

Relationships Between Symptom Distress and Positive Psychological Variables Among Stroke Patients: A Network Analysis

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Purpose: This study aims to investigate the topological structure of symptoms and positive psychological variables in stroke survivors through the network analysis method.

Patients and Methods: This is a cross-sectional study. A total of 622 Chinese stroke patients were recruited from six diverse tertiary general hospitals in Tianjin, China, from February to September 2024. The Assessment of Daily Living scale (ADL), Pittsburgh Sleep Quality Index (PSQI), Numerical Rating Scale (NRS), Mini-Mental State Examination (MMSE), Self-Rating Anxiety Scale (SAS), and Self-Rating Depression Scale (SDS) were employed to assess the distress caused by symptoms in these patients. Positive psychological constructs were quantified via the Herth Hope Index (HHI), Perceived Social Support Scale (PSSS), and General Self-Efficacy Scale (GSES). Network analysis was employed to investigate the interplay between these positive psychological variables and the distress associated with stroke symptoms.

Results: “Cognitive impairment” and “Functional disability” (MMSE-ADL, edge weight = -0.610) had the strongest negative connection. “Anxiety” and “Depression” (SAS-SDS, edge weight = 0.556) had the strongest positive connection. Depression (SDS) demonstrated the highest strength centrality, indicating its role as the most interconnected symptom. Family support (PSSS-1) emerged as the most central positive psychology variable, with the highest closeness and betweenness scores, acting as a critical bridge between psychological and somatic symptom clusters.

Conclusion: Depression and family support are pivotal nodes in stroke symptom networks. Integrating family-centered interventions with early depression screening may disrupt symptom propagation and improve outcomes. These findings underscore the need for multicomponent strategies addressing both psychological and social determinants of recovery in stroke care.

Keywords: depression, network analysis, physical symptoms, positive psychology, stroke

Introduction

Stroke is a cerebrovascular disorder caused by multiple etiologies, resulting in focal or global brain tissue damage.¹ It encompasses both ischemic and hemorrhagic subtypes, and may present with a spectrum of clinical manifestations, including limb weakness, numbness, dysarthria, headache, vomiting, and altered consciousness.² Currently, stroke represents a prevalent chronic disease that poses a significant threat to human health and ranks as the second most common cause of death and disability worldwide.³ According to the latest data, there is an estimated population of approximately 17.04 million stroke patients in China, and the annual incidence of stroke exceeds 2 million.⁴ Furthermore, approximately 75% to 80% of individuals who have experienced a stroke may experience different levels of dysfunction and symptom distress,^{5,6} which poses a significant threat to the health of the Chinese population.



Previous studies have demonstrated that post-stroke patients frequently experience psychosomatic symptoms of disability, cognitive impairment, depression, anxiety, sleep disturbances, and pain sensations.⁵ The Theory of Unpleasant Symptoms (TOUS) posits that the co-occurrence of unpleasant symptoms experienced or perceived by patients is common, and emphasizes their interdependence and reciprocal interactions.⁷ These symptoms significantly impact the patient's quality of life and social functioning. Previous studies have shown that up to 70–80% of recovering stroke patients experience distress of multiple symptoms during hospitalization and during the rehabilitation phase.⁸ Hence, mitigating symptom distress among stroke survivors assumes paramount importance in facilitating stroke recovery and enhancing patient longevity.

