and use of instrumental variables to address endogeneity in spousal cognitive functioning, the potential for unobserved variables remains. Factors such as spousal emotional bonds and lifestyle habits might concurrently influence levels of depression in middle-aged and older adults and their spousal cognitive functioning. Our analysis was conducted using the CHARLS database from China, and its applicability may be constrained by specific cultural and social contexts. Consequently, environmental and cultural differences should be considered when extrapolating these findings to other settings.

5. Conclusion

This study determined the impact of spousal cognitive functioning on depression levels in middle-aged and older adults based on the CHARLS2020 wave. Using an instrumental variables approach, we highlighted differences in this effect across population groups. The findings demonstrated that enhanced spousal cognitive functioning is significantly linked to reduced depression levels among middle-aged and older adults, in particular in female, middle-aged, rural populations. Besides, additional support is crucial to mitigate the negative impact of spousal cognitive decline on the mental health of older adults. Because cognitive decline is more prevalent in older adults, these supports ensure their wellbeing.

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