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ORIGINAL RESEARCH

Symptom Networks and Associations with Quality of Life in Patients with Early to Mid-Stage Parkinson's Disease: A Network Analysis

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Purpose: The symptoms of patients with early to mid-stage Parkinson's disease (PD) are closely associated with their quality of life. However, few studies have explored the relationship between symptoms and quality of life. This study aims to investigate the symptom profiles of patients with early to mid-stage PD, construct a symptom network to identify core symptoms, and examine their associations with quality of life.

Patients and Methods: This cross-sectional study was conducted from November 2024 to February 2025 among 954 patients with early to mid-stage PD in China, with stages 1–2 classified as early stage and stage 3 as mid stage. All participants completed the PD Symptom Experience Scale. Network models were constructed using R version 4.4.3 to identify core symptoms, describe inter-symptom relationships, and calculate centrality indices.

Results: The top three symptoms in terms of prevalence were bradykinesia (77.46%), resting tremor (75.05%), and rigidity (59.01%). The most severe symptom was resting tremor. In the symptom network analysis, the top three symptoms with the highest node centrality were bradykinesia (r_e=1.27), postural instability (r_e=1.16), and limb stiffness (r_e=1.96). In the quality of life network, the dimensions with the highest node centrality were "mobility" (r_{be}=0.52), "emotional well-being" (r_{be}=0.50), and "cognitions" (r_{be}=0.49). "Mobility" was positively correlated with difficulty turning over in bed (r=0.19), freezing of gait (r=0.09), and difficulty standing up or sitting down (r=0.08).

Conclusion: Multiple symptoms were simultaneously experienced by patients with early to mid-stage PD, and interrelationships among symptoms were observed. Bradykinesia was identified as the core symptom, and the "mobility" dimension was recognized as the central node in the quality of life network. Healthcare providers are advised to comprehensively consider patients' overall symptom profiles and their relationships with quality of life, and to implement targeted, integrated interventions.

Keywords: Parkinson's disease, symptom network, network analysis, symptom management, nursing intervention

Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disorder worldwide, primarily characterized by the degeneration and death of dopaminergic neurons in the substantia nigra.[1] It is commonly accompanied by motor symptoms such as resting tremor, bradykinesia, rigidity, and postural instability, as well as non-motor symptoms including cognitive impairment, anxiety, depression, urinary incontinence, and constipation are commonly observed.[2] Studies have demonstrated that symptoms in PD patients are interrelated, with more than half of the patients experiencing five or more non-motor symptoms,[2,3] severely compromising their quality of life.

Previous studies have investigated individual symptoms of PD, such as motor symptoms,[4] anxiety,[5] sleep disorders,[6] and pain[7] with severity often assessed based on total scale scores,[8] thereby overlooking the interrelationships among symptoms.[9,10] And Few studies have explored the relationship between symptoms and quality of life. Symptoms that are

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highly interconnected with others are referred to as core symptoms,[11,12] which should be prioritized for intervention. However, traditional methods that rely on total scale scores make it difficult to accurately identify core symptoms and lack a systematic and comprehensive analysis of multiple symptoms.

Network analysis abstracts system characteristics into nodes and edges to construct network models, which are presented visually to elucidate the complex and subtle relationships among variables.[13] The Guidelines for the Treatment of Parkinson's Disease suggest that early and proactive intervention targeting both motor and non-motor symptoms not only improves symptom management but may also slow disease progression.[14] Therefore, the accurate identification of core symptoms in patients with early to mid-stage PD is considered a prerequisite for effective symptom management and serves as the foundation for developing individualized intervention strategies. In light of this, this study aims to investigate the symptom profiles of patients with early to mid-stage PD and to explore the network of relationships between symptoms and quality of life, thereby providing a reference for healthcare professionals in developing targeted interventions to maximize improvements in patients' quality of life.

Materials and Methods

Study Design

This retrospective study utilized clinical data obtained from the Hubei Province Parkinson's Disease Clinical Research Center, which is part of the Parkinson's Disease & Movement Disorders Multicenter Database and Collaboration Network in China (PD-MDCNC). Patients who were clearly diagnosed with primary PD and enrolled in the database between June 2023 and April 2025 were included.

Participants

The inclusion criteria were as follows: (1) Meeting the clinical diagnostic criteria for PD;[15] (2) Hoehn and Yahr staging 1 to 3, with stages 1–2 classified as early stage and stage 3 as mid stage;[16] (3) at least 18 years old; (4) Complete assessment data available during the visit, including basic clinical information, symptom severity, and quality of life; (5) If multiple assessments were recorded for a patient, the most complete set of evaluation results was included; The exclusion criteria were as follows: (1) Incomplete assessment data; (2) Patients with a history of psychiatric disorders or other conditions that could result in severe communication impairment; According to the sample size requirements for network analysis, 24 items from the Symptom Experience Scale for Patients with PD were used, requiring estimation of 24 threshold parameters and 276 pairwise association parameters [24× (24–1)/2],[17] totaling 300 parameters. To ensure model reliability, a sample size of 3–5 cases per parameter was calculate,[18] resulting in a required sample size of 900–1500 cases; 954 cases were included in this study.

Measures

We retrospectively collected and organized clinical data from 954 early to mid-stage PD patients who had completed comprehensive evaluations in the Hubei Province Parkinson's Disease Clinical Research Center database (http://www.pd-mdcnc.com/index.html). Data entry was performed independently by two researchers, with discrepancies resolved through review and confirmation by a third senior neurologist.

Sociodemographic Information

The General Information Questionnaire was independently developed by the researchers through a literature review and includes gender, age, educational level, disease duration, living situation, monthly household income per capita, and disease severity level.

Symptom Experience Scale for PD Patients

The Symptom Experience Scale for PD Patients was developed in 2023 by Chinese scholar Xiao,[19] with an overall Cronbach's α coefficient of 0.968. In the present study, the overall Cronbach's α coefficient for this scale was 0.886. This scale consists of 24 items, scored using a 5-point Likert scale, with all items positively scored to assess the various symptoms experienced by PD patients over the past week. Symptoms assessed include resting tremor, rigidity, stiffness, bradykinesia, postural instability, freezing of gait, festinating gait, difficulty turning over in bed, dystonia

and so on. Additional symptoms not listed on the scale could be supplemented at the end to allow for a more comprehensive symptom assessment. Symptoms were assessed across three dimensions: frequency of occurrence, severity, and level of distress. Severity was rated from "not serious at all", "mild", "moderate", "severe", to "very severe".

39-Item Parkinson's Disease Questionnaire (PDQ-39)

The PDQ-39 was developed by Peto.[20] The PDQ-39 comprises eight dimensions: "mobility", "activities of daily living", "emotional well-being", "stigma", "social support", "cognitions", "communication", "bodily discomfort". A higher total score indicates poorer quality of life.

Data Analysis

Developing Symptom Network

Descriptive analyses and model construction were conducted using SPSS version 26.0 and R version 4.4.3, respectively in the descriptive analyses, categorical data were presented as frequencies and percentages. Symptom severity scores, which did not follow a normal distribution, were expressed as median (P25, P75), with the mean used as an auxiliary evaluation tool. Symptoms with an incidence rate greater than 20% were included in the network analysis, which was performed using R version 4.4.3. A symptom network was constructed based on the EBICglasso function and Spearman correlation analysis (tuning parameter=0.5). The least absolute shrinkage and selection operator algorithm was applied to reduce the number of weak edges and to obtain a simplified network. Symptoms were defined as network nodes, and the lines between nodes were considered network edges. Network edges represented partial correlation coefficients, with thicker edges indicating stronger correlations between symptoms.[18]

Node Centrality

The approach to symptom network analysis was most concerned with which symptom activation was more likely to activate other symptoms in the network. Among the centrality metrics, expected influence (EI) was the most commonly used indicator. It referred to the sum of the edge weights connecting a node to all other nodes in the network, representing the degree and nature of a node's connectivity. A higher absolute EI value indicated stronger connections, It is particularly useful when analyzing networks that include both positive and negative associations, as it provides a more accurate estimation of node importance in such contexts.[21,22] The Bridge Expected Influence (BEI) refers to the sum of all edge weights connecting a specific symptom to symptoms in other communities. A higher BEI value indicates that the symptom plays a more central role in the symptom network. The indices of expected Influence and bridge expected influence are denoted as r_e and r_{be}, respectively. Therefore, we focused our interpretation of the most relevant symptoms on r_e and r_{be} in the report.

