

Urban–Rural Differences in Networks of Mental Health, Sleep, Cognition, and Functioning Among Older Adults in China: A Nationwide Cross-Sectional Study

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Abstract

Background. Mental health symptoms, sleep problems, cognitive changes, and limitations in functioning often occur together in later life. Whether the pattern of these connections differs between urban and rural older adults in China is not known. We compared nine-indicator networks and bridge strength between the two settings.

Methods. We analysed cross-sectional data from 32,523 community-dwelling adults aged ≥ 65 years in the China Ageing and Health Survey (mean age, 74.2 years; 52.1% female; 62.5% urban). We estimated covariate-adjusted EBICglasso networks comprising PHQ-9, GAD-7, ISI, ESS, SCD, Cognitive-change screening (AD8), PF, GH, and SF. Urban–rural differences in the networks and bridge strength were tested with the Network Comparison Test and label permutations, respectively (1,000 each), with Benjamini–Hochberg correction. Sensitivity analyses excluded the PHQ-9 sleep item, excluded SF, and used ggmModSelect.

Results. PHQ-9 had the highest node strength in the overall, urban, and rural networks (overall strength = 1.401) and the highest bridge strength in both residential groups (urban = 0.715; rural = 0.682). Its edge with GAD-7 was the strongest in the network (partial $r = 0.699$). The urban and rural networks differed in structure ($p=.001$) and global strength ($p=.025$), and six edge differences survived false-discovery-rate correction. After correction across nine node-strength tests, AD8, SF, and ESS had higher strength in the urban network, whereas GAD-7 had higher strength in the rural network. AD8 and ESS also had higher bridge strength in the urban network after BH correction. Excluding SF left PHQ-9 as the highest-strength node, yielded high concordance with the primary edge weights (Pearson $r=.992-.995$), and preserved the structural difference ($p=.001$). The global-strength difference was no longer significant ($p=.232$), and only the AD8 and ESS centrality differences survived correction.

Conclusions. Depression was the most consistently connected indicator across residential settings. Urban–rural differences were concentrated in several sleep–cognition–emotion connections and in the bridge strength of AD8 and ESS. The SF-exclusion analysis preserved the main edge pattern but not the global-strength or corrected GAD-7 centrality differences. These results identify a small set of cross-domain differences for longitudinal testing.

1. Introduction

Population ageing in China is progressing at an unprecedented pace and scale. Adults aged 65 years and older already account for more than 12% of the population and are projected to exceed a quarter by 2050 [1]. In later life, mental health symptoms, sleep problems, cognitive concerns, and declines in physical or social functioning rarely appear alone; they tend to occur together, and each additional problem tends to make the others harder to manage [2, 3]. Network analysis can describe these connections directly, rather than treating each problem as though it existed in isolation.

Whether these connections take the same form in urban and rural settings remains unclear. Older adults in the two settings differ in access to healthcare and social services, education, economic security, and lifetime work. Rural older adults often face greater economic strain and more limited access to healthcare and community resources [5, 7, 21, 22]. Urban older adults, by contrast, generally have more education, greater economic security, and better access to services [5, 7, 22]. These differences may affect how sleep, mood, cognition, and functioning are experienced together.

Network analysis represents measured indicators as nodes and their conditional associations as edges [9, 10]. Node strength describes how strongly one indicator is connected with the rest of the network. Bridge strength describes its connections with indicators in other prespecified domains [10, 44]. Studies of older adults have used network methods to examine depression, anxiety, sleep, and cognition [11–15], but three gaps remain. Physical and social functioning have received less attention, adjustment for sociodemographic factors has been inconsistent, and large studies have rarely compared urban and rural networks formally in China.

We therefore estimated regularised partial-correlation networks for nine indicators: depression, anxiety, insomnia, daytime sleepiness, subjective cognitive decline, cognitive-change screening, physical functioning, social functioning, and general health. Before estimating the networks, we removed variation associated with five sociodemographic factors from each indicator. We first described the overall network and node strength. We then compared urban and rural network structure, global strength, edge weights, node strength, and bridge strength. Finally, we tested whether the findings changed after removing overlapping sleep content or SF, or when using another estimator.

We tested three hypotheses. First, because depression has been strongly connected across several older-adult networks [11, 13, 15], we expected PHQ-9 to have the highest strength in the overall network (H1). Second, because many rural older adults face greater economic insecurity and have less access to mental-health services [19–22], we expected GAD-7 strength to be higher in the rural network (H2). Third, we expected the largest urban–rural edge differences to involve sleep, cognition, and emotional symptoms (H3). We did not specify the direction of individual edge differences, and the bridge-strength comparisons were exploratory; both sets of tests were corrected for multiple comparisons.

2. Methods

2.1 Study Design and Participants

We used data from the China Ageing and Health Survey (CAHS), a nationwide survey covering all 31 provincial-level administrative regions of China. Participants were selected through multistage, stratified, probability-proportional-to-size sampling and completed structured electronic questionnaires administered by interviewers. Survey weights were not available in the analytic file, so all network estimates are unweighted and do not represent population prevalence.

The source file contained 41,859 records. We included participants with complete data on the nine network nodes, five prespecified covariates, and current urban–rural residence. This definition excluded 9,336 records (22.3%) and left 32,523 participants: 20,331 (62.5%) urban and 12,192 (37.5%) rural. Their mean age was 74.20 years (SD = 6.70; range, 65–102), and 16,956 (52.1%) were female. Residence was based on the participant's current residential area. We used the same participants in all node-exclusion analyses so that changes in the networks did not reflect changes in the sample.

2.2 Measures

Depression (PHQ-9). Depressive symptom severity over the past two weeks was assessed using the Patient Health Questionnaire-9 (PHQ-9) [23]. The nine items are rated from 0 to 3 and summed to yield a total score ranging from 0 to 27, with higher scores indicating greater depressive symptom severity. The PHQ-9 has demonstrated good reliability and validity in Chinese older adult populations [24, 25]. In the present sample, internal consistency was excellent (Cronbach's $\alpha = 0.91$).

