

Bidirectional Associations between Daily Activity Limitations and Depressive Symptoms among Middle-aged and Older Adults with Multimorbidity in China: A Cross-Lagged Panel Network Analysis

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Article

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Abstract

This study was based on the 2018 and 2020 rounds of the China Health and Retirement Longitudinal Study (CHARLS). A total of 5,850 middle-aged and elderly people aged 50 years and above with two or more chronic diseases were included. A cross-lagged panel network model was used to analyse the longitudinal predictive relationship between activities of daily living (ADL) and depressive symptoms (DS), stratified by sex. The results revealed that ADL functional limitations were used mainly as predictors, whereas depressive symptoms were mostly in the affected position. Among them, "Housework" (A7) and "Money management" (A12) had strong outwards predictive effects, especially with depression symptoms such as "Effortlessness" (D6) and "Inertia" (D7). A gender comparison revealed that basic ADL nodes such as "Dressing" (A1) and "Getting up" (A4) were more predictive in the female network, whereas "Housework" (A7) was the core predictive node in the male network. The network edge weights and node centrality are estimated with acceptable accuracy and stability. This study highlights that impaired functioning in complex instrumental daily activities (e.g., housework, money management) may be a prodromal indicator of depressive symptoms in middle-aged and older adults with multimorbidity. Gender heterogeneity exists in the association path between functional status and depressive symptoms, suggesting that targeted strategies should be implemented according to gender characteristics in interventions. Early monitoring of functional status is helpful for identifying and preventing mental health risks.

Introduction

Chronic diseases are major contributors to the increasing global burden of disease and inequalities in health outcomes^{1,2}. Globally, approximately one in three people with chronic diseases suffer from two or more such conditions simultaneously, a phenomenon known as multimorbidity³, and the risk of developing multimorbidity increases significantly with age⁴. With the general increase in life expectancy and the combined effects of multiple factors, such as high body mass index, unhealthy lifestyles, and socioeconomic changes, multimorbidity has become a major public health issue in the context of global aging^{5,6}. Relevant studies indicate that multimorbidity is particularly common among populations with limited health resources⁷. Multimorbidity is not merely the accumulation and prevalence of physical illnesses; its onset and progression are influenced by a combination of factors, including an individual's functional status, lifestyle, and social environment^{8,9}. Against this backdrop, a systematic examination of the functional status and mental health outcomes of older adults with multimorbidity is highly important for deepening our understanding of the mechanisms underlying the health impacts in this population¹⁰.

In older adults with multimorbidity, impaired functional status and mental health problems are often intertwined¹¹. Activities of daily living (ADL) are a core indicator for measuring the functional status of elderly individuals¹², and their decline not only reflects a decline in physical function but is also considered an important risk signal for the deterioration of mental health in elderly individuals¹³. Previous studies have generally suggested that ADL functional limitations can increase the risk of depressive symptoms by restricting individual activity ability, reducing social participation, and weakening the social support network¹⁴. In cross-sectional and longitudinal studies in different countries and cultural backgrounds, the prevalence of depression in older adults with ADL limitations is significantly greater than that in those with normal function^{15–18}. In the Chinese population, this association has been consistently supported by multiple studies^{19,20}.

Sex differences exist in the patterns of multimorbidity^{21,22}, characteristics of impaired functional status^{23,24}, and occurrence and manifestation of depressive symptoms²⁵. Men and women exhibit distinct characteristics in terms of disease spectrum composition, types of functional limitations, and psychological coping strategies; this sex heterogeneity may further influence the pathways linking functional status and depressive symptoms. However, existing studies predominantly analyse overall samples and rarely systematically explore these associations from a gender-specific perspective, which may obscure the differential roles of key functional limitation items and depressive symptom nodes across genders.

Furthermore, previous studies²⁶ have largely relied on overall scores or correlation coefficients for ADLs and depressive symptoms as the primary basis for their conclusions, with few studies conducting in-depth analyses of the structural associations between specific items of functional impairment and specific depressive symptoms. Moreover, the study populations have generally not focused on middle-aged and older adults with multiple comorbidities. Although some studies have begun to employ network analysis methods to characterize the complex relationships between functional and psychological symptoms^{27,28}, most of these studies employ cross-sectional designs, which are insufficient to reveal the dynamic interactions between functional limitations and depressive symptoms over time or their potential directionality.

In summary, it is necessary to adopt a longitudinal perspective and employ more refined analytical methods to systematically examine the bidirectional predictive relationship between ADLs and depressive symptoms in older adults with multimorbidity in the future. The cross-lagged panel network (CLPN) is a longitudinal analytical method that integrates network modelling with cross-lagged panel models. It can depict the predictive relationships between different variables at adjacent time points while controlling for autoregressive effects, thereby enhancing the inferential power regarding the directional associations between symptoms²⁹. This method aids in identifying functional or psychological symptom nodes that occupy key positions in temporal evolution, thereby providing a basis for identifying precise intervention targets³⁰.

Therefore, this study uses data from the 2018 and 2020 waves of the China Health and Retirement Longitudinal Study (CHARLS) to examine middle-aged and older adults with multimorbidity. A cross-lagged panel network model was constructed to systematically examine the stability and dynamic characteristics of the association structure between various ADL functional items and depressive symptoms and to further compare differences in network structure from a sex-specific perspective. This study was performed to provide empirical evidence for elucidating the mechanisms of psychosomatic comorbidity in this population and to formulate intervention strategies.