Accuracy and Stability Estimation

We estimated the accuracy and stability of the networks using the novel R package bootnet. An evaluation of the accuracy and stability of centrality measurements was conducted by bootstrapping (nBoots=1000). First, edge weights with 95% confidence intervals (CIs) were bootstrapped to measure the edge's accuracy.[23] Second, a subsetting bootstrap was used to determine the centrality stability of the coefficient (CS-coefficient), Stability refers to the consistency of the centrality rankings within the network structure when certain samples or nodes are removed. In general, it is recommended that a CS coefficient should be no less than 0.25 and ideally higher than 0.50.[18]

Difference Tests

We performed a difference test to identify whether the estimations of network connections and centrality for different variables differ. Bootstrapped difference tests (nBoots=1000) were conducted between edge weights and centrality indices in the least absolute shrinkage and selection operator regularization of partial correlation networks based on polychoric correlation matrices.[24]

Results

Characteristics of Participants

This study included 954 participants in the analysis. Regarding age distribution, 26.2% were between 18 and 60 years old, 41.9% were aged 61 to 70 years, and 31.9% were over 70 years old. Among the participants, 55.9% were male and 44.1% were female. In terms of educational attainment, 66.4% had completed secondary school or below, 24.4% had received post-secondary education, and 9.2% had attained a university degree or higher. The duration of illness ranged from one to over ten years, with 67.4% having been ill for 1 to 5 years, 23.7% for 6 to 10 years, and 8.9% for more than 10 years. Regarding disease severity, based on the Hoehn and Yahr staging, 78.8% of participants were in stages 1 to 2, and 21.2% were in stage 3. Most participants lived with others (90.4%), while 9.6% lived alone. Marital status indicated that 89.2% were married, 1.2% were single, and 9.6% were widowed or divorced. With respect to family monthly income, 26.4% reported an income of less than 3000 Chinese yuan, 60.8% reported 3000 to 5000 yuan, and 12.8% reported an income greater than 5000 yuan. In terms of perceived economic pressure, 21.8% reported lighter pressure, 63.1% reported average pressure, and 15.1% reported heavier pressure. Furthermore, 47.4% of the participants reported having other chronic diseases, while 52.6% did not. Regarding hospitalizations, 65.8% had been hospitalized once, 21.3% had been hospitalized twice, and 12.9% had experienced three or more hospitalizations. The characteristics of the participants are shown in Table 1.

Table 1 Characteristics of Participants (n=954)

Items	Variables	n (%)
Age (years)	18~60	250 (26.2)
	>60~70	400 (41.9)
	>70	304 (31.9)
Gender	Male	533 (55.9)
	Female	421 (44.1)
Education attainment	Second school or below	633 (66.4)
	Post- secondary	233 (24.4)
	University or above	88 (9.2)
Years of illness (years)	≥1~5	643 (67.4)
	>5~10	226 (23.7)
	>10	85 (8.9)
Hoehn and Yahr staging	1-2	751 (78.8)
	3	203 (21.2)
Living status	Living alone	92 (9.6)
	Living with others	862 (90.4)
Marital status	Married	851 (89.2)
	Single	11 (1.2)
	Widowed or divorced	92 (9.6)
Family monthly income	<3000	252 (26.4)
(Chinese yuan)	≥3000~5000	580 (60.8)
	>5000	122 (12.8)
Economic pressures	Lighter	208 (21.8)
	Average	602 (63.1)
	Heavier	144 (15.1)
Combined with other chronic diseases	Yes	452 (47.4)
	No	502 (52.6)
Hospitalizations	1	628 (65.8)
	2	203 (21.3)
	≥3	123 (12.9)

Symptom Prevalence and Severity

In this study, the three most common symptoms among patients with early to mid-stage PD were bradykinesia (77.46%), resting tremor (75.05%), and rigidity (59.01%); The three symptoms with the highest severity scores were resting tremor (1.62 ± 1.21), bradykinesia (1.62 ± 1.20), and rigidity (1.34 ± 1.27). Details are presented in Table 2. The prevalence of hypogeusia in this study was 16.46% (<20%), To ensure the stability of the network model, hypogeusia was excluded from the symptom network analysis.

Symptom Network Analysis

Symptom Network and Centrality Measures

Analysis of the symptom network, based on the thickness of the edges and corresponding network results, revealed that the three strongest symptom pairs were urgency and frequency of urination (r=0.59), depression and anxiety (r=0.54), and rigidity and stiffness (r=0.37) (Figure 1A). Centrality indices ranked bradykinesia (r_e=1.27), postural instability (r_e=1.16), and stiffness (r_e=1.06) as the top three most central symptoms. Therefore, bradykinesia was identified as the core symptom in early to mid-stage PD, with postural instability and stiffness ranked second and third, respectively (Figure 1B).

Accuracy, Stability and Difference Test of Symptom Network

The CS coefficient was 0.751, indicating good stability of the results (Figure 2A). Additionally, the bootstrapped difference test for edge weights showed a high degree of overlap between the 95% confidence intervals of the bootstrapped samples and the original dataset, suggesting that the estimated edge weights were sufficiently robust (Figure 2B). Figure 3A shows the results of the bootstrapped edge difference test. The bootstrapped difference test for edge weights showed that the three strongest edge weights, "urgency and frequency of urination", "depression and anxiety" and "rigidity and stiffness", were

Table 2 Symptom Prevalence and Severity (n=954)

Symptoms	n (%)	M (P25, P75)	Mean (SD)
Resting tremor	716(75.05)	2(0.75, 2)	1.62(1.21)
Rigidity	563(59.01)	1(0, 2)	1.34(1.27)
Stiffness	515(53.98)	1(0, 2)	1.09(1.23)
Bradykinesia	739(77.46)	2(1, 3)	1.62(1.20)
Postural instability	420(44.03)	0(0, 2)	0.83(1.07)
Freezing of gait	327(34.28)	0(0, 2)	0.74(1.15)
Festinating gait	451(47.27)	0(0, 2)	0.81(0.99)
Difficulty turning over in bed	448(46.96)	0(0, 2)	0.92(1.16)
Dystonia	452(47.38)	0(0, 3)	1.13(1.36)
Difficulty standing up or sitting down	407(42.66)	0(0, 2)	0.88(1.22)
Salivation	393(41.19)	0(0, 1)	0.68(0.96)
Dysphagia	202(21.17)	0(0, 0)	0.30(0.65)
Depression	449(47.06)	0(0, 2)	0.82(1.04)
Anxiety	487(51.05)	1(0, 2)	0.90(1.07)
Apathy	255(26.73)	0(0, 1)	0.46(0.88)
Fatigue	350(36.69)	0(0, 2)	0.71(1.05)
Speech dysfunction	246(25.79)	0(0, 1)	0.36(0.67)
Hyposmia	320(33.54)	0(0, 1)	0.72(1.18)
Hypogeusia	157(16.46)	0(0, 0)	0.21(0.52)
Insomnia	420(44.03)	0(0, 2)	0.96(1.26)
Pain	264(27.67)	0(0, 1)	0.42(0.76)
Restless legs syndrome	246(25.79)	0(0, 1)	0.35(0.67)
Constipation	497(52.10)	1(1, 3)	1.29(1.41)
Urinary frequency	406(42.56)	0(0, 2)	0.83(1.13)
Urinary urgency	385(40.36)	0(0, 2)	0.80(1.15)

Abbreviations: M, median; SD, standard deviation.