In recent years, the emergence and development of positive psychology have garnered increasing attention in the reduction of symptoms related to depression and anxiety, facilitation of positive emotions among patients, and enhancement of their overall quality of life. Prior studies have demonstrated a significant association between external factors and internal factors regarding psychological symptoms in stroke patients.⁹ Understanding these relationships can inform the development of effective strategies to manage stroke-related stressors and life difficulties. Social support involves the comfort, care, and assistance an individual receives from their supportive social network.¹⁰ Previous studies have demonstrated that perceived social support is negatively associated with depression and poor sleep quality among stroke patients, indicating that interventions enhancing social support may improve psychological well-being and sleep quality, and thereby contribute to a better quality of life.^{11,12} Moreover, self-efficacy, as an intrinsic psychological resource, pertains to an individual's belief in their ability to overcome challenges or obstacles and effectively execute their intended actions through subjective conviction and self-management proficiency.^{13,14} Research has shown that self-efficacy is negatively associated with symptoms of depression and anxiety in stroke patients, while physical disability and cognitive impairment are independent predictors of lower self-efficacy, highlighting its crucial role in post-stroke rehabilitation and psychological well-being.^{9,15,16} Furthermore, hope—defined as a future-oriented belief in achievable goals—frequently emerges as a disease-related coping response; evidence indicates that higher hope is negatively associated with depressive and anxiety symptoms and enables patients to mobilize internal resources, thereby enhancing emotional well-being.^{17,18} Although a growing body of evidence has independently documented the high prevalence of symptom distress and the protective role of positive psychological factors in stroke recovery, the complex, bidirectional relationships between these domains remain largely unexplored. It is unclear how specific symptoms (eg, depression, functional disability) dynamically interact with and are influenced by positive resources (eg, hope, self-efficacy, social support). Traditional statistical methods are limited in their ability to map these intricate interactions. Therefore, a critical knowledge gap exists in understanding the interconnected network of post-stroke symptoms and positive psychological variables. Elucidating this network structure is a necessary step toward developing integrated interventions that not only reduce distress but also actively promote psychological well-being.

Network analysis is an emerging analytical methodology that can be employed to elucidate the intricate interplay and mutual reinforcement between symptoms and positive psychological variables, facilitating the construction of visually informative symptom network graphs by quantifying the complex connections among diverse symptoms and positive psychological resources. From the perspective of network theory,¹⁹ interactions between symptomatic or non-symptomatic variables emerge actively, as opposed to the traditional latent variable model, which views symptoms as passive reflections of underlying variables. Previous network-analytic studies on stroke-related depression and post-stroke symptoms have demonstrated that therapeutic interventions targeting functional disability and negative mood can alleviate symptom burden.^{20–22} However, these studies have primarily focused on mechanistic analyses of individual functional or psychological symptoms, neglecting the interactions between symptoms as well as correlations between symptom clusters and positive psychological variables. Therefore, a more comprehensive approach is warranted to effectively reduce the overall burden of stroke symptoms.

Moreover, there is a dearth of studies employing network analysis to investigate the intricate interplay between symptom burden and positive psychological resources in stroke patients, which hampers our ability to comprehensively comprehend the target of interventions and symptom management. Therefore, the aim of our study was to employ network analysis as a means (1) to explore the interconnectedness between symptoms and positive psychological variables and (2) to identify the most influential node of positive psychological variables on the symptoms.

Methods

Design and Participants

This cross-sectional study was carried out at six diverse tertiary general hospitals in Tianjin, China, from February to September 2024. The inclusion criteria comprised patients who: (1) met the diagnostic criteria for cerebrovascular disease and were diagnosed with cerebral infarction or cerebral hemorrhage by head computed tomography or magnetic resonance imaging;²³ (2) had to be aged 18 years or older; (3) were conscious and had no communication difficulties; (4) were provided with informed consent and had the option to participate voluntarily in this study. The exclusion criteria comprised of patients who: (1) had severe cardiac, hepatic, and renal insufficiency diseases; (2) had a previous history of psychiatric illness; (3) were currently receiving psychotropic medication or psychotherapy; (4) had participated in other psychological studies.

Data Collection

This study adopted a cross-sectional design, and the data collection period lasted for 8 months, specifically from February to September 2024. Researchers in the inpatient neurology department help identify eligible patients. After unified training, all investigators issued paper questionnaires to participants face to face, filled them out, and collected them on the spot. Before data collection, all participants were informed of the study's purpose. They were also made aware that their participation was voluntary, requiring them to sign an informed consent form, and that they had the option to leave the study at any point. Patients are encouraged to complete the questionnaire independently (15–20 minutes) to ensure accuracy. The investigators helped those struggling to read and fill out the questionnaire item by item and recorded their answers. In terms of ethical review, this study has received initial approval from the Ethics Committee of the Tianjin Medical University. The approval date was December 23, 2021 (approval number: TMUHMEC2022005). The research was conducted strictly in accordance with the Helsinki Declaration and domestic ethical norms.