Anxiety (GAD-7). Anxiety symptoms over the past two weeks were assessed using the Generalized Anxiety Disorder-7 (GAD-7) scale [26]. The seven items are rated from 0 to 3 and summed to yield a total score ranging from 0 to 21. The GAD-7 has been validated for use in Chinese community samples [27]. In the present sample, internal consistency was excellent (Cronbach's $\alpha = 0.95$).

Insomnia (ISI). Insomnia severity was assessed using the Insomnia Severity Index (ISI), a seven-item questionnaire evaluating insomnia symptoms, daytime interference, and distress [28]. Total scores range from 0 to 28. The Chinese version of the ISI has demonstrated adequate psychometric properties in older adults [29]. In the present sample, internal consistency was acceptable (Cronbach's $\alpha = 0.74$).

Daytime Sleepiness (ESS). Daytime sleepiness was assessed using the Epworth Sleepiness Scale (ESS), which evaluates the likelihood of falling asleep in eight common situations [30]. Total scores range from 0 to 24, with scores of 11 or higher indicating excessive daytime sleepiness. The ESS has been widely used in Chinese ageing research [31]. In the present sample, internal consistency was excellent (Cronbach's $\alpha = 0.91$).

Subjective Cognitive Decline (SCD). Subjective cognitive decline was assessed using a nine-item self-report scale capturing perceived cognitive decline compared with the previous year. Subjective cognitive decline is increasingly recognised as a potential early marker of dementia risk and has been linked to emotional well-being [32, 33]. This scale has demonstrated good reliability and validity in Chinese older adult populations [34]. In the present sample, internal consistency was good (Cronbach's $\alpha = 0.89$).

Cognitive-change screening (AD8). Cognitive change was assessed with the eight-item AD8 questionnaire, which covers perceived changes in memory, orientation, judgement, and everyday functioning [35, 36]. Scores range from 0 to 8, with higher scores indicating more cognitive change. The AD8 is a screening measure, not an objective cognitive test or a clinical diagnosis. Internal consistency was good in this sample (Cronbach's $\alpha = 0.88$).

Health-related quality of life (SF-36). Physical functioning (PF), general health (GH), and social functioning (SF) were derived from the SF-36 and transformed to 0–100 scales; higher scores indicate better functioning or health perceptions [37–39]. Internal consistency was good for PF ($\alpha = 0.89$) and GH ($\alpha = 0.83$) but low for the two-item SF subscale ($\alpha = 0.38$). We retained SF in the primary network to cover social functioning and repeated the main analyses without it because its low reliability could affect edges and node strength.

2.3 Covariates

Models adjusted for sex, age, education, personal monthly income, and pre-retirement occupational rank. Each network node was residualised on these five covariates before network estimation, once in the full sample and separately within the urban and rural groups. Education, income, and occupational rank were entered as ordinal scores (ranges 1–10, 1–8, and 1–5, respectively).

2.4 Network Estimation

2.4.1 Network Analysis

Regularised partial-correlation networks were estimated in R using EBICglasso as implemented in bootnet and qqgraph [40, 41]. The Extended Bayesian Information Criterion hyperparameter γ was set to 0.50 [42]. Separate networks were estimated for the overall, urban, and rural samples. Edge weights are regularised partial correlations among covariate-residualised indicators. Blue and red edges denote positive and negative associations, respectively, and thickness represents absolute magnitude.

EBICglasso selected a tuning value below $0.1 \times \lambda_{\max}$ and issued a warning that the network was dense. We therefore did not interpret the smallest edges. We also examined bootstrap results and repeated the analysis with ggmlModSelect [46].

2.4.2 Network Comparison Test

Urban–rural differences were assessed with the Network Comparison Test (NCT; 1,000 permutations) [43]. The NCT tested network-structure invariance, global-strength invariance, all 36 edge-weight differences, and strength-centrality differences for all nine nodes. Benjamini–Hochberg (BH) correction was applied separately to the 36 edge tests and nine node tests; Bonferroni-adjusted edge p-values were also reported. Global tests were not included in these families. All tests were two-sided with $\alpha = .05$.

2.4.3 Node Strength and Bridge Strength

Node strength was the sum of the absolute edge weights connected to a node and served as the primary centrality measure. Bridge strength was the sum of the absolute weights connecting a node to nodes in other domains. We defined four domains before the analysis: sleep (ISI, ESS), mood (PHQ-9, GAD-7), cognition (SCD, AD8), and functioning/health (PF, GH, SF). To compare bridge strength, we permuted group labels 1,000 times while preserving group sizes and re-estimated both networks each time. We applied BH correction across the nine node tests.

2.4.4 Stability and Accuracy of Network Estimates

We assessed network accuracy and stability with 1,000 bootstrap samples [45]. Nonparametric bootstrap confidence intervals described the precision of edge weights. For node strength, case-dropping bootstrap analysis estimated the correlation-stability (CS) coefficient. This coefficient is the largest proportion of cases that can be removed while retaining, with 95% probability, a correlation of at least .70 with the original estimates.

2.4.5 Sensitivity and Robustness Analyses

We used three analyses to test robustness. First, we removed PHQ-9 Item 3 from the PHQ-9 total to reduce overlap with the sleep measures. Second, we removed SF because of its low internal consistency while retaining the same 32,523 participants. We repeated the overall and group-specific networks, NCT tests, BH and Bonferroni adjustments, edge-weight concordance analysis, and 1,000-sample bootstrap analyses. Third, we re-estimated the overall network with ggmModSelect [46] and compared its edge weights and strength rankings with the EBICglasso results.