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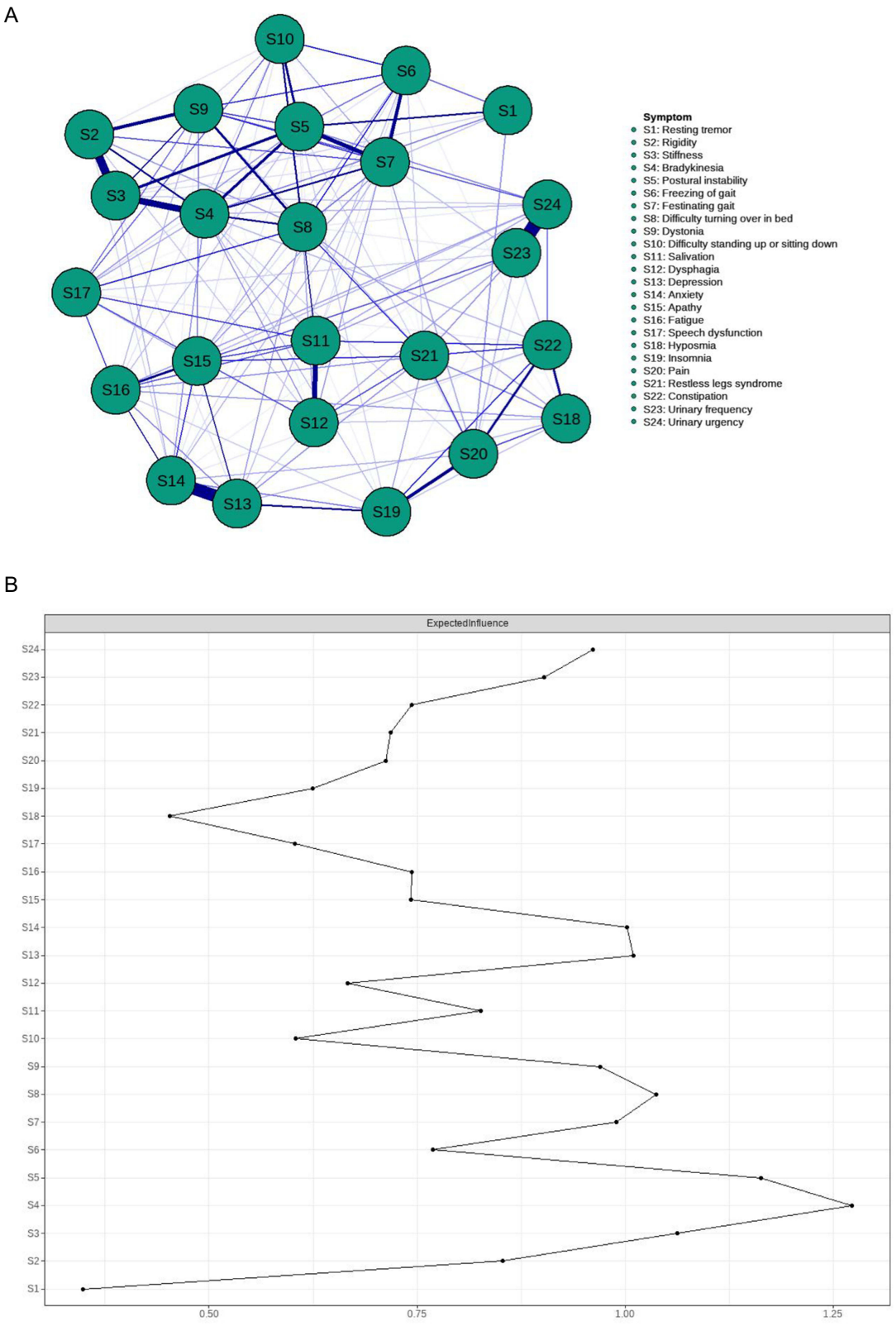

Figure 1 (**A**) Symptom network of 24 symptoms. (**B**) Expected influence of 24 symptoms.

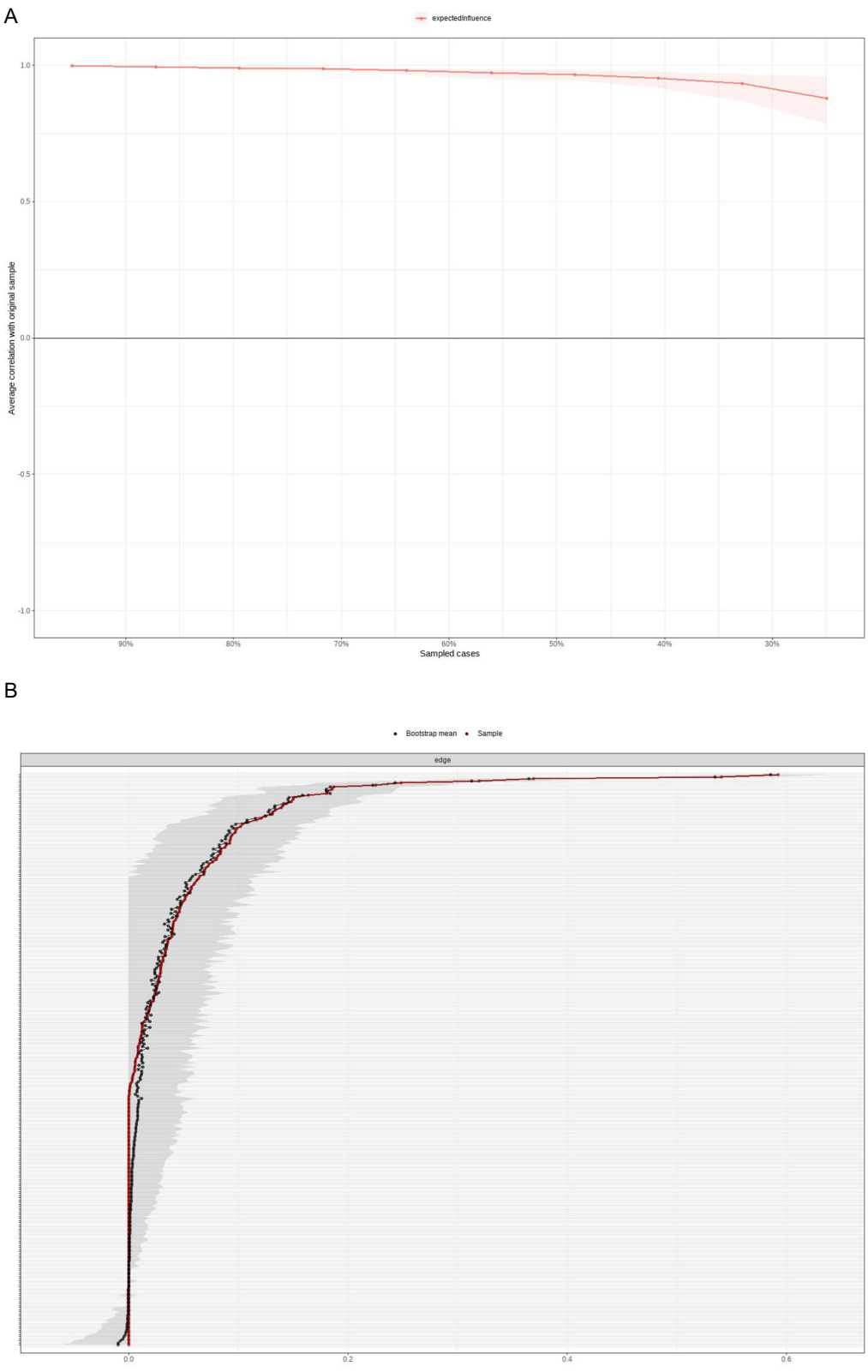

Figure 2 (**A**) Correlation stability coefficient for expected influence. (**B**) Bootstrap analysis results of the edge weights of symptom network.