Methods

Study design and participants

This study utilized data from the fourth and fifth waves (2018 and 2020) of the China Health and Retirement Longitudinal Study (CHARLS), which is available at <https://charls.charlsdata.com/pages/Data/2018-charls-wave4/zh-cn.htm> and <https://charls.charlsdata.com/pages/Data/2020-charls-wave5/zh-cn.html>. Conducted by the National School of Development at Peking University, CHARLS is a nationally representative survey designed to provide high-quality microdata on China's middle-aged and elderly populations. It serves as a vital resource for research on population aging and its socioeconomic impacts. Since its launch in 2011, CHARLS has

employed a multistage stratified random sampling method covering 150 counties and 450 villages across 28 provinces (regions and municipalities). Subsequent surveys are conducted every 2–3 years, with data released to the public one year after each survey is conducted. This study focused on individuals aged ≥ 50 years with at least two chronic conditions from the CHARLS 2018 and 2020 datasets to investigate their mental health status. Among them, 19,816 older adults participated in the 2018 CHARLS. To ensure the accuracy and reliability of the data, we applied the following inclusion criteria: (1) key demographic variables (such as sex, age, educational attainment, marital status, smoking, alcohol consumption, and number of chronic conditions); (2) completion of all items on the Center for Epidemiological Studies Depression Scale (CESD-10) and the Activities of Daily Living Scale; (3) having at least two chronic conditions; (4) being aged 50 years or over; and (5) participation in both the fourth and fifth waves of the survey. Following rigorous screening and data cleaning, 13,966 records were excluded due to missing data or failure to meet the criteria, leaving a final sample of 5,850 participants. Figure 1 shows the sample selection process (Figure 1).

In utilizing the CHARLS data, we strictly adhered to the principles of data privacy and complied with all regulations governing the use of the CHARLS database. Prior to downloading and analysing the data, we obtained formal approval from the database administrator. This study complied with the principles of the Declaration of Helsinki, and the CHARLS study was approved by the Biomedical Ethics Committee of Peking University (IRB0000 052-11015).

Measurement of depressive symptoms

In the CHARLS project, depression was assessed via a shortened version of the CESD-10, comprising 10 items: feeling down, feeling lonely, being troubled by things, feeling afraid, difficulty concentrating, struggling, inability to get started, sleep quality, hope for the future, and feeling happy, with ‘hope for the future’ and ‘feeling happy’ reverse-scored. A 4-point Likert scale ranging from 10 to 40 was used, with higher scores indicating greater severity of depression. In this study, the scale demonstrated adequate reliability and validity, with a Cronbach’s alpha coefficient of 0.811.

Assessment of ADL Disability

In the CHARLS project, activities of daily living (ADL) are measured on the basis of basic activities of daily living (BADL) and instrumental activities of daily living (IADL). The assessment of ADLs comprises two components: BADLs and instrumental ADLs (IADLs). Six BADL scales and six IADL scales were used to assess ADLs. The BADL scale comprises six items: dressing, bathing, eating, getting in and out of bed, using the toilet, and controlling urination or defecation. The IADL scale comprises six items: housework, cooking, shopping, making telephone calls, taking medication, and managing finances. The responses to each item are coded as follows: ‘Can perform independently’ is coded as 0. ‘Some difficulty or worse’ was coded as 1. In this study, the Cronbach’s alpha coefficients for BADLs and IADLs were 0.749 and 0.755, respectively.

Data analysis

In this study, we first summarized the demographic characteristics of the participants and calculated the scores on the relevant scales via SPSS 27.0. We subsequently used R 4.5.1 software to estimate the CLPN for older Chinese adults, women, and men. By combining cross-lagged panel models and network models, the CLPN aims to explore the temporal associations between symptoms²⁹. Notably, the CLPN method allows for

the modelling of directed networks across two time points. The construction of the CLPN model involves several key steps: (a) estimating autoregressive and cross-lagged coefficients via regularized regression, (b) determining the unexpected and expected influences (EI) for each node, and (c) assessing the accuracy and stability of the network.

In the initial stage, the CLPN was estimated via a series of regularized regression models to calculate the autoregressive and cross-lagged effects at two time points³¹. The autoregressive effects captured the coefficients of the 2018 symptoms, predicting their own values in 2020 while controlling for all other symptoms and covariates in 2018. After accounting for all other symptoms and covariates in 2018, the cross-lagged effects involved the coefficients of the 2018 symptoms predicting different symptoms in 2020. The estimation process uses maximum likelihood with Lasso regularization applied to the regression coefficients³¹. This method effectively reduces overfitting and eliminates trivial paths by shrinking small regression paths to zero, thereby enhancing the generalizability of the results³². The *glmnet* package³¹ was used to compute the regularized regression, and the *qgraph* package³³ was used for network visualization. Following the estimation, two centrality indices were calculated for each node: the out-EI and in-EI of the cross-lagged effects. The cross-lagged out-EI indicates the extent to which the 2018 node predicts the 2020 node, whereas the in-EI indicates the extent to which the 2020 node is predicted by the 2018 node, excluding autoregressive paths.

The accuracy and stability of the network were subsequently assessed via two bootstrapping methods supported by the *bootnet* package³³. The accuracy of the edge weights was determined by calculating 95% confidence intervals (CIs) around each edge weight via 1,000 iterations of nonparametric bootstrapping. To evaluate the stability of the network, the case-drop bootstrapping method was employed to calculate the coefficient of stability (CS), thereby estimating the stability of the order centrality measures. A CS coefficient greater than 0.25 is considered acceptable, whereas a value above 0.50 is deemed excellent³³. Furthermore, statistical significance tests were conducted to examine the differences between edge weights and node centrality³³.

Following the CLPN group comparison guidelines²⁹, the following steps were undertaken: (a) estimating the correlation between the edge list and the proportion of edges with the same direction (positive, negative, or neutral), providing a global measure of symptom connectivity; and (b) estimating the correlation between centrality indices across networks, as well as the consistency between the most central symptoms and the strongest edges, providing specific insights into central symptoms and their associations.