3. Results

3.1 Sample Characteristics

Of the 41,859 source records, 32,523 met the complete-case definition. We excluded 9,336 (22.3%) because at least one primary node, covariate, or residence value was missing. The analytic sample comprised 20,331 urban participants (62.5%) and 12,192 rural participants (37.5%). Women made up 52.1% of the full sample, 53.2% of the urban group, and 50.3% of the rural group.

Mean age was 74.20 years (SD = 6.70); the median was 72 years and the range was 65–102 years. Table 1 reports education, income, occupational rank, the nine network indicators, missingness in the source data, and urban–rural comparisons. The largest standardised differences were in personal income (SMD = 0.697), education (SMD = 0.667), and occupational rank (SMD = 0.424), with higher values in the urban group. Differences in the nine network indicators were small (absolute SMD $\leq$ 0.140). These unweighted complete-case statistics describe the analytic sample, not population prevalence.

Table 1
Characteristics of the corrected complete-case analytic sample

Characteristic	Overall	Urban	Rural	Source missing, n (%)	p	SMD U – R
Participants, n	32,523	20,331	12,192	0 (0.0%)		
Age, years	74.20 (6.70)	74.32 (6.86)	73.98 (6.43)	3 (0.0%)	< .001	+ 0.051
Female sex, n (%)	16,956 (52.1%)	10,822 (53.2%)	6,134 (50.3%)	0 (0.0%)	< .001	+ 0.058
Education category (1–10)	2.0 [2.0–3.0]	3.0 [2.0–4.0]	2.0 [1.0–3.0]	0 (0.0%)	< .001	+ 0.667
Personal-income category (1–8)	1.0 [1.0–2.0]	2.0 [1.0–2.0]	1.0 [1.0–1.0]	5,735 (13.7%)	< .001	+ 0.697
Pre-retirement occupational rank (1–5)	1.0 [1.0–1.0]	1.0 [1.0–1.0]	1.0 [1.0–1.0]	0 (0.0%)	< .001	+ 0.424
Insomnia severity (ISI)	7.33 (4.12)	7.18 (4.14)	7.56 (4.07)	17 (0.0%)	< .001	-0.092
Daytime sleepiness (ESS)	4.81 (4.77)	4.69 (4.75)	5.01 (4.80)	3,867 (9.2%)	< .001	-0.067
Depressive symptoms (PHQ-9)	4.10 (4.28)	3.90 (4.17)	4.44 (4.45)	0 (0.0%)	< .001	-0.126
Anxiety symptoms (GAD-7)	2.39 (3.53)	2.20 (3.41)	2.69 (3.70)	0 (0.0%)	< .001	-0.138
Subjective cognitive decline (SCD)	3.78 (2.93)	3.69 (2.93)	3.92 (2.93)	0 (0.0%)	< .001	-0.079
Cognitive-change screening (AD8)	1.28 (2.12)	1.24 (2.10)	1.34 (2.14)	0 (0.0%)	< .001	-0.045
Physical functioning (PF)	75.28 (23.39)	75.56 (23.53)	74.80 (23.14)	0 (0.0%)	.004	+ 0.033
General health (GH)	59.23 (18.94)	59.95 (18.81)	58.01 (19.09)	0 (0.0%)	< .001	+ 0.102
Social functioning (SF)	78.13 (19.66)	79.16 (19.54)	76.41 (19.73)	0 (0.0%)	< .001	+ 0.140

Note. Values are mean (SD), median [IQR], or n (%). Missingness is calculated in all 41,859 source records; the 32,523-person analytic sample is complete on all displayed variables. p values compare urban and rural groups using Welch t, Pearson chi-square, or Wilcoxon rank-sum tests as appropriate. SMD is the standardised difference (urban minus rural); positive values indicate higher urban values.

Education, income, and occupational-rank values are ordinal category codes. Cognitive-change screening refers to AD8. Higher PF, GH, and SF scores indicate better functioning or perceived health; higher symptom and cognitive-change screening scores indicate greater burden.

3.2 Overall Network Structure

Figure 1 shows the covariate-adjusted network of nine indicators. PHQ-9–GAD-7 was by far the strongest positive edge (regularised partial $r = 0.699$), followed by SCD–AD8 ($r = 0.387$). The next four positive edges were PF–SF ($r = 0.272$), PF–GH ($r = 0.255$), GH–SF ($r = 0.241$), and ISI–ESS ($r = 0.215$). The four strongest negative edges were PHQ-9–SF ($r = -0.130$), SCD–GH ($r = -0.124$), PHQ-9–GH ($r = -0.103$), and ESS–SF ($r = -0.103$). All remaining edges had $|r| \leq 0.166$ and were not interpreted individually because the estimator produced a dense-network warning.

3.3 Overall Node Centrality

PHQ-9 had the highest strength (1.401), followed by SF (0.946), GAD-7 (0.845), SCD (0.839), GH (0.822), PF (0.778), AD8 (0.636), ESS (0.583), and ISI (0.553) (Fig. 2). Depression was the most connected indicator in the network, supporting H1.

3.4 Urban and Rural Network Structures and Centrality

The NCT indicated an urban–rural difference in network structure ($M = 0.067$, $p = .001$) and global strength ($S = 0.115$, $p = .025$). Global strength was 3.741 in the urban network and 3.626 in the rural network. The corresponding urban and rural network structures are shown in Fig. 3.

PHQ-9 had the highest strength in both the urban (1.406) and rural (1.389) networks (Fig. 4). The next highest nodes in the urban network were SF (0.974), SCD (0.859), GAD-7 (0.814), GH (0.809), and PF (0.783). In the rural network, GAD-7 ranked second (0.888), followed by SF (0.880), GH (0.844), SCD (0.817), and PF (0.757).