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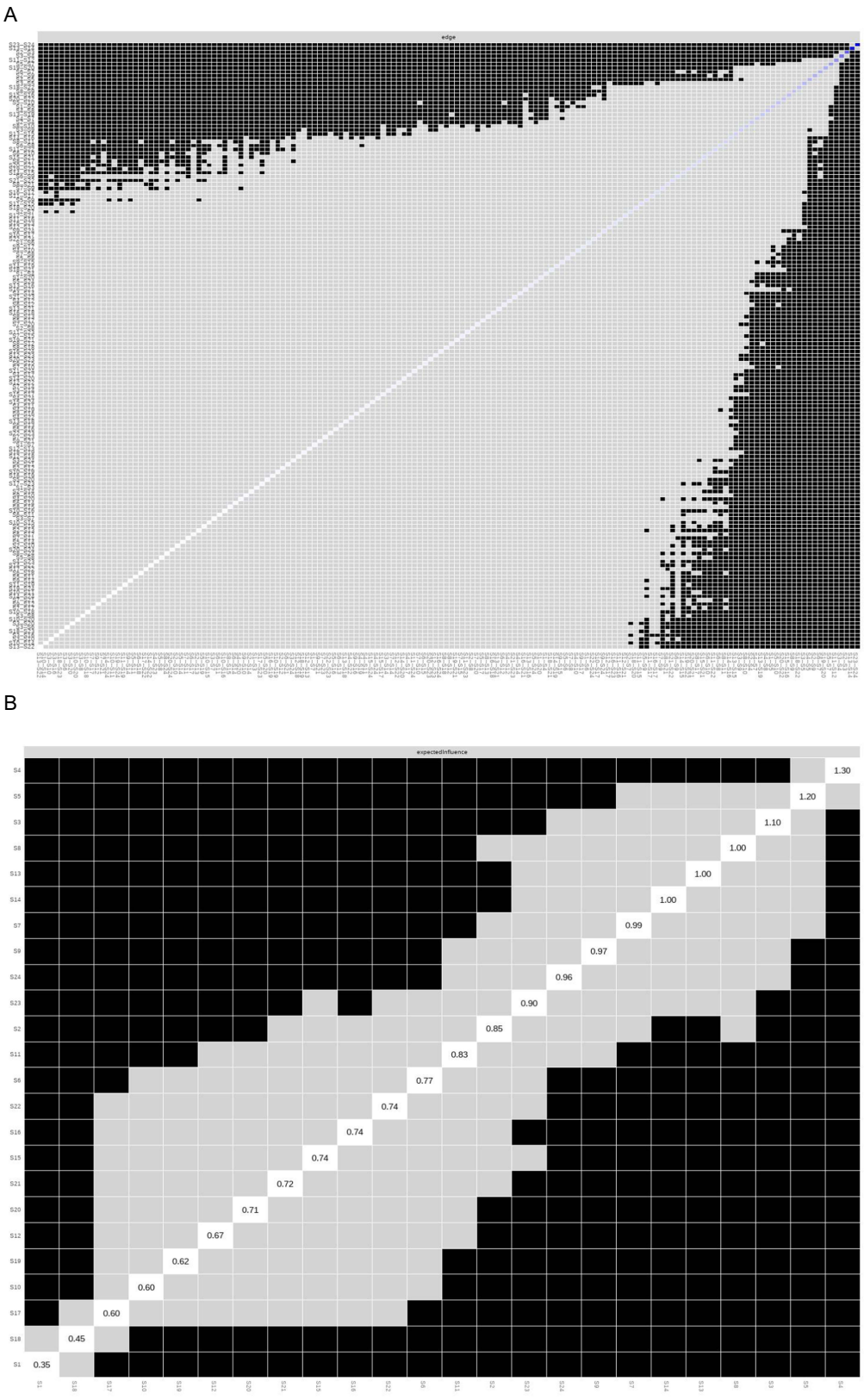

Figure 3 (**A**) Bootstrapped difference test for edges of symptom network. (**B**) Bootstrapped difference test for nodes of symptom network.

significantly different from approximately 95% of the other edge weights. Figure 3B shows the results of the bootstrapped node difference test. Bradykinesia significantly differed from other nodes (DTs=1.20).

Quality of Life Network Analysis

Quality of Life Network and Centrality Measures

Eight dimensions from the PDQ-39, including "mobility", "activities of daily living", "emotional well-being", "stigma", "social support", "cognitions", "communication", "bodily discomfort", were incorporated into the quality of life network. The network analysis results revealed that, among the edge weights (with blue lines representing positive correlations and red lines representing negative correlations), the strongest positive associations were observed between "mobility" and "activities of daily living" (r=0.52), "social support" and "communication" (r=0.20), "emotional well-being" and "stigma" (r=0.20), "cognitions" and "bodily discomfort" (r=0.15), and "social support" and "stigma" (r=0.13). Specifically, "mobility" was strongly correlated with difficulties in turning over in bed (r=0.19), freezing of gait (r=0.09), and difficulty standing up or sitting down (r=0.08); "emotional well-being" was strongly correlated with depression (r=0.16), anxiety (r=0.12), and insomnia (r=0.10); "cognitions" was strongly correlated with constipation (r=0.14), pain (r=0.12), and Salivation (r=0.05); "social support" was negatively correlated with difficulties in turning over in bed (r=−0.05) (Figure 4A). Based on the network's bridge centrality index, The "mobility" dimension showed the closest associations with various symptoms: "mobility" (r_{be}=0.52), "emotional well-being" (r_{be}=0.50), and "cognitions" (r_{be}=0.49). "mobility" was identified as the most central node in the quality of life network (Figure 4B).

Accuracy, Stability and Difference Test of Quality of Life Networks

The stability results of the network indicated that the CS coefficient was 0.594, suggesting that the constructed network demonstrated good stability (Figure 5A). The Bootstrapped variability test of edge weights showed that the 95% CS overlap between the Bootstrapped sampling set and the original dataset was high, indicating that the edge weights of the constructed network were sufficiently accurate (Figure 5B). Figure 6A shows the results of the bootstrapped edge difference test. The bootstrapped difference test for edge weights showed that the three strongest edge weights, "mobility and activities of daily living", "social support and social interaction" and "emotional well-being and stigma", were significantly different from approximately 95% of the other edge weights. Figure 6B shows the results of the bootstrapped node difference test. "Mobility" dimensions significantly differed from other nodes (DTs=0.35).