Results

Sociodemographic characteristics of the participants

This study included 5,850 older adults aged between 50 and 91 years (mean age 62.88 ± 7.95) with at least two chronic conditions. Of these, 51.9% were women, and 48.1% were men. Table 1 summarizes the participants' demographic characteristics. As shown in Table 2, between the two surveys, there was a discernible trend in both the level of disability in activities of daily living (ADL) and in depressive symptoms among older adults in China. In the overall sample, the proportion of patients with ADL item impairment ranged from 2.1% to 15.9% in 2018, increasing to 3.2%–19.5% by 2020. Among these, toileting (A5) and housing (A7) consistently had the highest impairment rates, whereas eating (A3) had the lowest impairment rate but also showed an increasing

trend. Analysis by gender revealed that women had higher impairment rates than men across all the ADL/IADL items in both surveys did, with a more pronounced increase over time. In 2020, women had the highest impairment rates for "Toileting" (A5) (23.9%) and "Housework" (A7) (20.7%), whereas men had relatively lower impairment rates for these corresponding items. In terms of depressive symptoms, the mean scores for all items in the overall sample ranged from 0.45–1.34 in 2018 and from 0.49–3.29 in 2020; specifically, the mean scores for "Hopelessness" (D9) and "Unhappiness" (D10) were higher in 2020 than in 2018. The results by gender revealed that women's levels of depressive symptoms were consistently greater than those of men. The mean scores for women across all items were 0.59–1.51 in 2018 and 0.64–1.52 in 2020, with relatively higher scores for "Restlessness" (D8), "Effortfulness" (D6) and "Hopelessness" (D9). Compared with those in 2018, men in 2020 presented lower overall levels of depressive symptoms, although scores for some symptoms increased slightly.

Table 1. Baseline characteristics of the study population, stratified by sex

Total(%) / Mean(SD)	All	Female	Male
N	N=5850	N=3038	N=2812
Age	62.88(7.95)	62.43(7.87)	63.37(8.00)
Educational level			
Below primary school	2290(39.1%)	1562(51.4)	728(25.9)
Primary school	1389(23.7%)	625(20.6)	764(27.2)
Middle school	1379(23.6%)	563(18.5)	816(29.0)
High school and above	792(13.5%)	288(9.5)	504(17.9)
Marital status			
Married	4788(81.8%)	2347(77.3)	2441(86.8)
other	1062(18.2%)	691(22.7)	371(13.2)
Number of Chronic Conditions			
2~4	4518(77.2%)	2298(75.6)	2220(78.9)
5~7	1187(20.3%)	661(21.8)	466(16.6)
8~13	145(2.5)	79(2.6)	66(2.3)
Alcohol Drinking Status			
Yes	1915(32.7%)	412(13.6%)	1503(53.4)
No	3935(67.3%)	2626(86.4%)	1309(46.6)
Smoking Status			
Yes	1442(24.6%)	162(5.3%)	1280(45.5)
No	4408 (75.4)	2876(94.7%)	1532(54.5)

Table 2. Activities of daily living (ADL) disability and depressive symptoms of the study population, stratified by sex and year

ADL disability	Nodes	All (2018)	All (2020)	Female (2018)	Female (2020)	Male (2018)	Male (2020)
		Total(%)					
Dressing	A1	398(6.8)	526(9.0)	232 (7.6)	307 (10.1)	166(5.9)	219(7.8)
Bathing	A2	492(8.4)	561(9.6)	307 (10.1)	338 (11.1)	185(6.6)	223(7.9)
Eating	A3	124(2.1)	187(3.2)	73(2.4)	95(3.1)	51(1.8)	92(3.3)
Getting up	A4	434(7.4)	505(8.6)	303 (10.0)	351 (11.6)	131(4.7)	154(5.5)
Toileting	A5	789(13.5)	1141(19.5)	527 (17.3)	725 (23.9)	262(9.3)	416(14.8)
Elimination control	A6	287(4.9)	347(5.9)	149 (4.9)	178 (5.9)	138(4.9)	169(6.0)
Housework	A7	932(15.9)	1022(17.5)	599 (19.7)	629 (20.7)	333(11.8)	393(14.0)
Cooking	A8	616(10.5)	655(11.2)	368 (12.1)	413 (13.6)	248(8.8)	242(8.6)
Shopping	A9	475(8.1)	454(7.8)	325 (10.7)	303 (10.0)	150(5.3)	151(5.4)
Phone use	A10	531(9.1)	391(6.7)	363 (11.9)	246 (8.1)	168(6.0)	145(5.2)
Medication	A11	295(5.0)	353(6.0)	216 (7.1)	262 (8.6)	79(2.8)	91(3.2)
Money management	A12	670(11.5)	578(9.9)	461 (15.2)	377 (12.4)	209(7.4)	201(7.1)
Depressive Symptoms		Mean(SD)					
Depressiveness	D1	1.03(1.105)	1.04(1.116)	1.19 (1.146)	1.21 (1.145)	0.85 (1.031)	0.86(1.053)
Loneliness	D2	0.66(1.052)	0.69(1.063)	0.76 (1.121)	0.79 (1.117)	0.55 (0.961)	0.57(0.99)
Bortheredness	D3	1.04(1.132)	1.11(1.143)	1.21 (1.169)	1.28 (1.175)	0.85 (1.059)	0.92(1.076)
Fearfulness	D4	0.45(0.885)	0.49 (0.929)	0.59 (0.988)	0.64 (1.032)	0.30 (0.729)	0.33(0.771)
Cognitive trouble	D5	1.03(1.122)	1.12 (1.149)	1.18 (1.158)	1.28 (1.172)	0.87 (1.059)	0.95(1.099)
Effortfulness	D6	1.12(1.182)	1.14 (1.203)	1.25 (1.211)	1.26 (1.217)	0.97 (1.132)	1.01(1.175)

Intertia	D7	0.5(0.94)	0.56 [0.997]	0.59 [1.01]	0.67 [1.064]	0.39(0.846)	0.45(0.907)
Restlessness	D8	1.29(1.231)	1.29 [1.228]	1.51 [1.225]	1.52 [1.222]	1.06(1.193)	1.03(1.184)
Hopelessness	D9	1.34(1.255)	2.29 [1.250]	1.35 [1.234]	1.4 [1.24]	1.33(1.277)	1.36(1.260)
Unhappiness	D10	1.1(1.181)	3.29 [1.173]	1.17 [1.195]	1.17 [1.175]	1.03(1.162)	1.05(1.167)