After BH correction across nine node-level tests (Table 2), AD8 ($\Delta = 0.093$, $p_{BH} = .005$), SF ($\Delta = 0.094$, $p_{BH} = .005$), and ESS ($\Delta = 0.053$, $p_{BH} = .012$) had higher strength in the urban network, whereas GAD-7 had higher strength in the rural network ($\Delta = -0.073$, $p_{BH} = .043$). The GH difference was significant before correction ($p = .038$) but not afterwards ($p_{BH} = .068$). H2 was supported in the primary model, although the SF-exclusion analysis below attenuated evidence for the GAD-7 difference.

Table 2
Node-level strength differences (urban–rural; NCT)

Node	Δ strength (U – R)	Raw p	Direction	pBH
AD8	0.093	0.001	Urban > Rural	0.005
SF	0.094	0.001	Urban > Rural	0.005
ESS	0.053	0.004	Urban > Rural	0.012
GAD-7	–0.073	0.019	Rural > Urban	0.043
GH	–0.035	0.038	Rural > Urban	0.068
SCD	0.042	0.149	n.s.	0.224
PF	0.026	0.383	n.s.	0.456
PHQ-9	0.017	0.405	n.s.	0.456
ISI	0.013	0.655	n.s.	0.655

Note. Δ is urban strength minus rural strength; positive values indicate higher urban strength. Raw p-values are based on 1,000 permutations. pBH values control the false discovery rate across the nine node tests.

3.5 Bridge Strength

PHQ-9 had the highest bridge strength in the urban (0.715) and rural (0.682) networks. After 1,000 label permutations and BH correction across nine nodes, urban bridge strength was higher for AD8 (urban = 0.286, rural = 0.204; Δ = 0.082; pBH=.0045) and ESS (urban = 0.392, rural = 0.324; Δ = 0.067; pBH=.0045). No other bridge-strength difference survived correction (all pBH $\geq$.092). Full results are provided in Supplementary Section S4, Table S7, and Figure S11.

3.6 Urban–Rural Network Comparison

Ten edge differences had uncorrected p<.05 (Table 3). Six remained significant after BH correction across 36 edges: PHQ-9–SCD, ESS–AD8, PHQ-9–AD8, ESS–GAD-7, ISI–GH, and PF–SF. PHQ-9–SCD, ESS–AD8, and PHQ-9–AD8 also survived Bonferroni correction. The four differences that were significant only before correction were small (absolute Δ < .030) and were not treated as reliable findings.

Four of the six BH-significant edges linked sleep, cognition, and emotional symptoms, consistent with H3. PHQ-9–SCD (Δ = 0.043) and ESS–AD8 (Δ = 0.067) were stronger in the urban network, whereas PHQ-9–AD8 (Δ =–0.043) and ESS–GAD-7 (Δ =–0.042) were stronger in the rural network. ISI–GH was more negative in the rural network, and PF–SF was stronger in the urban network.

Table 3
Urban–rural edge-weight differences (Network Comparison Test)

Edge	Urban	Rural	Diff (U – R)	Direction	p	p_FDR	p_Bon
PHQ9–SCD	0.142	0.099	0.043	Urban > Rural	0.001	0.012	0.036
ESS–AD8	0.075	0.008	0.067	Urban > Rural	0.001	0.012	0.036
PHQ9–AD8	0.018	0.061	–0.043	Rural > Urban	0.001	0.012	0.036
ESS–GAD7	0.039	0.081	–0.042	Rural > Urban	0.002	0.014	0.072
ISI–GH	–0.073	–0.111	0.038	Urban > Rural	0.002	0.014	0.072
PF–SF	0.288	0.247	0.041	Urban > Rural	0.003	0.018	0.108
ISI–SCD	0.053	0.027	0.026	Urban > Rural	0.023	0.118	1.000
GAD7–SCD	0.000	–0.012	0.012	Urban > Rural	0.027	0.121	1.000
SCD–PF	–0.061	–0.085	0.024	Urban > Rural	0.043	0.158	1.000
ISI–PF	0.000	–0.010	0.010	Urban > Rural	0.044	0.158	1.000

Note. *pBH*=Benjamini–Hochberg adjusted across 36 edges; *pBon*=Bonferroni adjusted. Positive differences indicate larger urban edge weights. Acronyms are defined in Fig. 1.

3.7 Network Stability

Node strength was highly stable in the case-dropping analysis of the overall network (Fig. 5). The smallest edges had wider bootstrap intervals and were not interpreted individually.

3.8 Sensitivity Analyses

Removing PHQ-9 Item 3 produced networks that closely matched the primary analysis (Supplementary S1). The modified PHQ-9 remained the highest-strength node overall (1.323), and PHQ-9–GAD-7 remained the largest edge. PHQ-9 strength fell by no more than 0.078 in any network, so overlap with sleep content did not account for its high connectedness.

Excluding SF while retaining the same 32,523 participants also preserved the main network pattern (Supplementary S3). Edge weights among the eight common nodes correlated strongly with the corresponding primary-network edges (Pearson $r=.993$ overall, $.992$ urban, and $.995$ rural). PHQ-9 remained the highest-strength node overall (1.389), urban (1.397), and rural (1.380). Network structure still differed ($M = 0.069$, $p=.001$), whereas global strength did not (urban = 3.081, rural = 3.029; $p=.232$). Five edge differences survived BH correction: PHQ-9–SCD, ESS–AD8, PHQ-9–AD8, ESS–GAD-7, and ISI–GH. AD8 and ESS retained BH-significant strength differences; the GAD-7 difference was nominal ($p=.038$) but not BH-significant ($pBH=.101$). The no-SF strength CS coefficient was .75.

3.9 Robustness Check Using an Alternative Estimation Method

The ggmModSelect and EBICglasso overall networks were closely aligned (Pearson $r = .986$ for strength; Spearman $\rho = .967$). The highest-ranking nodes and major edges were preserved (Supplementary S2). The main descriptive pattern therefore did not depend on one regularisation method.