Discussion

Bradykinesia is the Most Prevalent Core Symptom

The top five symptoms with the highest incidence (bradykinesia, resting tremor, rigidity, stiffness, and constipation) differed from those reported in the study by Rodriguez-Blazquez (Daytime sleepiness, Pain, fatigue, Urinary problems, Sleep problems),[25] which may be attributed to regional differences. Bradykinesia refers to the impairment of the ability to adjust body posture, initiate and execute movements, and perform continuous and simultaneous tasks,[26] In this study, bradykinesia had the highest incidence (77.46%) and the greatest intensity (r_e=1.27), indicating that it is the most important symptom in early to mid-stage PD patients. This may be related to the fact that bradykinesia is a diagnostic criterion for PD.[27] Additionally, bradykinesia is significantly correlated with several symptoms. A study indicated that PD can lead to the death of dopaminergic neurons,[28] dysfunction of the dopaminergic system not only contributes to bradykinesia in patients with PD, but also plays a crucial role in the onset and progression of cognitive impairment, thereby triggering typical disease symptoms such as resting tremor, rigidity, and bradykinesia. Bradykinesia not only affects motor function but also restricts daily activities such as writing, using a smartphone, and engaging in hobbies. It severely impacts personal independence, such as dressing and personal hygiene, and significantly affects quality of life.[29]

Therefore, it is recommended to strengthen the screening and management of bradykinesia in early to-mid-stage PD patients by establishing a multidisciplinary expert management team, developing individualized management strategies, and improving bradykinesia health management in these patients. Previously, bradykinesia was typically assessed by experienced clinicians using the Unified Parkinson's Disease Rating Scale part III (UPDRS-III), which involves subjective observation of four repetitive motor tasks: forearm pronation and supination, fist clenching and opening,

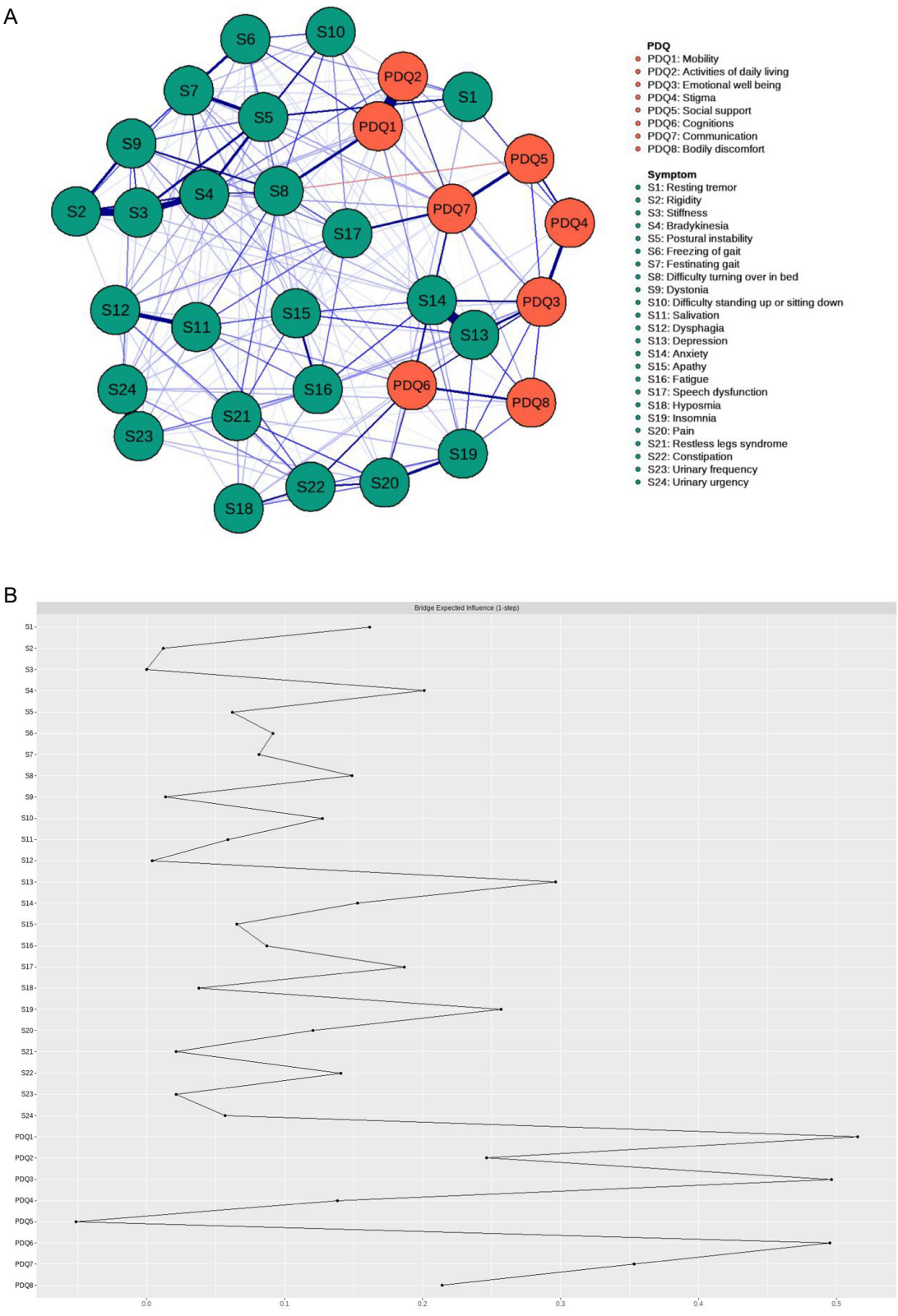

Figure 4 (**A**) Network of quality of life. (**B**) Bridge expected influence of network.

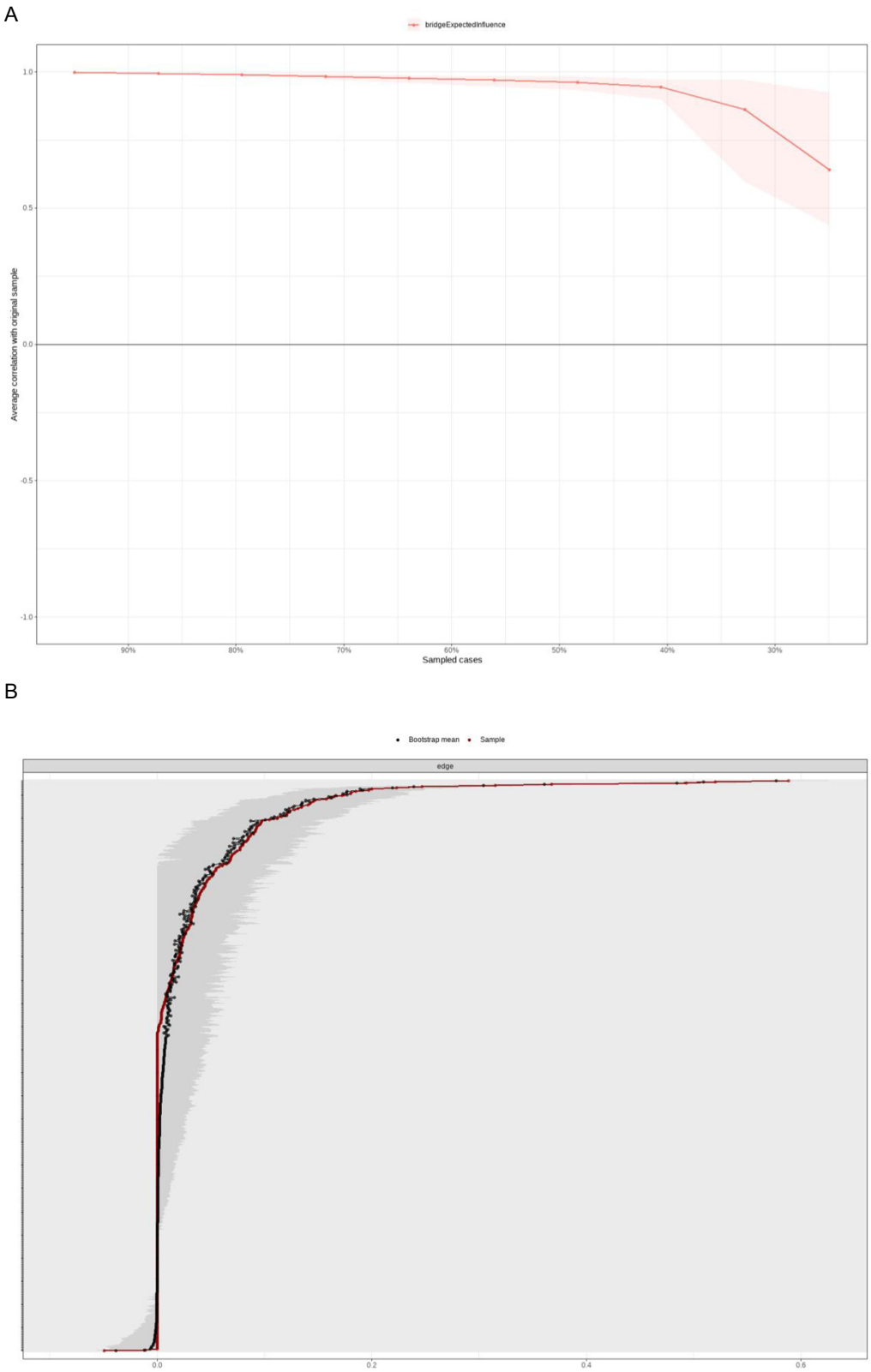

Figure 5 (**A**) Correlation stability coefficient for bridge expected influence. (**B**) Bootstrap analysis results of the edge weights of network of quality of life.