Assessment Metrics

Demographic Features

This study evaluated various demographic features, such as gender, age, marital status, educational attainment, residential location, monthly household income per person, and diagnosis based on self-reported information.

Measurement of Symptoms

Symptoms were assessed via a unidimensional assessment scale in stroke patients. (1) We employed the Self-rating Anxiety Scale (SAS) and the Self-rating Depression Scale (SDS),^{24,25} which were translated by Zhang to measure anxiety and depression.²⁶ These scales are widely utilized clinical instruments for assessing anxiety and depressive symptoms, encompassing a comprehensive set of 20 items with a cumulative score of 100. In China, an SAS score of ≥ 50 is considered to be the presence of anxiety symptoms, and an SDS score of ≥ 53 is considered to be the presence of depression symptoms. The Cronbach's α coefficients for both scales in this study were found to be 0.85. (2) The Barthel Index pertains to the essential tasks performed by individuals on a daily basis in order to fulfill their everyday life requirements.²⁷ It primarily evaluates patients' functional status and ability to engage in activities necessary for daily living.²⁸ The evaluation method is easy to understand and highly operable. The total possible scores range from 0 to 100, where lower scores reflect greater levels of functional disability. In this study, the Cronbach's α for the scale was found to be 0.84. (3) The Numerical Rating Scale (NRS) serves as a straightforward and practical approach for evaluating pain symptoms in both clinical practice and scientific studies.²⁹ Respondents are requested to rate their pain intensity on a scale from 0 to 10, reflecting the level of discomfort they experience at rest and during activities. The Cronbach's α coefficient was found to be 0.90 for stroke patients in the current study. (4) The Pittsburgh Sleep Quality Index (PSQI) is employed to evaluate subjective sleep quality during the past two weeks.³⁰ Scores on the PSQI can range from 0 to 21, where a cumulative score below 7 reflects good sleep quality, whereas a score of 7 or higher indicates potential sleep disturbances. The Chinese adaptation of the PSQI has shown strong psychometric characteristics. In our study, the Cronbach's α coefficient was determined to be 0.89. (5) The Chinese adaptation of the Mini-Mental State Examination (MMSE) includes evaluations of time and place orientation,³¹ short-term and long-term memory, focus and arithmetic

skills, as well as language abilities. It consists of 30 items, with each item carrying a value of one point within a score range of 0–30 points. Different diagnostic criteria are applied based on literacy levels: ≤ 24 for junior high school and above, ≤ 20 for primary school level, and ≤ 16 for illiterate individuals. In the present study, the Cronbach's α of the scale was 0.86.

Measurement of Positive Psychological Variables

(1) The participants' level of hope was assessed using the Herth Hope Index Scale (HHI), a measurement tool created by Herth et al and adapted into Chinese by Zhao and Wang.^{32,33} The scale consisted of 12 items in total. Responses were measured using a 4-point Likert scale, which ranged from 12 to 48. In the present study, the Cronbach's α of the scale was 0.89. (2) The Perceived Social Support Scale (PSSS) was created by Zimet et al and subsequently adapted into Chinese by Jiang,^{34,35} in order to assess an individual's perceived support. The score range of 1 (extremely inconsistent) to 7 (extremely consistent) was utilized to assign a seven-level grade, reflecting a total score between 12 and 84. A higher score reflects a stronger sense of perceived social support. In this study, the Cronbach's α coefficient for the scale was 0.9. (3) The Chinese version of the General Self-Efficacy Scale (GSES) was used to assess the general self-efficacy level of patients,³⁶ with higher scores indicating greater individual self-efficacy. In this study, the Cronbach's α was 0.84.

Statistical Analysis

The demographic distribution and symptoms of stroke patients were analyzed using SPSS 27.0, employing descriptive statistical methods. Continuous variables were presented as either the median or mean with standard deviation (SD), while categorical variables were expressed as percentages (%).