4. Discussion

PHQ-9 was the most connected node and the strongest bridge between domains in both urban and rural networks. The groups differed in network structure and in six corrected edges, most of which linked sleep, cognition, and emotional symptoms. AD8 and ESS were more central and had greater bridge strength in the urban network. The higher rural GAD-7 strength and the difference in global strength were less stable because neither survived the analysis without SF. As these data are cross-sectional, the networks describe co-occurrence rather than cause and effect.

4.1 Shared and setting-specific network patterns

PHQ-9 had the highest node and bridge strength in both networks, and PHQ-9–GAD-7 was the strongest edge in each network. PHQ-9 also retained the highest node strength after removing its sleep item, excluding SF, and using ggmModSelect. Previous network studies in older adults have reported a similarly strong position for depressive symptoms [11, 13, 15]. At a theoretical level, this broad connectedness is compatible with network accounts in which low mood, sleep disruption, fatigue, and concentration problems can reinforce one another rather than merely index a single underlying disorder [9, 10]. Because PHQ-9 covers emotional, sleep, energy, and concentration symptoms, part of its centrality may reflect the breadth of depressive symptomatology across the domains analysed here. Its ranking remained unchanged after the sleep item was removed, indicating that sleep-content overlap alone did not account for this pattern. However, the present analysis used scale totals and cross-sectional data, so high strength should be interpreted as broad statistical connectedness, not evidence that depression causally drives the other domains.

4.2 Sleep–cognition–emotion differences across settings

Daytime sleepiness connected more closely with AD8 in the urban network and with GAD-7 in the rural network. Both differences remained after SF was removed. Prior studies have linked daytime sleepiness with cognitive performance [6] and subjective sleep characteristics with anxiety and depression in older adults [47], so both edges are plausible. The novel result is their relative prominence by residence. Differences in healthcare access and social resources may contribute [19–22], but daily cognitive demands, help-seeking, and service use were not measured. The networks therefore show setting-specific clustering, not the mechanism that produced it.

Depressive symptoms were more strongly connected with SCD in the urban network and with AD8 in the rural network. Both differences persisted without SF. The two measures differ in content: SCD captures a general appraisal of cognitive decline, whereas AD8 asks about specific changes in memory, orientation, judgement, and everyday functioning [32, 35, 36, 48]. The urban PHQ-9–SCD edge may therefore reflect closer coupling between mood and global cognitive appraisal, whereas the rural PHQ-9–AD8 edge may reflect closer coupling between mood and more specific cognitive-functional complaints. Previous studies have linked depressive symptoms to SCD in Chinese older adults [55] and identified depression risk as a strong predictor of a positive AD8 screen [56], indicating that both measures can be mood-sensitive. Chinese data also show urban–rural differences in media use and pathways to health literacy [57], which could affect how cognitive changes are noticed and labelled. However, health literacy and activity context were not measured here, and education, income, and occupational rank had already been residualised. The residential split should therefore be treated as hypothesis-generating rather than as evidence for a specific mechanism.

5. Limitations

This study has four main limitations. First, the cross-sectional design means centrality and edge estimates describe patterns of co-occurrence, not causal pathways or intervention targets. Second, the nine indicators are scale scores, not clinical diagnoses, and the network should be read accordingly rather than as a map of comorbid disease. Third, complete-case analysis excluded 22.3% of source records, which could introduce bias if missingness was not random. Fourth, education, income, and occupational rank were treated as covariates rather than as outcomes of residence; the reported urban–rural differences therefore exclude the component of that difference operating through these socioeconomic channels. If these variables are better understood as mediators of residence rather than confounders of it, the adjusted estimates may understate the true magnitude of urban–rural network differences.

6. Conclusions

Across both residential groups, PHQ-9 had the highest node and bridge strength. Urban and rural networks differed in structure and in specific connections among sleep, cognition, and emotional symptoms; AD8 and ESS also had greater bridge strength in the urban network. Removing the low-reliability SF node preserved the main edge differences but not the global-strength or corrected GAD-7 centrality differences. These results define a small set of cross-domain associations that require longitudinal testing.

Abbreviations

AD8

Ascertain Dementia 8

BH

Benjamini–Hochberg
CAHS
China Ageing and Health Survey
EBICglasso
Extended Bayesian Information Criterion graphical least absolute shrinkage and selection operator
ESS
Epworth Sleepiness Scale
GAD-7
Generalized Anxiety Disorder-7
GH
general health
ISI
Insomnia Severity Index
NCT
Network Comparison Test
PF
physical functioning
PHQ-9
Patient Health Questionnaire-9
SCD
subjective cognitive decline
SF
social functioning.

Declarations

Clinical trial number: not applicable.

Ethics approval and consent to participate

The China Ageing and Health Survey was approved by the Ethics Committee of Beijing Hospital (No. 2021BJYYEC-114-01) and conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent. This secondary analysis was conducted under the relevant data-use authorisation.

Consent for publication

Not applicable.

Availability of data and materials

The CAHS data were analysed under authorisation and are not publicly available. Access may be requested from the corresponding authors, subject to approval by the data custodian and applicable data-use conditions.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

LZ and CC conceptualised the study, conducted the formal analysis, and drafted the manuscript. HHLF and JL supervised the work and critically revised the manuscript. JS and HS contributed data resources and curation. YJ, XZ, and JR reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Not applicable.