The ADL-Depression Symptom Network among the Elderly Population in China

The correlation matrix for the older adult population in China is presented in Supplementary Table S1. The cross-lagged panel network analysis (CLPN) is visualized as a directed network in Figure 1. The arrows in the figure represent cross-lagged associations between ADLs and depressive symptoms; the model simultaneously controlled for the main effects of each variable in 2018 and the influence of covariates. The autoregressive cross-lagged network diagram incorporating all the variables is shown in Supplementary Figure S1. Among all cross-lagged pathways, the three associations with the largest effect sizes were "Housework" (A7) → "Effortfulness" (D6) ($\beta=0.204$), "Cooking" (A8) → "Housework" (A7) ($\beta = 0.136$), and "Elimination control" (A6) → "Depressiveness" (D1) ($\beta = 0.130$). Furthermore, "Money management" (A12) exhibited relatively concentrated cross-lagged associations with multiple depressive symptoms, including "Money management" (A12) → "Intertia" (D7) ($\beta = 0.122$), "Money management" (A12) → "Hopelessness" (D9) ($\beta = 0.121$), "Money management" (A12) → "Cognitive trouble" (D5) ($\beta = 0.119$), and "Money management" (A12) → "Depressiveness" (D1) ($\beta = 0.119$). Further results of the cross-lagged relationships are presented in Supplementary Table S2.

In terms of node centrality, "Money management" (A12) had the highest out-expected influence (Out-EI) (1.033), followed by "Housework" (A7) (Out-EI = 0.924), indicating that these ADL nodes play a strong predictive role in the network. Conversely, regarding In-Expected Influence (In-EI), "Effortfulness" (D6) had the highest In-EI (1.023), followed by "Intertia" (D7) (In-EI = 0.902), suggesting that these depression symptom nodes are more susceptible to the influence of the past states of other variables within the network. The standardized estimates of node centrality are shown in Figure 2. The detailed results for unstandardized coefficients are listed in Supplementary Table S3, and the distribution of differences in node centrality is illustrated in Supplementary Figures S2–S3.

ADL–Depression Symptom Networks among Middle-Aged and Older Chinese Women and Men

The correlation matrices for middle-aged and older Chinese women and men are presented in Supplementary Tables S4 and S5. Figure 3 illustrates the cross-lagged networks of ADLs and depression symptoms in middle-aged and older Chinese women and men. The similarity analysis of network edge weights revealed a significant yet limited correlation between the edge weights of the male and female networks ($r = 0.30$, 95% CI: 0.21–0.38, $p < 0.001$), suggesting a degree of consistency in the overall cross-lagged association structure between the two sexes, although differences remained in the specific path strengths and connection patterns. In the female network, "Getting up" (A4) presented a high degree of outwards predictive power, with significant cross-lagged associations with multiple depression symptom nodes. Furthermore, a strong bidirectional predictive

relationship existed between "cooking" (A8) and "dressing" (A1), and both formed dense cross-lagged connections with other ADL nodes, constituting a highly interconnected ADL subnet. Other cross-lagged associations in the female network are shown in Supplementary Table S6 (Figure 3). In contrast, in the male network, "Housework" (A7) emerged as the primary predictive node. Other cross-lagged associations in the male network are shown in Supplementary Table S7 (Figure 3). Cross-lagged network diagrams incorporating autoregressive models for all variables in the networks of older Chinese women and men are shown in Supplementary Figure S4.

With respect to node centrality, the out-EI of the male and female networks showed a moderate positive correlation ($r = 0.43$, 95% CI: 0.01–0.72, $p = 0.048$), indicating that some nodes possessed similar predictive importance in both networks, although the nodes playing the primary predictive role were not entirely consistent. Specifically, in the female network, "Dressing" (A1) had the highest out-EI (0.906), whereas in the male network, "Housework" (A7) had the highest out-EI (1.352). In contrast, the In-EIs of the male and female networks exhibited a high degree of consistency ($r = 0.76$, 95% CI: 0.50–0.90; $p < 0.001$). Overall, the in-EI was primarily concentrated in nodes related to depressive symptoms, indicating that depressive symptoms were more likely to act as influenced nodes in both networks. Specifically, in the female network, "Intertia" (D7) had the highest In-EI (1.040), whereas in the male network, "Effortfulness" (D6) had the highest In-EI (1.158); both were significantly higher than other nodes in their respective networks. Detailed information on other nodes for females and males is provided in Supplementary Tables S8 and S9 (Figure 4).

Accuracy and Stability of Network Parameters

The accuracy of the edge weights was tested via the bootstrap method. As shown in Supplementary Figure S6, the 95% confidence intervals for each edge weight were generally narrow, indicating that the edge weight estimates of the network model were highly accurate. The stability of the centrality indices (In-EI and Out-EI) was assessed via the case–drop bootstrap method. As shown in Supplementary Figure S7, as the sample size decreases, the average correlation coefficient between the ranking of centrality indices and the original sample ranking gradually decreases. The correlation stability (CS) coefficients were 0.750 (out-EI) and 0.672 (in-EI), indicating that the order of node centrality exhibited a high degree of stability.

To assess the stability of the network estimates by gender, this study conducted nonparametric bootstrap accuracy analyses of edge weights (1,000 iterations each) on the female ($N = 3,038$) and male ($N = 2,812$) subsamples. As shown in Supplementary Figure S8 (women) and S9 (men), the edge weight estimates for both sex-specific networks exhibited moderate precision. Specifically, the 95% confidence intervals for most edge weights were wide and overlapped extensively, indicating numerous associations with high estimation uncertainty within the networks. However, for several edges with the strongest predicted effects in each network, the confidence intervals were relatively narrow and did not include zero, suggesting that the estimates for these core associations were relatively stable and more reliable.