We constructed the network of hope, self-efficacy, social support, and symptoms using the EBICglasso function and Spearman correlation analysis. Network analysis was performed using the "bootnet" (version 1.4.3) and "qgraph" (version 1.6.9) packages.^{37,38} Firstly, we utilized graphical Lasso based on an extended Bayesian information criterion option in the "qgraph" package to establish the network structure. Secondly, we employed the centrality plot function provided by the "qgraph" package to compute three widely-used node centrality indices, namely strength, closeness, and betweenness. Thirdly, the "bootnet" package was employed to examine the sequence invariance of the nodes on the central index, ensuring their stability. The stability coefficient, which should exceed 0.25 and preferably surpass 0.5, quantifies the robustness of the centrality index. Subsequently, a nonparametric bootstrap procedure was utilized with the "bootnet" package to assess the accuracy of edge weights by determining 95% confidence intervals (CIs). A narrower CI indicates a more reliable network. Finally, to evaluate edge weight accuracy, a nonparametric bootstrap procedure was conducted, and 95% CIs determined using the "bootnet" package were employed. Edge accuracy was assessed based on narrower CIs, indicating a more reliable network.

Results

Demographic Features

Table 1 displays the sociodemographic features of the participants. A total of 622 participants were recruited for this study, with an average age of 65.12 ± 13.31 years. The majority of the participants were male (62.1%), married (83.0%), and had attained primary or junior school education (73.2%). A majority of the participants (56.6%) lived in cities. Cerebral infarction was the most prevalent diagnosis among the participants (84.6%), followed by cerebral hemorrhage (15.4%). More than half of the participants (60.8%) had a disease course of less than 6 months.

Network Analysis

Network Architecture

The network illustrates the strength of the connections between GSES and HHI, PSSS, and symptoms, as depicted in Figure 1. The edges between "Cognitive impairment" and "Functional disability" (MMSE-ADL, edge weight = -0.610) had the strongest negative edges within their community. While the strongest positive connections within their respective communities were observed between "Anxiety" and "Depression" (SAS-SDS, edge weight = 0.556) as well as between "Temporality" and "Positive readiness and expectancy" (HHI-1-HHI-2, edge weight = 0.517).

Table 1 Participant Characteristics

Variables	Characteristics	Participants (n=622)
Age		65.12±13.31
Gender	Men	386 (62.1)
	Women	236 (37.9)
Educational level	Primary school and below	197 (31.7)
	Junior high school	258 (41.5)
	High school and above	167 (26.8)
Marital status	Unmarried	106 (17.0)
	Married	516 (83.0)
Permanent residence	City	352 (56.6)
	Town	94 (15.1)
	Countryside	176 (28.3)
Stroke diagnosis	Cerebral infarction	526 (84.6)
	Cerebral hemorrhage	96 (15.4)
Disease course (month)	<6	378 (60.8)
	6~12	231 (37.1)
	≥13	13 (2.1)

Note: n, the number of individuals included in the sample.

Centrality Indices

The z-scores for strength, closeness, and betweenness centrality are presented in Figure 2. In general, “Depression” (SDS) exhibited the highest strength score, while “Family support” (PSSS-1) demonstrated both the greatest closeness and betweenness scores. These results suggest that this factor is highly interconnected with adjacent nodes and holds