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Figures

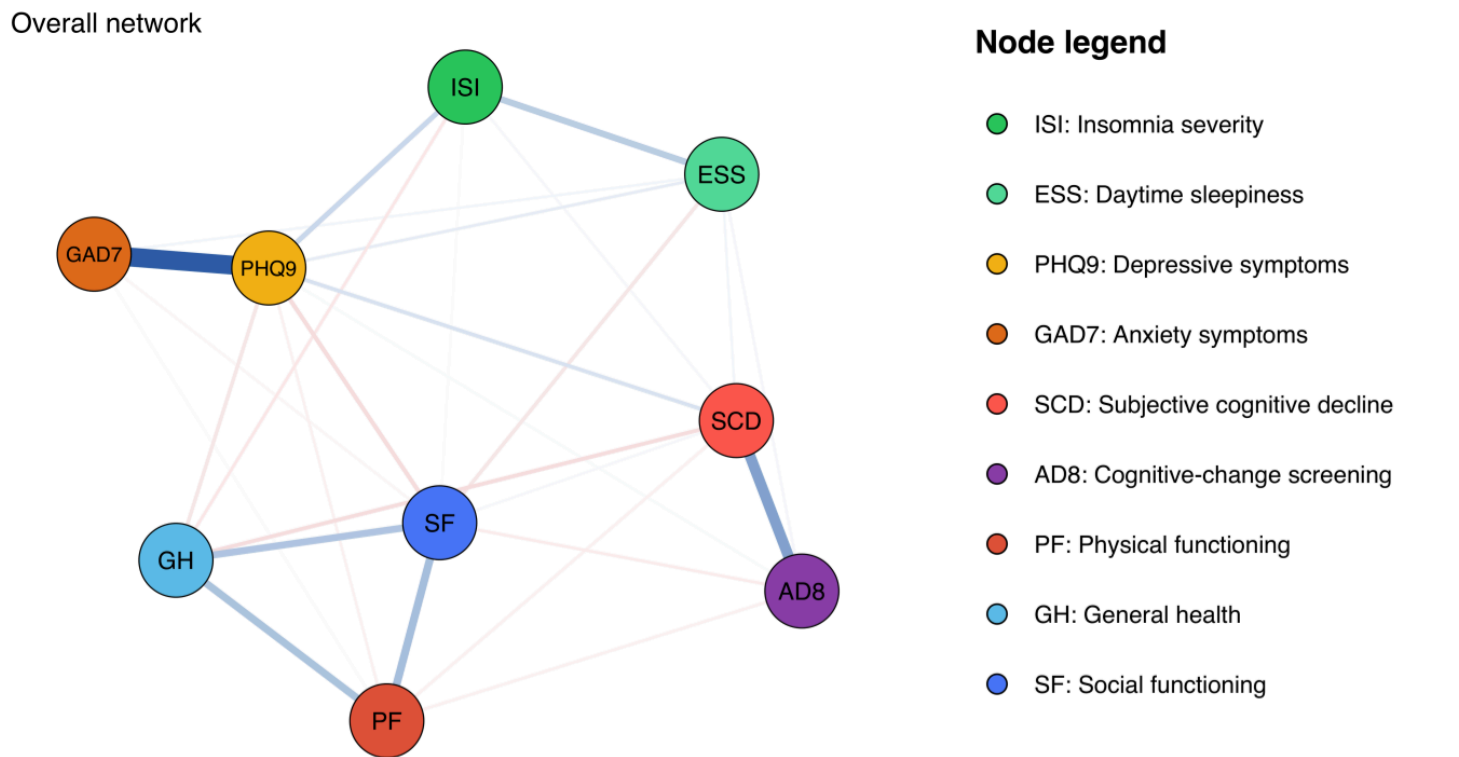


Figure 1

Overall health-indicator network (full analytic sample, N=32,523)

Note. Nodes represent depression (PHQ-9), anxiety (GAD-7), insomnia (ISI), daytime sleepiness (ESS), subjective cognitive decline (SCD), cognitive-change screening (AD8), physical functioning (PF), social functioning (SF), and general health (GH). Networks were estimated with EBICglasso after residualising each node on five covariates. Blue and red edges indicate positive and negative regularised partial correlations; thickness is proportional to absolute magnitude.