To assess the stability of node centrality metrics by gender, this study employed the case–drop bootstrap method to analyse subsamples of women ($N = 3038$) and men ($N = 2812$). As shown in Supplementary Figure S10 (women) and S11 (men), there were differences in the correlation stability (CS) coefficients of the node centrality rankings. The out-EI order exhibited moderate stability: the CS coefficient was 0.672 for the female subsample and 0.595 for the male subsample, both exceeding the recommended threshold of 0.50, indicating

that the out-EI node ordering possessed acceptable robustness across gender groups. In contrast, the order of In-EI is less stable: the CS coefficient for both the female and male subsamples is 0.283, which is higher than the minimum acceptable standard of 0.25.

Centrality-based tests of differential analysis revealed that, in the networks of older women and men, the symptoms exhibiting the strongest out-EI/in-EI values were statistically more pronounced than most other symptoms in the networks, as shown in Supplementary Figures S12–S13 (women) and S14–S15 (men). This further demonstrates that the results of the centrality analysis are robust and generalizable.

Discussion

On the basis of longitudinal data from a cohort of middle-aged and older adults with multimorbidity in China, this study employed a cross-lagged panel network model to systematically elucidate the time series interactions between impaired activities of daily living (ADL) function and depressive symptoms. The findings indicate that, after controlling for autoregressive effects, ADL functional items primarily act as outwards-predicting nodes within the network, whereas depressive symptoms are predominantly in a position of being influenced. These findings suggest that, in the context of multimorbidity, functional impairment may be a significant precursor to the onset and exacerbation of depressive symptoms. Furthermore, although the overall network structure was consistent across sexes, significant sex differences were observed at the level of key predictive nodes, suggesting that the functional-emotional association pathways exhibit a degree of sex heterogeneity in populations with multimorbidity.

Among the specific functional items, A7 “Housework” exhibited high predictive power and centrality within the network; impairment in this function significantly predicted core depressive symptoms such as D6 “Effortfulness”. This finding is consistent with the results of previous studies^{27,34}. Chen³⁵ *et al.* found through latent profile analysis that, across different subgroups of ADL impairment, the degree of impairment in IADL was generally higher than that in BADL, and this was particularly pronounced in the high-impairment group. Compared with the basic, largely autonomous activities covered by BADLs, IADL—particularly household chores—often involve multistep operations, situational judgement, and sustained physical and cognitive effort; consequently, they are more susceptible to changes in health status and external environmental factors^{36–38}. In the context of multimorbidity, the cumulative burden of disease combined with a decline in functional compensatory capacity means that such complex activities often become the first functional domains to be impaired^{39–43}. The findings of this study further indicate that such functional limitations precede the onset of depressive symptoms in a time series, suggesting a potential precursor role in the functional emotional change pathway.

Notably, the relationship between functional limitations and depressive symptoms was not unidirectional. Previous studies have shown that depressive states can impair older adults’ ability to perform household activities by affecting their attention, memory, and executive function⁴⁴. Moreover, depression-related sleep disturbances, reduced energy levels, and increased anxiety may further limit physical endurance and task persistence^{45,46}. However, in conjunction with the findings of this study, which are based on a longitudinal cross-lagged network model, the evidence tends to support the view that, in the context of multimorbidity, impairment in complex daily functioning occurs early in the functional–emotional change pathway.

In addition to domestic activities, A12 “money management” also played a prominent and pivotal role in this study, exhibiting the highest out-degree and forming relatively concentrated predictive pathways with multiple depressive symptoms. As a highly complex instrumental activity of daily living, A12 “money management” relies on higher-order cognitive abilities such as memory, attention, and executive function and reflects an individual’s overall capacity to maintain long-term self-management and independence in daily life⁴⁷. Among middle-aged and older adults with multiple comorbidities, issues such as treatment costs, long-term medication management, and daily living expenses are often more complex⁴⁸. When financial management abilities are impaired, individuals are more likely to perceive increased economic uncertainty and a diminished sense of control over their lives, thereby amplifying negative emotional experiences through multiple pathways and driving the development of depressive symptoms. Previous research provides important theoretical explanations for this. Among older adults with cognitive frailty and Alzheimer’s disease, a close bidirectional association between financial management ability and depression has been established. Its impairment may serve as an early manifestation of cognitive decline or significantly increase the risk of depression by undermining self-efficacy and decision-making autonomy⁴⁹. Furthermore, some studies suggest that greater financial management competence can, to a certain extent, buffer the adverse effects of loneliness on depressive symptoms, demonstrating its potential psychological protective value⁵⁰. Taken together, the pivotal role of financial management within the ADL depression symptom network revealed in this study suggests that it may serve as a key entry point for the early identification of depression risk and comprehensive intervention.

This study constructed and compared cross-lagged networks of ADLs and depressive symptoms in women and men. The results indicate that while the networks of both genders exhibit a degree of consistency in their overall structure, there are marked differences in key predictive nodes and path strengths, suggesting that the interaction between functional limitations and psychological symptoms presents distinct structural characteristics across genders. Previous research has highlighted differences between men and women in terms of functional performance and the trajectory of BADL and IADL⁵¹. In general, men maintain a relatively high level of functional ability in BADLs, whereas women tend to demonstrate greater participation and autonomy in IADL, particularly in activities related to housework; this disparity may be linked to long-established patterns of gender-based division of labour^{52,53}. Furthermore, research indicates that women are more prone to a decline in BADLs during advanced age or when experiencing cognitive impairment, suggesting that their baseline self-care abilities are more sensitive to changes in overall health status⁵⁴.

The cross-lagged network analysis in this study has, to some extent, broadened the interpretative scope of these findings. Among older women with multiple comorbidities, nodes related to BADLs—such as A4 “Getting up” and A1 “Dressing”—exhibited a stronger outwards predictive effect and were linked to depressive symptoms via multiple cross-lagged pathways, suggesting that impaired basic self-care abilities may have a more widespread impact on their mental health. In contrast, within the male network, “Housework”—an activity closely associated with IADL—emerged as the most predictive node. This may reflect men’s greater reliance on external support and the family environment in such activities, with limitations in this area being more likely to trigger negative emotional responses. Although some studies have not reported significant sex differences in the overall level of functional dependence⁵⁵, this study indicates that sex differences are more evident in the pathways and mechanisms through which functional impairment influences depressive symptoms than in the degree of functional impairment itself.