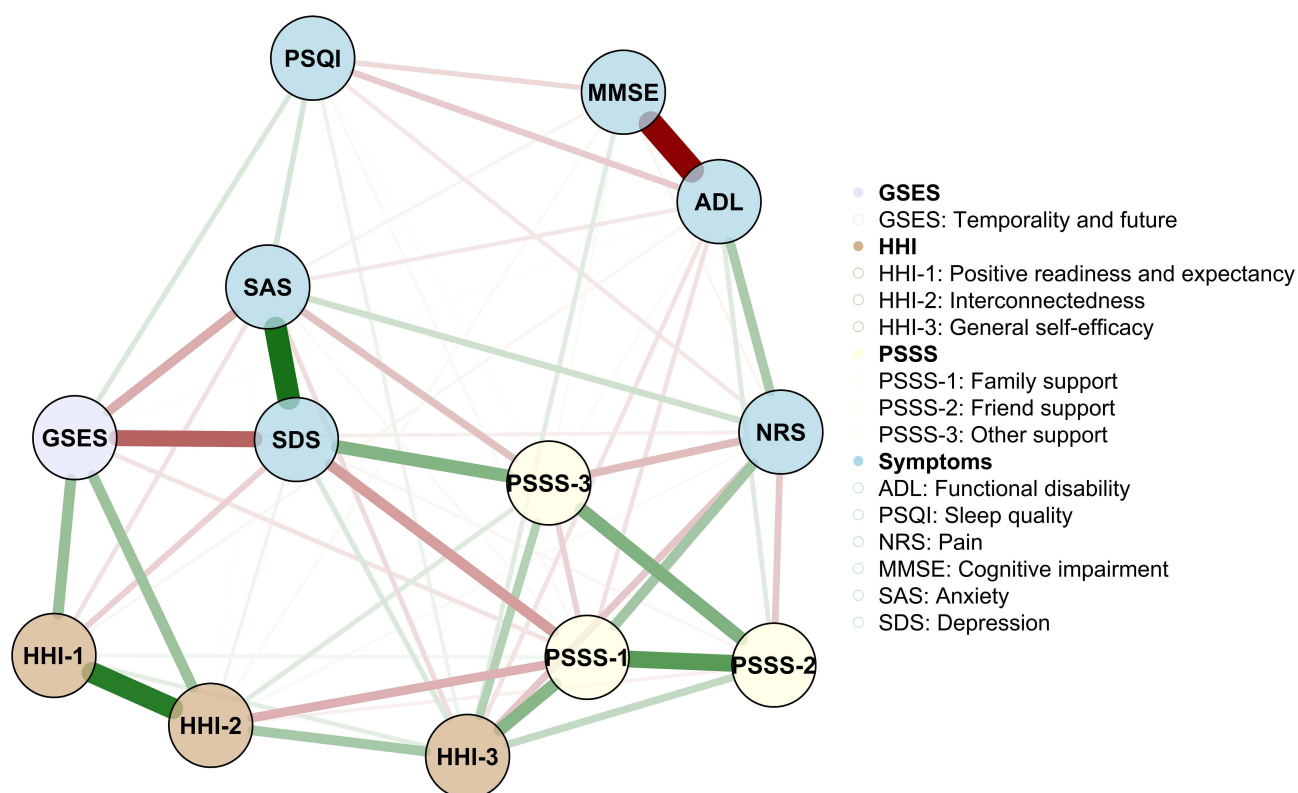


Figure 1 Network analysis of symptoms, hope, general self-efficacy and perceived social support in stroke patients.

Abbreviations: GSES, General Self-Efficacy Scale; HHI, Herth Hope Index; PSSS, Perceived Social Support Scale; PSQI, Pittsburgh Sleep Quality Index; NRS, Numerical Rating Scale; MMSE, Mini-Mental State Examination; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale.