Overall Network Node Strength

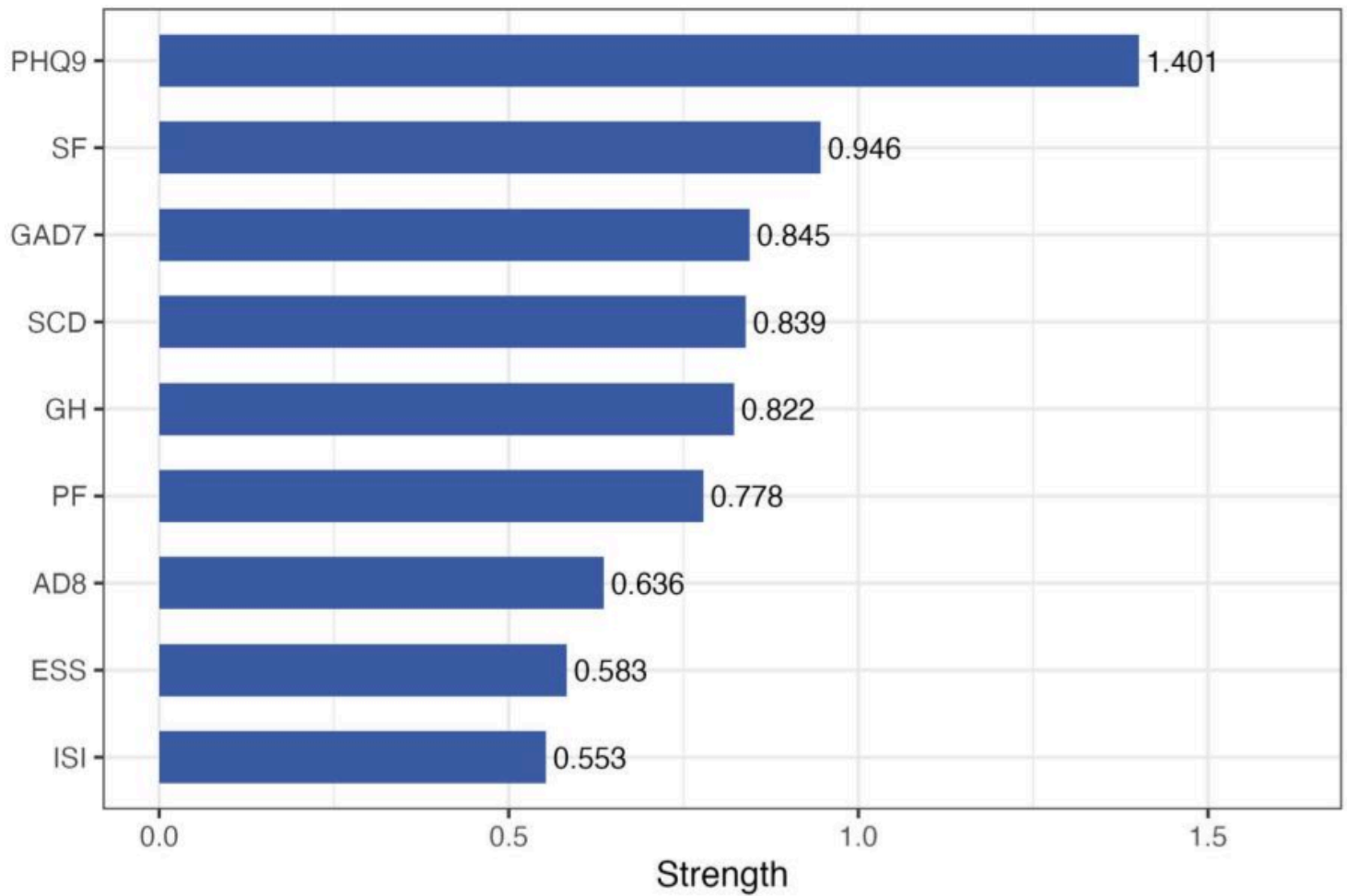
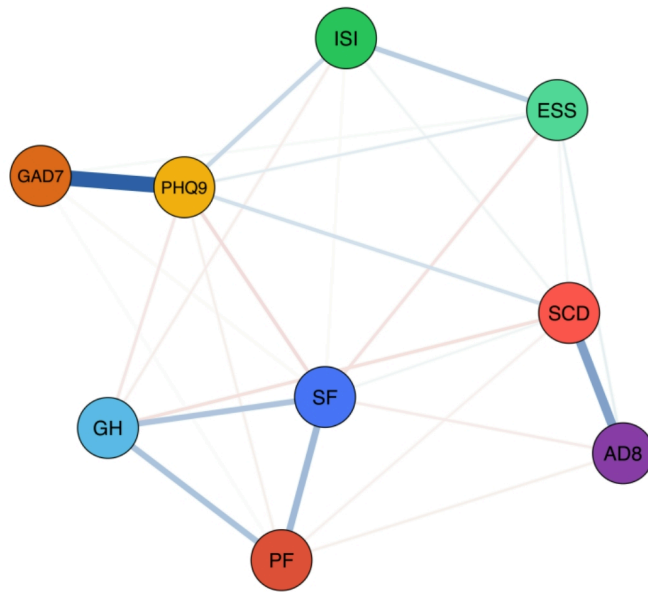


Figure 2

Node strength centrality for the overall network.

Note. Strength centrality represents the sum of the absolute edge weights connected to each node.

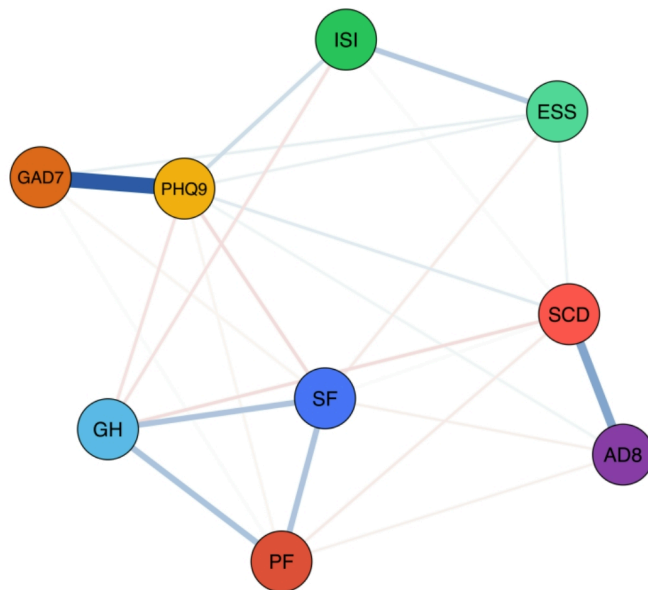
Urban network



Node legend

- ISI: Insomnia severity
- ESS: Daytime sleepiness
- PHQ9: Depressive symptoms
- GAD7: Anxiety symptoms
- SCD: Subjective cognitive decline
- AD8: Cognitive-change screening
- PF: Physical functioning
- GH: General health
- SF: Social functioning

Rural network



Node legend

- ISI: Insomnia severity
- ESS: Daytime sleepiness
- PHQ9: Depressive symptoms
- GAD7: Anxiety symptoms
- SCD: Subjective cognitive decline
- AD8: Cognitive-change screening
- PF: Physical functioning
- GH: General health
- SF: Social functioning

Figure 3

Urban (top) and rural (bottom) health-indicator networks

Note. Urban $n=20,331$; rural $n=12,192$. Nodes and edge conventions match Figure 1. Both networks were estimated with EBICglasso from group-specific covariate-residualised scores using the same layout.