Limitations

First, although the use of a longitudinal cross-lagged network model helps reveal the time series associations between variables, it cannot entirely rule out the influence of potential unmeasured confounding factors on the results; therefore, caution is needed when drawing causal inferences. Second, both ADL and depressive symptoms were based on self-report scales, which may be subject to recall bias or social desirability bias; in particular, subjective errors may arise in the assessment of complex functions (such as money management). Furthermore, as the study sample was drawn from a population of middle-aged and older adults with multimorbidity in China, the generalizability of the findings to populations with different cultural backgrounds or disease profiles requires further validation. This study did not distinguish between the types or severity of chronic diseases; future research could incorporate disease characteristics, biological markers, and intervention trials to further explore the mechanisms of the functional-emotional pathway and its potential for intervention.

Conclusions

On the basis of a longitudinal cross-lagged network model, this study systematically elucidated the time series dynamic relationship between impaired ADL function and depressive symptoms in older adults with multimorbidity. The results indicate that complex instrumental activities of daily living (such as Housework and Money management) occupy a central position in the network; impairment in these functions precedes the onset of depressive symptoms in the time series, suggesting that such functional impairments may serve as early predictors of changes in mental health. Gender-stratified analysis further revealed that impairment in basic activities of daily living (BADL) has a more widespread impact on mental health in women, whereas limitations in instrumental activities of daily living (IADL) (such as Housework) are more likely to trigger negative emotional responses in men, suggesting significant gender heterogeneity in the functional-emotional pathway. This finding suggests that in health management and intervention practices for individuals with multiple comorbidities, early functional monitoring and risk assessment should be prioritized. Strategies should be tailored to gender-specific characteristics while multidisciplinary resources, including nursing, rehabilitation, and psychological and social support, should be integrated to achieve synergistic interventions that maintain functional capacity and promote mental health.

Abbreviations

CHARLS Chinese Health and Retirement Longitudinal Study

DS Depressive symptoms

ADL Activities of daily living

CLPN Cross-lagged panel network

Declarations

Data availability

The datasets used and/or analyzed during the current study are publicly available from the China Health and Retirement Longitudinal Study (CHARLS) repository.

The specific datasets include:

- China Health and Retirement Longitudinal Study (CHARLS), Wave 4 (2018):

<https://charls.charlsdata.com/pages/Data/2018-charls-wave4/zh-cn.html>

- China Health and Retirement Longitudinal Study (CHARLS), Wave 5 (2020):

<https://charls.charlsdata.com/pages/Data/2020-charls-wave5/zh-cn.html>

The data are publicly available to researchers upon registration via the official CHARLS website.

Author contributions

Jiahui Ding is the first author and made significant contributions to the experimental design, data processing, and analysis, and participated in the drafting of the manuscript. Xiaojin Hu and Meiling Sun contributed to data analysis and reviewed and revised the initial draft. Shanshan Ge, as the corresponding author, led the overall research direction, supervised the entire study process, and approved the final manuscript. All authors have read and agreed to the published version of the manuscript.

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Competing interests

The authors declare that they have no competing interests.