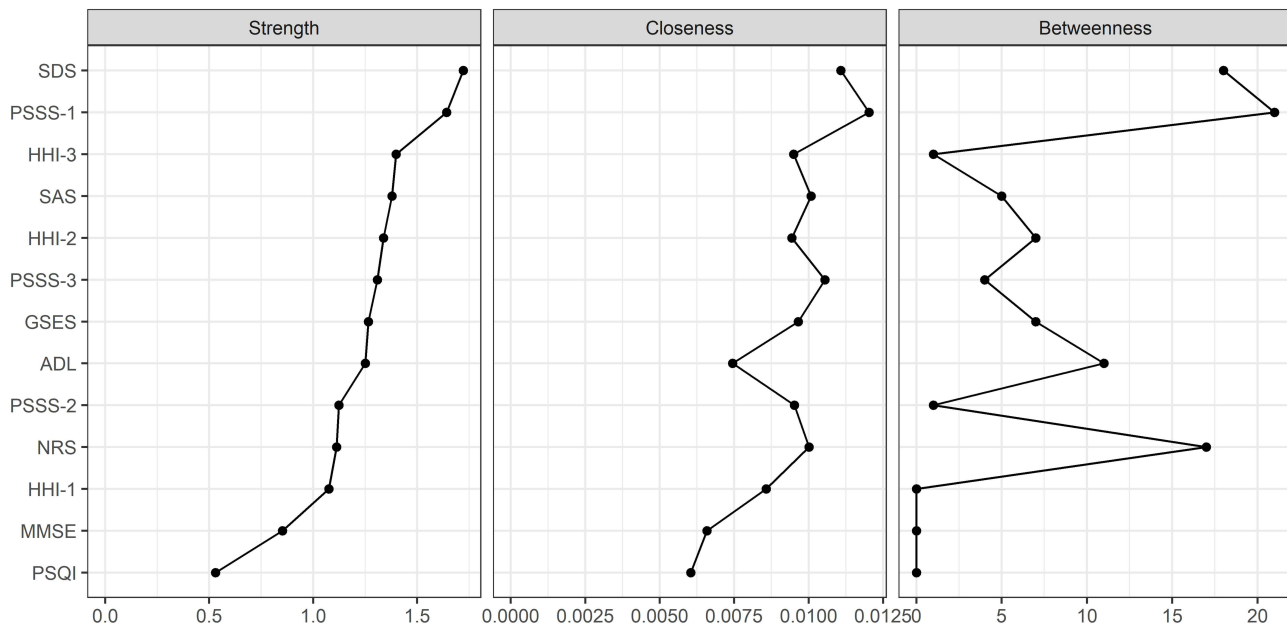


Figure 2 The estimated network’s centrality indices include node strength, closeness, and betweenness.
Abbreviations: GSES, General Self-Efficacy Scale; HHI, Herth Hope Index; PSSS, Perceived Social Support Scale; PSQI, Pittsburgh Sleep Quality Index; NRS, Numerical Rating Scale; MMSE, Mini-Mental State Examination; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale; ADL, Functional disability; HHI-1, Temporality and future; HHI-2, Positive readiness and expectancy; HHI-3, Interconnectedness; PSSS-1, Family support; PSSS-2, Friend support; PSSS-3, Other support.

significant importance within the network. Its activation exerts the most substantial impact on other nodes in the network. Additionally, it functions as a connector bridging different node communities. Conversely, “Sleep quality” (PSQI) showed the lowest values for strength, closeness, and betweenness.

Stability of Centrality Indices

Figure 3 presents the graphical representation of the stability of centrality indices. As the proportion of the sample used for estimation reduces (as depicted on the X-axis, where subset samples decline from 95% to 25% of the original

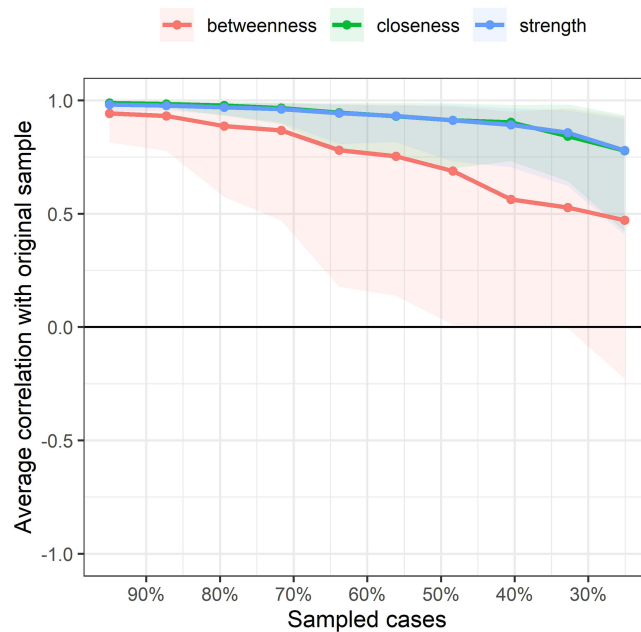


Figure 3 Stability of the centrality indices.