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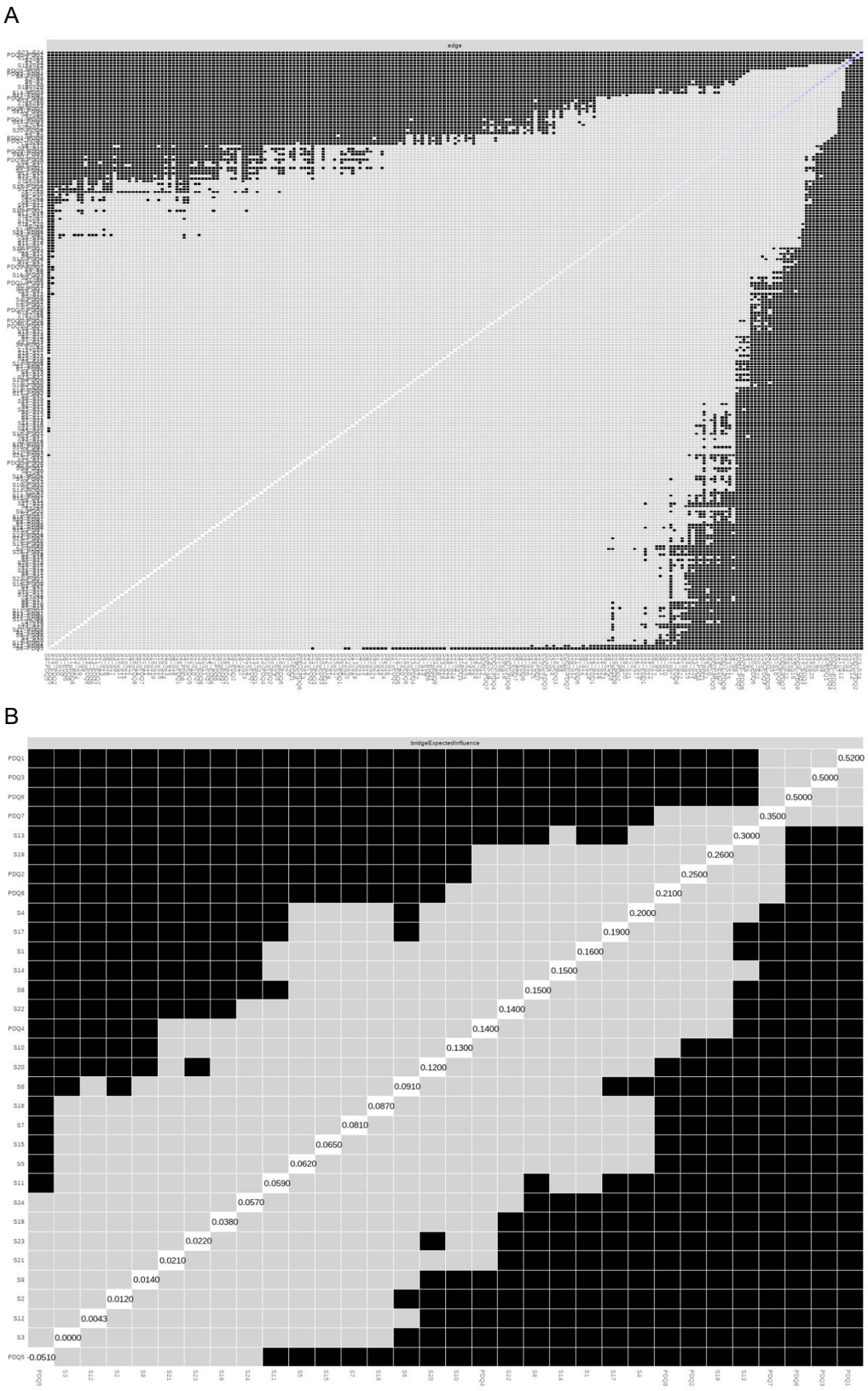

Figure 6 (**A**) Bootstrapped difference test for edges of network of quality of life. (**B**) Bootstrapped difference test for nodes of network of quality of life.

finger tapping in the upper limbs, and heel tapping in the lower limbs.[30] However, British scholar Memar argued that bradykinesia should not be viewed simply as the sum of isolated joint movements, but rather needs to be assessed as a global multi-joint motor impairment during tasks that involve multiple body parts.[31] In this regard, Memar and his team utilized wearable inertial measurement units to quantify full-body movements and proposed a novel bradykinesia assessment and screening method for walking and standing up from a chair. This could provide insights for more precise assessment and screening of bradykinesia in early-to-mid-stage PD patients. Meanwhile, studies combining wearable sensors with artificial intelligence (AI) have shown strong potential in detecting motor symptoms such as bradykinesia and gait disturbances by analyzing signals like muscle and brain activity, and for supporting ongoing symptom management. However, translating these tools into widespread clinical practice remains challenging, particularly in terms of standardization, validation, and real-world usability.[32] Future systems will need to be well-integrated into patients' daily lives—offering high accuracy, comfort, and long-term usability.

Postural Instability and Stiffness are Important Symptoms

The centrality indices of postural instability and stiffness are second only to bradykinesia. In the early stages of PD, increased stiffness typically results in a reduced amplitude of body sway during quiet standing,[33] which impairs the ability to adjust to dynamic balance disturbances. As the disease progresses, this trend reverses, with patients exhibiting increased spontaneous body sway in all directions,[34] This change may represent the core pathophysiological mechanism of postural instability in PD patients. Furthermore, not only does a forward flexed posture contribute to increased body sway in the anteroposterior direction, but the asymmetric distribution of PD signs may also lead to increased sway in the lateral direction, further exacerbating postural instability.[35] The latter is strongly associated with disease severity and fall risk,[36] Some researchers also suggest that postural instability may be closely linked to cognitive impairment.[37] This suggests that early intervention to improve stiffness may, to some extent, slow the progression of postural instability symptoms, potentially delaying disease progression and the occurrence of adverse events such as falls. Additionally, the occurrence of Levodopa-Induced Dyskinesia (LID) during the "on" period may impair balance and independently exacerbate postural instability.[38] Clinicians should advise PD patients not to engage in high-amplitude activities during the "on" period to prevent falls. Moreover, this study also found a strong correlation between postural instability and stiffness, suggesting that these symptoms may influence each other. Future research should further investigate the patterns and underlying mechanisms of these motor symptoms. For example, the increasingly utilized cross-lagged panel network (CLPN) analysis, a network modeling approach designed for longitudinal data, enables the examination of reciprocal predictive relationships between symptoms over time. It also allows for the assessment of how a symptom at an earlier time point predicts itself at a later time point. This approach may provide a more comprehensive and nuanced understanding of the progression of PD and could offer new directions for future research.[39]

The "Mobility" Dimension is the Most Central Node in the Network of Quality of Life