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Figures

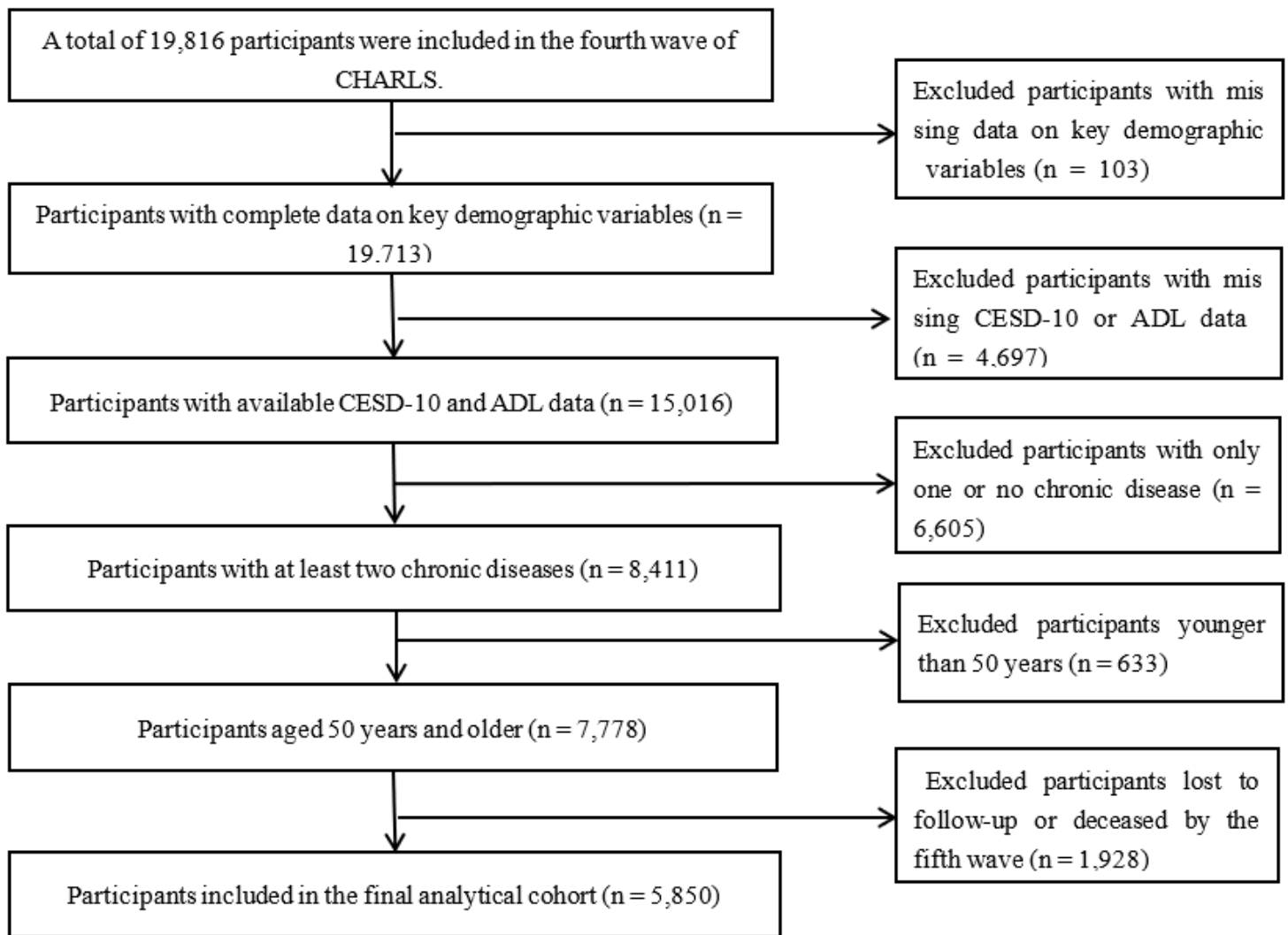


Figure 1

Panel network of the cross-lagged relationship between ADL and depression symptoms. Note: N = 5,850. Blue arrows indicate positive predictions, whereas red arrows indicate negative predictions; the thickness of the arrows reflects the strength of these effects, with thicker arrows indicating a stronger relationship. Covariates (i.e., sex, age, marital status, smoking, alcohol consumption, and education) and autoregressive edges have been omitted from the figure to facilitate visual interpretation.

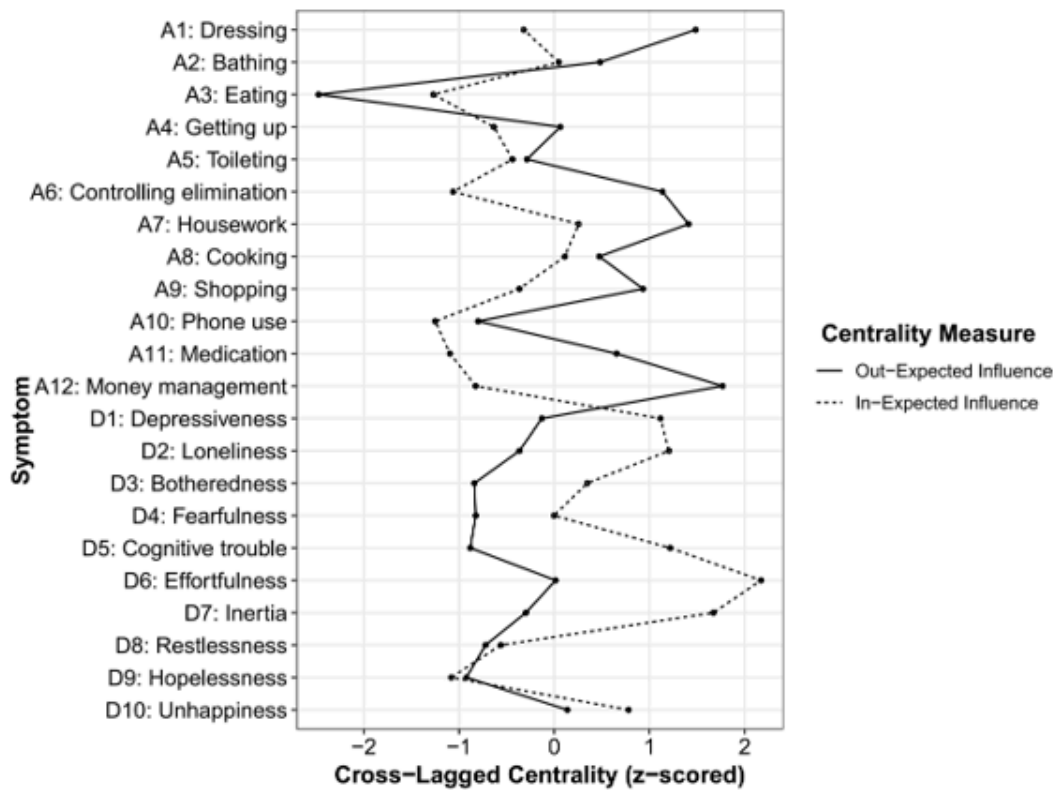


Figure 2

Standardized centrality estimates for the ADL depression symptom network. Note: N = 5,850. Higher values indicate greater centrality of the node.