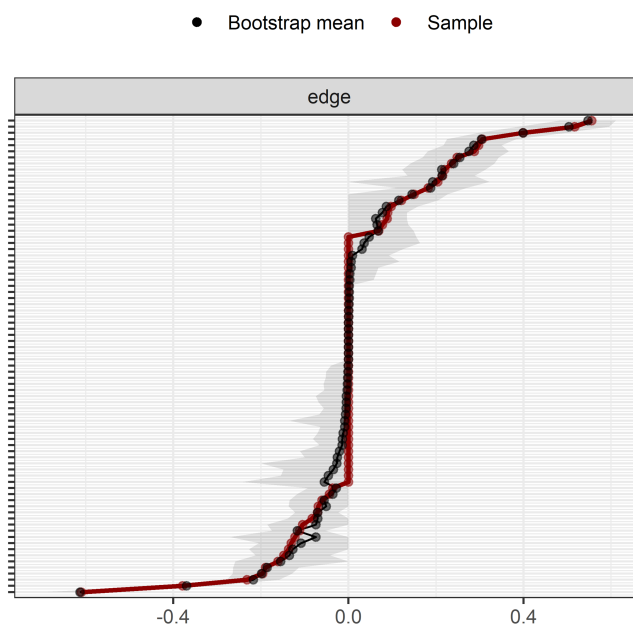


Figure 4 Accuracy of the edge-weight estimates (red line) and the 95% confidence intervals (gray bars) for the estimates. The x-axis represents the percentage of patients, while each line on the y-axis corresponds to a specific edge.

sample), the correlation between the subsample estimates and the estimates derived from the full original sample gradually decreases. Notably, only when the subset sample size drops below 30% of the original does the betweenness estimate fall below 0.7. However, both strength and closeness estimates remain above 0.75.

Edge Weight Accuracy

The bootstrapped CIs for the edge weights are presented in Figure 4. Overall, these intervals were relatively narrow, suggesting a reasonable level of accuracy and indicating that many edges showed significant differences from one another. The number of edges was estimated to be 0. For certain edges, the estimates were greater than 0, and their CIs did not encompass zero. In contrast, some edges, although having estimates above 0, had CIs that still included zero. Considering this pattern of CIs for the edge weights, the network should be cautiously interpreted.

Discussion

This study employed network analysis to systematically elucidate the dynamic interactions between multidimensional symptoms and positive psychological variables in Chinese stroke survivors, establishing a robust symptom network model based on cross-sectional data. The centrality indices demonstrated substantial stability, with strength and closeness centrality maintaining high reliability coefficients, while betweenness centrality exhibited moderate stability. Visual network mapping revealed significant associations between positive psychological constructs and somatic symptom clusters, corroborating prior evidence on the pervasive comorbidity of physical and psychological symptoms in stroke populations.^{39,40} Notably, bidirectional reinforcement loops were identified between neuropsychiatric symptoms and functional impairments, suggesting limitations in conventional unidimensional intervention paradigms. By pinpointing core symptom nodes and their interconnections with psychological resources, this study provides a theoretical foundation for developing multi-target integrated intervention strategies. These findings underscore the necessity of adopting a systemic perspective in stroke symptom management, emphasizing the interplay between psychological resilience and somatic burden to optimize clinical outcomes.

Our findings highlight depression as the most central node within the symptom network, exhibiting the highest strength centrality and serving as a critical mediator between psychological distress and somatic dysfunction. Our finding that depression served as the most central node in the symptom network is consistent with the recent longitudinal work by Zhang et al, who identified depressive symptoms as both key drivers and consequences within the psychopathological

network of new-onset stroke patients over time,⁴¹ this aligns with robust evidence indicating that post-stroke depression (PSD) is not merely a secondary consequence but a pivotal driver of adverse outcomes, including cognitive decline, prolonged functional disability, and elevated mortality.^{42–44} The strong positive association between depression and anxiety underscores their synergistic exacerbation of symptom burden, consistent with prior reports of shared neurobiological pathways and reciprocal behavioral reinforcement in stroke survivors.^{45–47} Notably, diminished functional disability demonstrated a robust negative correlation with cognitive impairment, suggesting that functional disability may amplify psychological distress through loss of autonomy, thereby perpetuating a maladaptive cycle.⁴⁸ Crucially, family support (PSSS-1) emerged as the primary bridging node with the highest betweenness centrality, modulating depressive symptoms through culturally embedded caregiving dynamics in China's familial social structure. Furthermore, in this study, more than half of the participants had a disease course within 6 months, placing them in the acute to early subacute phase of stroke. This finding highlights the necessity for early screening and intervention. This is strongly supported by evidence from Mikami et al, who demonstrated that depression can be effectively predicted during the acute and subacute phases following an ischemic stroke.⁴⁹ These findings confirm that this early period constitutes a critical window during which timely identification of at-risk patients is not only feasible but essential for implementing preventive strategies and mitigating the long-term burden of PSD. Moreover, our results align with and extend the mechanistic pathway elucidated by Zhao et al, who found that perceived social support is a significant mediator between disability and depression.¹¹ Our network analysis specifically identifies family support as the central bridge within this pathway, offering a precise target for intervention. Therefore, the network structure we identified likely reflects the dynamic interactions between symptoms and resources characteristic of this early stage of recovery. Future longitudinal network studies tracking patients from the acute phase into chronic recovery are needed to determine whether these central nodes remain stable or whether the network topology evolves over time.