In the quality of life network, the "mobility" dimension is positively correlated with daily activities, emotional health, and social dimensions, indicating that poorer motor function in early to mid-stage PD patients may be associated with worse daily living activities, increased depression and anxiety, and more difficulty in social interactions. The "mobility" dimension is strongly associated with the top three symptoms: difficulty turning over in bed, freezing of gait (FoG) and difficulty standing up or sitting down. These are common motor symptoms in PD, with 80% of PD patients exhibiting these symptoms during transitions between various motor states.[40] Difficulty turning over in bed is an early symptom of PD,[41] In newly diagnosed patients, this symptom is mainly associated with bradykinesia (OR1.1, P=0.005),[42] which also explains why bradykinesia is the most prevalent symptom in this study. Patients experiencing difficulty turning over in bed are more likely to develop more severe motor complications within 5 years (ß=0.05, P<0.001), and report decreased sleep quality. The underlying mechanism of FoG may involve insufficient compensatory cortical activation and loss of functional connectivity during complex motor tasks,[43] Early signs of postural instability and gait disturbances,[44] contribute to increased difficulty with actions such as turning over in bed and rising or sitting down.[45,46] These factors are primary intrinsic causes of falls and are closely associated with cognitive impairment, significantly reducing patients' independence and functional ability.[40,47] However, it is worth noting that although "mobility" (r_{be}=0.52) showed

associations with difficulty turning over in bed (r=0.19), FoG (r=0.09), and difficulty standing up or sitting down (r=0.08), the absolute values of these correlation coefficients were relatively low (<0.2), indicating weak association strength. Future studies with larger samples and alternative algorithms are needed to confirm these findings.

Clinical care should focus on motor symptoms in early to mid-stage PD, especially targeting FOG to improve difficulties in turning over in bed and sit-to-stand transitions. Exercise not only improves cognitive function in PD patients, but also alleviates FoG.[48,49] Additionally, his study shows that social support is negatively correlated with difficulty turning over, suggesting that lower levels of social support are associated with increased difficulty in turning over. Health education for caregivers of PD patients should be implemented to enhance social support and reduce the disease burden on PD patients. Engaging and easily understandable educational videos could be created to improve the health literacy of early to mid-stage PD patients and their caregivers. This would help foster healthy behaviors, exercise routines, and caregiving strategies, ultimately improving the quality of life for these patients.

Limitations

First, a retrospective cross-sectional design was used to construct the symptom network for early to middle-stage PD patients, which may introduce selection bias. Second, the design does not allow for the establishment of causal relationships between symptoms. These factors may limit the interpretation and generalizability of the findings. Future studies should adopt multicenter, large-sample, prospective designs, employ different algorithms to validate the findings of this study; and construct longitudinal dynamic network models to identify changes in the mechanisms of symptom associations, thereby uncovering the underlying mechanisms of symptom progression and providing a basis for efficient and precise symptom management.

Conclusion

Bradykinesia is the most prevalent symptom in early to mid-stage PD patients, and the core symptoms include bradykinesia, postural instability, and stiffness. Intervention should focus on these core symptoms. Furthermore, attention should also be given to symptoms strongly associated with the “mobility” dimension of quality of life in early to mid-stage PD patients, such as difficulty turning over in bed, FoG and difficulty standing up or sitting down, in order to improve their quality of life. However, In light of the aforementioned limitations, the findings of this study need to be verified by larger samples and using different algorithms.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

This study was reviewed and approved by the Ethics Committee of Xiangyang First People’s Hospital, affiliated with Hubei University of Medicine (No.2025KY009). This study was conducted in accordance with the Declaration of Helsinki, Since It was a retrospective study, the Institutional Review Board (IRB) granted a waiver of informed consent. Patient confidentiality was guaranteed by ensuring the patient data was “de-identified and anonymous”.

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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.

References

1. Song Y, Lee JH, Kim HK, et al. Longitudinal trajectory of dopamine and serotonin transporters in Parkinson disease. *J Nuclear Med*. 2025;66(2):286–292. doi:10.2967/jnumed.124.268365
2. Hill DR, Huters AD, Towne TB, et al. Parkinson's disease: advances in treatment and the syntheses of various classes of pharmaceutical drug substances. *Chem Rev*. 2023;123(23):13693–13712. doi:10.1021/acs.chemrev.3c00479
3. Park SJ, Kim KW, Lee EJ. Gut-brain axis and environmental factors in Parkinson's disease: bidirectional link between disease onset and progression. *Neural Regeneration Res*. 2025;20(12):3416–3429. doi:10.4103/nrr.Nrr-d-24-00994
4. Yang Y, Wang Y, Gao T, et al. Effect of physiotherapy interventions on motor symptoms in people with Parkinson's disease: a systematic review and meta-analysis. *Biol Res Nurs*. 2023;25(4):586–605. doi:10.1177/10998004231171587
5. Apostol AE, Mohamed B, Thomas C, et al. CBT for generalized anxiety disorder in Parkinson's disease: a case study. *Clin Gerontolog*. 2024;47(2):352–361. doi:10.1080/07317115.2023.2254311
6. Ogaki K, Fujita H, Nozawa N, Shiina T, Sakuramoto H, Suzuki K. Factors contributing to sleep disturbances and excessive daytime sleepiness in patients with Parkinson's disease. *Front Neurol*. 2023;14:1097251. doi:10.3389/fneur.2023.1097251
7. Amadio E, Cimini L, Ruotolo I, et al. Rehabilitation treatment for shoulder pain in Parkinson's disease: a pilot study. *J Clin Med*. 2025;14(4):1127. doi:10.3390/jcm14041127
8. Park J, Cheon SM, Lee MJ, Rhu DW, Yoo D. Comparison of impact of various exercise modalities on Parkinson's disease. *J Movement Disord*. 2025;18(3):222–230. doi:10.14802/jmd.25038
9. Borsboom D. A network theory of mental disorders. *World Psychiatry*. 2017;16(1):5–13. doi:10.1002/wps.20375
10. Zhu Z, Sun Y, Kuang Y, et al. Contemporaneous symptom networks of multidimensional symptom experiences in cancer survivors: a network analysis. *Cancer Med*. 2023;12(1):663–673. doi:10.1002/cam4.4904
11. Silk TJ, Malpas CB, Beare R, et al. A network analysis approach to ADHD symptoms: more than the sum of its parts. *PLoS One*. 2019;14(1):e0211053. doi:10.1371/journal.pone.0211053
12. Mullarkey MC, Marchetti I, Beevers CG. Using network analysis to identify central symptoms of adolescent depression. *J Clin Child Adolescent Psychol*. 2019;48(4):656–668. doi:10.1080/15374416.2018.1437735
13. Hevey D. Network analysis: a brief overview and tutorial. *Health Psychol Behav Med*. 2018;6(1):301–328. doi:10.1080/21642850.2018.1521283
14. Höglinger G, Trenkwalder C, Becktepe J. Diagnosis and treatment of Parkinson´s disease (guideline of the German society for neurology). *Neurol Res Pract*. 2024;6(1):30. doi:10.1186/s42466-024-00325-4
15. Postuma RB, Berg D, Stern M, et al. MDS clinical diagnostic criteria for Parkinson's disease. *Movement Disord*. 2015;30(12):1591–1601. doi:10.1002/mds.26424
16. Martínez-Martín P, Rodríguez-Blázquez C, Mario A, et al. Parkinson's disease severity levels and MDS-unified Parkinson's disease rating scale. *Parkinsonism Related Disord*. 2015;21(1):50–54. doi:10.1016/j.parkreldis.2014.10.026
17. Papachristou N, Barnaghi P, Cooper B, et al. Network analysis of the multidimensional symptom experience of oncology. *Sci Rep*. 2019;9(1):2258. doi:10.1038/s41598-018-36973-1
18. Epskamp S, Borsboom D, Fried EI. Estimating psychological networks and their accuracy: a tutorial paper. *Behav Res Methods*. 2018;50(1):195–212. doi:10.3758/s13428-017-0862-1
19. Xiao M. *Compilation and Application of Symptom Experience Scale for Patients with Parkinson's Disease* [Master's]. Zhengzhou University; 2023. In Chinese.
20. Peto V, Jenkinson C, Fitzpatrick R, Greenhall R. The development and validation of a short measure of functioning and well being for individuals with Parkinson's disease. *Quality Life Res*. 1995;4(3):241–248. doi:10.1007/bf02260863
21. Jones PJ, Ma R, McNally RJ. Bridge centrality: a network approach to understanding comorbidity. *Multivariate Behav Res*. 2021;56(2):353–367. doi:10.1080/00273171.2019.1614898
22. Robinaugh DJ, Millner AJ, McNally RJ. Identifying highly influential nodes in the complicated grief network. *J Abnormal Psychol*. 2016;125(6):747–757. doi:10.1037/abn0000181
23. Li Y, Jia S, Cao B, Chen L, Shi Z, Zhang H. Network analysis of somatic symptoms in Chinese patients with depressive disorder. *Front Public Health*. 2023;11:1079873. doi:10.3389/fpubh.2023.1079873
24. Armour C, Fried EI, Deserno MK, Tsai J, Pietrzak RH. A network analysis of DSM-5 posttraumatic stress disorder symptoms and correlates in U.S. military veterans. *J Anxiety Disord*. 2017;45:49–59. doi:10.1016/j.janxdis.2016.11.008
25. Rodriguez-Blazquez C, Schrag A, Rizos A, Chaudhuri KR, Martinez-Martin P, Weintraub D. Prevalence of non-motor symptoms and non-motor fluctuations in Parkinson's disease using the MDS-NMS. *Mov Disord Clin Pract*. 2021;8(2):231–239. doi:10.1002/mdc3.13122
26. Pal G, Goetz CG. Assessing bradykinesia in parkinsonian disorders. *Front Neurol*. 2013;4:54. doi:10.3389/fneur.2013.00054
27. Munhoz RP, Tumas V, Pedroso JL, Silveira-Moriyama L. The clinical diagnosis of Parkinson's disease [O diagnóstico clínico da doença de Parkinson]. *Arq Neuro-Psiquiatr*. 2024;82(6):1–10. doi:10.1055/s-0043-1777775
28. Surmeier DJ. Determinants of dopaminergic neuron loss in Parkinson's disease. *FEBS J*. 2018;285(19):3657–3668. doi:10.1111/febs.14607
29. Gardoni A, Sarasso E, Agosta F, Filippi M, Corbetta D. Rehabilitative interventions for impaired handwriting in people with Parkinson's disease: a scoping review. *Neurolog Sci*. 2023;44(8):2667–2677. doi:10.1007/s10072-023-06752-6