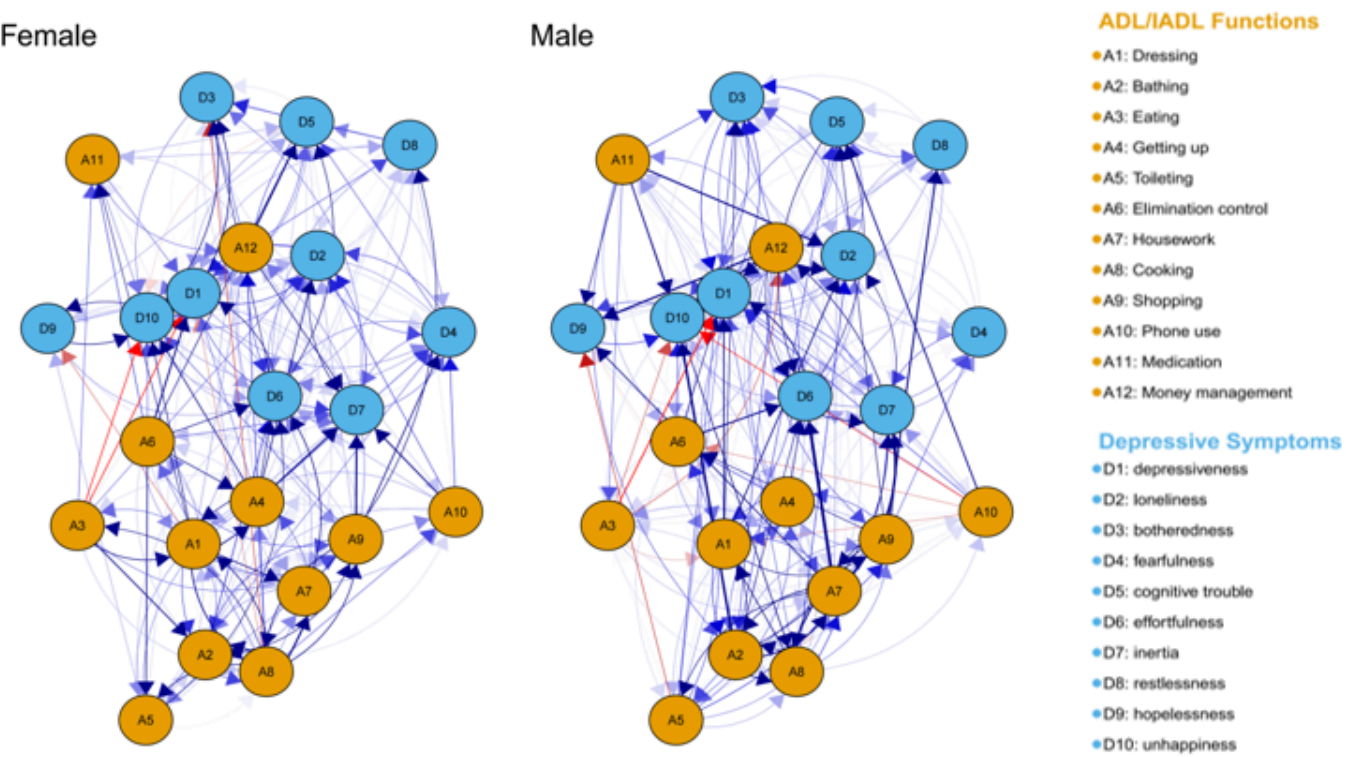


Figure 3

Cross-lagged panel network of ADL and depressive symptoms in older women (left) and men (right). Note: Blue arrows indicate positive predictions, whereas red arrows indicate negative predictions; the thickness of the arrows indicates the strength of these effects, with thicker arrows denoting stronger relationships. Covariates (i.e., age, marital status, smoking, alcohol consumption, and education) and autoregressive edges have been omitted from the figure to facilitate visual interpretation.

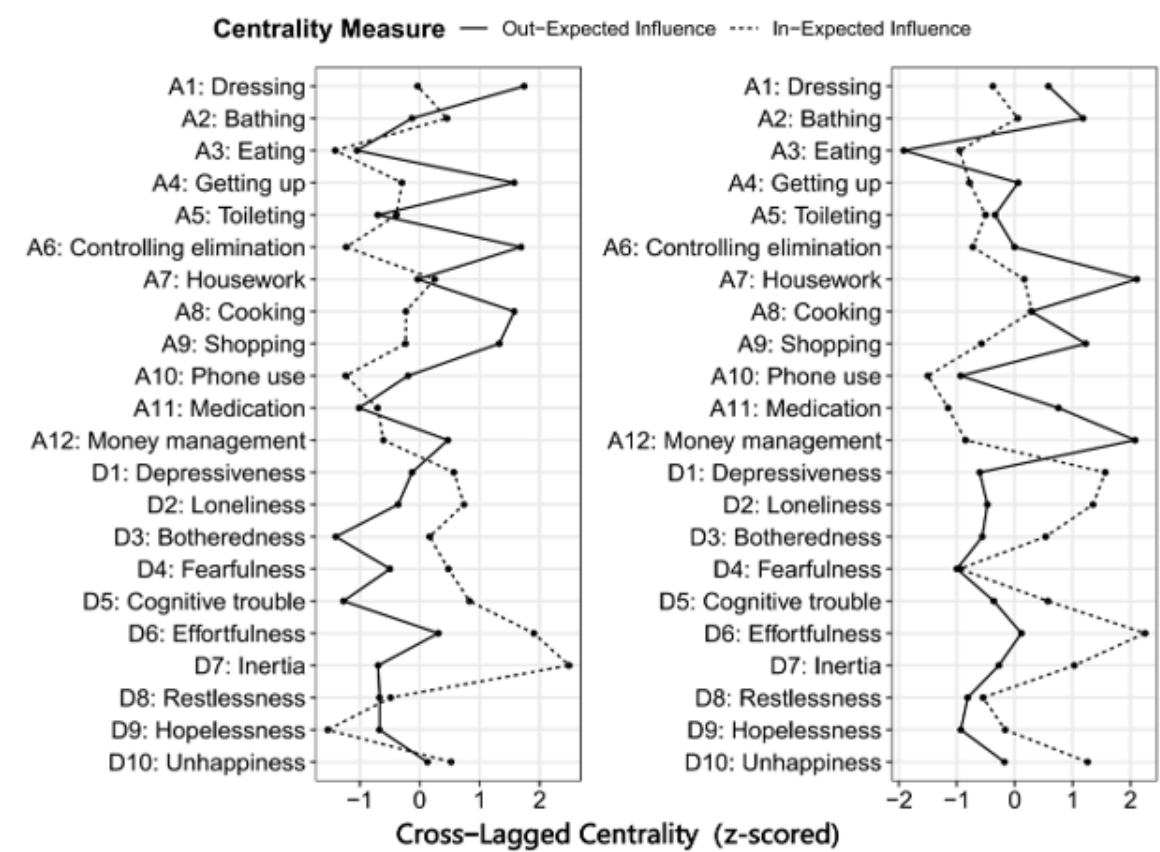


Figure 4

Standardized centrality estimates for the ADL depression symptom network in elderly women (left) and men (right). Note: Higher values indicate a stronger centrality.

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