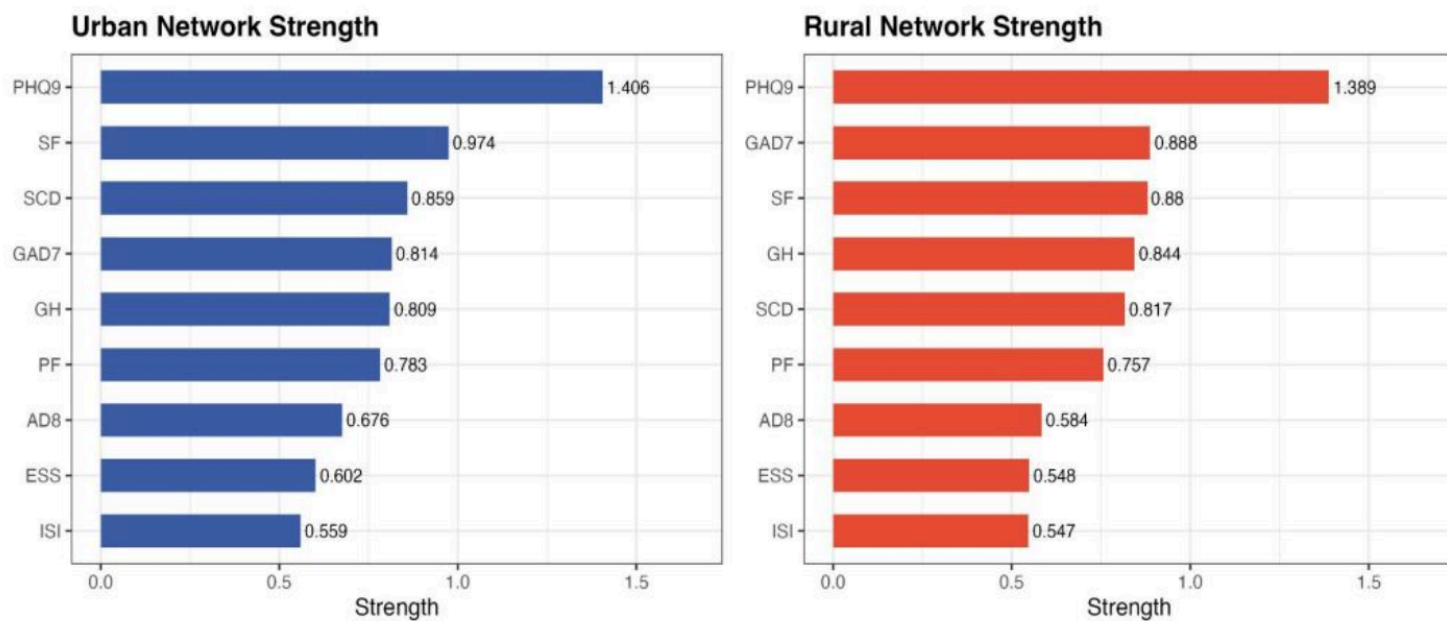


Figure 4

Node strength centrality for urban (blue) and rural (red) subgroup networks.

Bootstrap Stability (Overall Network)

A

B

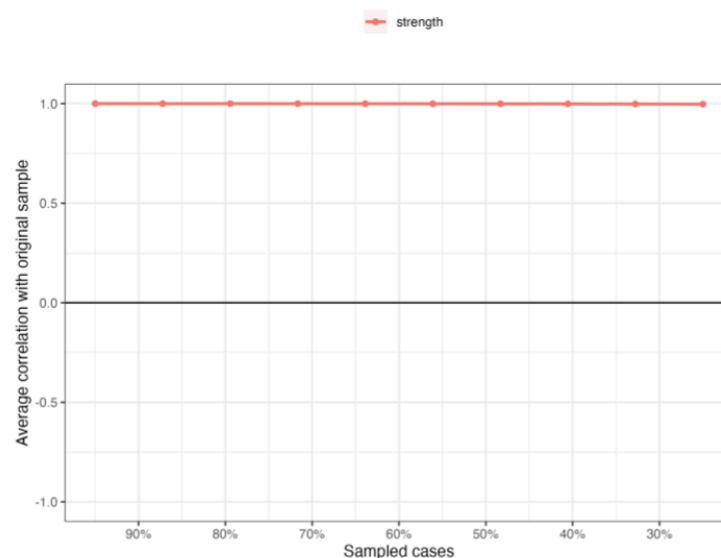
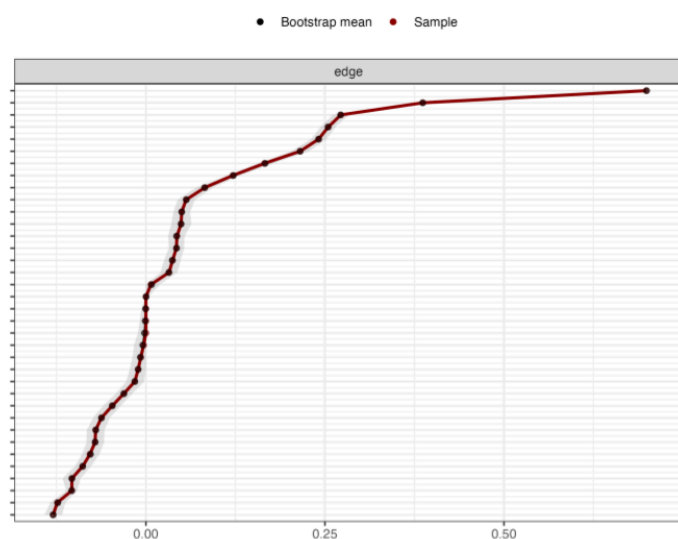


Figure 5

Bootstrap stability analyses for the overall network.

Note. Panel A: Bootstrapped 95% confidence intervals for edge weights. Panel B: Average correlation stability for node strength centrality across case-dropping proportions.

Supplementary Files

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