30. Buck PO, Wilson RE, Seeberger LC, Conner JB, Castelli-Haley J. Examination of the UPDRS bradykinesia subscale: equivalence, reliability and validity. *J Parkinsons Dis*. 2011;1(3):253–258. doi:10.3233/jpd-2011-11035
31. Memar S, Delrobaei M, Pieterman M, McIsaac K, Jog M. Quantification of whole-body bradykinesia in Parkinson's disease participants using multiple inertial sensors. *J Neurol Sci*. 2018;387:157–165. doi:10.1016/j.jns.2018.02.001
32. Bougea A. Application of wearable sensors in Parkinson's disease: state of the art. *J Sensor Actuator Networks*. 2025;14(2):23. doi:10.3390/jsan14020023
33. Bloem BR, van Vugt JP, Beckley DJ. Postural instability and falls in Parkinson's disease. *Adv Neurol*. 2001;87:209–223.
34. Błaszczyk JW, Orawiec R, Duda-Kłodowska D, Opala G. Assessment of postural instability in patients with Parkinson's disease. *Exp Brain Res*. 2007;183(1):107–114. doi:10.1007/s00221-007-1024-y
35. Rocchi L, Chiari L, Cappello A, Horak FB. Identification of distinct characteristics of postural sway in Parkinson's disease: a feature selection procedure based on principal component analysis. *Neurosci Lett*. 2006;394(2):140–145. doi:10.1016/j.neulet.2005.10.020
36. Mitchell SL, Collins JJ, De Luca CJ, Burrows A, Lipsitz LA. Open-loop and closed-loop postural control mechanisms in Parkinson's disease: increased mediolateral activity during quiet standing. *Neurosci Lett*. 1995;197(2):133–136. doi:10.1016/0304-3940(95)11924-l
37. Lee JM, Koh SB, Chae SW, et al. Postural instability and cognitive dysfunction in early Parkinson's disease. *Can J Neurol Sci*. 2012;39 (4):473–482. doi:10.1017/s0317167100013986
38. Armand S, Landis T, Sztajzel R, Burkhard PR. Dyskinesia-induced postural instability in Parkinson's disease. *Parkinsonism Related Disord*. 2009;15(5):359–364. doi:10.1016/j.parkreldis.2008.08.007
39. Williams DR, Rhemtulla M, Wysocki AC, et al. On nonregularized estimation of psychological networks. *Multivariate Behav Res*. 2019;54 (5):719–750. doi:10.1080/00273171.2019.1575716
40. Zhang Q, Xie H, Zhao B, et al. Fronto-parieto-subthalamic activity decodes motor status in Parkinson's disease. *CNS Neurosci Ther*. 2023;29 (7):1999–2009. doi:10.1111/cns.14155
41. Dijkstra F, de Volder I, Viaene M, Cras P, Crosiers D. Impaired bed mobility in prediagnostic and de novo Parkinson's disease. *Parkinsonism Related Disord*. 2022;98:47–52. doi:10.1016/j.parkreldis.2022.04.007
42. Bhidayasiri R, Trenkwalder C. Getting a good night sleep? The importance of recognizing and treating nocturnal hypokinesia in Parkinson's disease. *Parkinsonism Related Disord*. 2018;50:10–18. doi:10.1016/j.parkreldis.2018.01.008
43. Pietracupa S, Suppa A, Upadhyay N, et al. Freezing of gait in Parkinson's disease: gray and white matter abnormalities. *J Neurol*. 2018;265 (1):52–62. doi:10.1007/s00415-017-8654-1
44. Lewis SJ, Shine JM. The next step: a common neural mechanism for freezing of gait. *Neuroscientist*. 2016;22(1):72–82. doi:10.1177/ 1073858414559101
45. Mezzarobba S, Grassi M, Pellegrini L, et al. Action observation improves sit-to-walk in patients with Parkinson's disease and freezing of gait. Biomechanical analysis of performance. *Parkinsonism Related Disord*. 2020;80:133–137. doi:10.1016/j.parkreldis.2020.09.029
46. Sringean J, Taechalertpaisarn P, Thanawattano C, Bhidayasiri R. How well do Parkinson's disease patients turn in bed? Quantitative analysis of nocturnal hypokinesia using multisite wearable inertial sensors. *Parkinsonism Related Disord*. 2016;23:10–16. doi:10.1016/j.parkreldis.2015.11.003
47. Gao C, Liu J, Tan Y, Chen S. Freezing of gait in Parkinson's disease: pathophysiology, risk factors and treatments. *Transl Neurodegeneration*. 2020;9(1):12. doi:10.1186/s40035-020-00191-5
48. Silva-Batista C, Almeida FO, Batista A, Barbosa ER, Horak FB, Ugrinowitsch C. Complex exercises improve cognition in people with Parkinson's disease and freezing of gait. *Neurorehabil Neural Repair*. 2025;39(1):3–15. doi:10.1177/15459683241290793
49. Ge Y, Zhao W, Zhang L, et al. Home physical therapy versus telerehabilitation in improving motor function and quality of life in Parkinson's disease: a randomized controlled trial. *BMC Geriatr*. 2024;24(1):968. doi:10.1186/s12877-024-05529-6