Building upon network theory,^{50,51} our analysis identified family support (PSSS-1) as the most critical bridging node, exhibiting the strongest edge connections and mediating interactions across distinct symptom communities. This centrality underscores its dual role as both a protective buffer against psychological distress and a facilitator of functional recovery, consistent with the stress-buffering hypothesis that positions social support as a mitigator of illness-related adversity.⁵² Notably, the predominance of family support over other social support dimensions aligns with China's collectivist cultural ethos, where 83.0% of participants were married and embedded in multigenerational caregiving systems. In such contexts, familial obligations and intergenerational cohesion create a unique psychosocial scaffold that enhances coping mechanisms and reinforces positive health behaviors.^{11,53} Mechanistically, sound family functioning can mitigate disability-related stigma by providing emotional validation and mobilizing practical resources to facilitate ongoing care access, thereby alleviating depressive symptoms. These culturally mediated pathways underscore the necessity for adaptive, evidence-based interventions.

Limitations

The study has several limitations that should be taken into account. Firstly, due to its cross-sectional design, this network only reveals partial correlations. Therefore, it is recommended to conduct prospective clinical studies in the future to validate the findings of this study. Secondly, this study employed commonly used clinical practice scale tools to assess the five symptom dimensions of self-care ability, pain, cognitive function, sleep, and psychology. Although these single-dimension scales demonstrate increased sensitivity towards disease specificity, they may overlook concurrent symptoms experienced during the course of illness. Therefore, it is recommended that future stroke symptom assessment tools incorporate a multidimensional approach for a more comprehensive evaluation. Thirdly, this study was conducted in China, thus limiting its generalizability to other cultural contexts. Fourthly, the observed network associations between psychological and somatic symptoms might be partly shaped by underlying medical conditions (such as chronic comorbidities) or lifestyle factors (including smoking and alcohol use). Future studies should incorporate detailed assessment of these clinical and behavioral covariates to better elucidate the distinct relationships within the symptom network.

Conclusion

This network analysis reveals that depression serves as a central hub within the interconnected symptom landscape of stroke survivors in China, mediating bidirectional interactions between psychological distress and functional disability. The identification of family support as a key bridge node highlights the cultural significance of kinship networks in moderating post-stroke recovery trajectories, particularly within the context of China's collectivist society. Our findings challenge the traditional unidimensional intervention paradigm by demonstrating that targeted modulation of core nodes, such as early depression screening combined with family-focused resilience training, can more effectively disrupt maladaptive symptom cycles compared to isolated symptom management. Although the cross-sectional design limits causal inference, the robust stability of the centrality index provides a solid foundation for developing culturally appropriate multi-target interventions. Future research should prioritize longitudinal validation of these network dynamics across diverse cultural contexts and integrate biomarkers to elucidate the neurobehavioral mechanisms underlying symptom transmission. By integrating network theory with clinical practice, this study advances the paradigm shift from passive treatment to active systems-level management, positioning family capital as a catalyst for stroke rehabilitation.

Ethics Approval

The study protocol was approved by the Ethics Committee of Tianjin Medical University under the approval number TMUHMEC2022005. All methods were performed in accordance with the relevant rules and regulations of the Declaration of Helsinki. Informed consent was obtained from all participants, and they were kept anonymous.

Acknowledgments

An unauthorized version of the Chinese MMSE was used by the study team without permission, however this has now been rectified with PAR. The MMSE is a copyrighted instrument and may not be used or reproduced in whole or in part, in any form or language, or by any means without written permission of PAR (www.parinc.com).

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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