

The path linking cognitive function with activity of daily living in patients with Parkinson's disease: the moderated mediating effect of nutrition, depression, and quality of life

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Abstract

Background

In the past few decades, although the prevalence rate of Parkinson's disease (PD) among people over 60 in China has not changed significantly, the total number of PD patients has continued to increase. There are differences in culture, economic development, and dietary habits between the south China and the north China. Therefore, this study selected a representative city in northern China for a cross-sectional exploration of whether and how nutritional status, depression, and quality of life (QOL) mediate the relevance of cognitive function and activities of daily living (ADL) in patients with PD.

Methods

We conducted a cross-sectional questionnaire study involving 347 patients with PD in Taiyuan, China. The diagnostic criteria will follow the China Parkinson's Disease Diagnostic Criteria (2016 edition), using the Unified Parkinson's Disease Rating Scale (UPDRS), supplemented by black mole ultrasound examination and clinical imaging for confirmed cases. Exclusion criteria include: participants who refuse to participate; patients with severe aphasia due to the severity of their illness; patients with extremely missing unit data; patients with severe cognitive impairment or serious psychiatric and psychological disorders; patients who, due to critical illness, lose their ability to act and are treated by family members on their behalf; patients who present Parkinson's Disease-like symptoms due to anxiety or other mental states but are not actually diagnosed with Parkinson's Disease; and patients initially diagnosed with Parkinson's Disease but later re-diagnosed with another disease after multiple visits due to unresolved symptoms. Cognitive function, ADL, nutritional status, depression, and QOL were evaluated. We used conditional process models to examine the moderated mediating effects of nutritional status, QOL, and depression on cognitive function and ADL.

Results

Depression was found to be significantly associated with the relationship between cognitive function and nutritional status ($\beta = 0.006$, $p = 0.049$), suggesting a potential moderating role. This association was observed at medium ($\beta = -0.057$, 95% CI: -0.127 - -0.003) and high levels of depression ($\beta = -0.112$, 95% CI: -0.202 - -0.040). QOL was significantly associated with the relationship between nutritional status and ADL ($\beta = 0.097$, $p = 0.002$), indicating a potential moderating role. This pattern was evident at low ($\beta = -0.103$, 95% CI: -0.198 - -0.028) and medium levels of QOL ($\beta = -0.067$, 95% CI: -0.133 - -0.017).

Conclusions

Focusing on changes in nutritional status, depression, and QOL with cognitive function should be an essential part of strategies to improve ADL in patients with Parkinson's disease. However, due to the cross-sectional design of this study, it is difficult to draw causal conclusions. Future studies using longitudinal data will be conducted to further enrich and validate these findings.

Background

Parkinson's disease (PD) is a chronic, progressive neurodegenerative disorder that affects middle-aged and older individuals^[1]. Cognitive impairment is a common neurological complication of PD. It is estimated that 40% of patients with PD have cognitive dysfunction^[2]. As the disease progresses, cognitive impairment gradually increases and eventually develops into Parkinson's dementia^[3]. Given the progressive nature of cognitive decline in PD, its impact on patients' functional abilities in daily life has become an important area of research.

Katz proposed the concept of activities of daily living (ADL) in 1963^[4], which has since become a widely-used, important index to measure the self-care abilities of the elderly^[5]. ADL encompasses routine tasks that individuals perform independently for self-care, such as eating, dressing, bathing, and mobility^[6]. ADL disability refers to impairments or limitations in the ability to independently perform these basic activities of daily life due to health problems or physical functional limitations^[7]. Previous studies have demonstrated that in older adults, good cognitive function reduces the risk of BADL/IADL disability. Depressive symptoms downregulate the protective effect of cognitive function on BADL/IADL over time^[8].

In addition to psychological factors, nutritional status also plays a critical role in PD progression. The prevalence of malnutrition in patients with PD ranges from 15% to 22%^[9]. Previous studies have suggested that cognitive impairment may reduce the ability to maintain

adequate nutritional intake due to impaired executive function and self-care capacity, while nutritional status, in turn, is known to impact ADL^[10, 11]. Further evidence indicates that the negative effects of cognitive decline on sarcopenia are mediated by nutritional status^[12], and sarcopenia impairs the ability to perform ADL in community-dwelling elderly people^[13, 14, 15]. Taken together, these findings support the hypothesis that nutrition may serve as a mediator in the pathway from cognitive impairment to ADL.

The prevalence of depression in PD is 11.17%^[16], indicating that depression plays a key role in the life course of patients. Multiple studies have demonstrated a strong association between depressive symptoms and ADL disability^[17, 18]. Depressive symptoms frequently coexist with ADL disability, and the presence of depressive symptoms significantly predicts the subsequent development of ADL disability^[19, 20]. A cross-sectional study encompassing 5,863 elderly adults established a positive association between depressive symptoms and ADL disability among Chinese elderly adults^[21]. Concerning the relationship between cognition and mood in patients with PD, existing studies have confirmed an interaction between depressive state and level of cognitive function^[22, 23, 24]. However, the pathogenesis of PD and its related complications such as depression and cognitive impairment remain unclear. Given that depressive symptoms interact with both cognitive function and ADL disability, depression may serve as a moderating factor that influences the pathway through which cognitive impairment affects ADL.

Quality of life (QOL) is another important factor that is significantly negatively correlated with ADL in patients with PD^[25], much like it is in patients with stroke^[26]. QOL, in turn, appears to be affected by cognitive function in patients with PD. Previous studies have shown that depression and frailty were significantly negatively correlated with all domains of QOL, while nutritional status was positively correlated with QOL across physical, psychological, social, and environmental dimensions^[27]. Given that QOL is interconnected with cognitive function, nutritional status, and ADL, it is plausible that QOL may moderate one or more pathways in the model—potentially influencing the relationship between cognitive impairment and nutrition, or between nutrition and ADL, or both.

The mediation method was first proposed by Tolman in 1932 and developed rapidly. In recent years, the combination of mediation method and PD has also emerged one after another. In 2015, Hui-Ing Ma^[28] applied the mediation analysis method to study the QOL of PD patients. He Y^[29] tried to explore the internal relationship between cognitive function and QOL with the mediation research method. In 2021, Zhang C^[30] applied a moderated mediation model to investigate chronic diseases, aiming to identify latent factors underlying the progression of PD. By targeting cognitive function and depressive symptoms, this approach contributed to improving both psychological and physical rehabilitation, thereby enhancing the precision and effectiveness of PD management and treatment. However, two important gaps remain. First, it is unclear whether the progression of PD is influenced by additional moderators and more complex pathways involving multiple factors. In particular, the role of nutritional status in the pathway affecting quality of life in patients with PD has not been fully explored. Second, existing studies using mediation models to investigate PD-related mechanisms have largely focused on single factors or single pathways. In contrast, PD progression is a long-term and multifactorial process, and there is still considerable scope for applying more complex mediation frameworks to better capture these mechanisms. Based on this background, the present study adopts a “multi-factor, multi-pathway” analytical framework and employs conditional process analysis to examine the factors involved in PD progression and to quantify their effects.

Methods

Sample

This cross-sectional study included 347 outpatients and inpatients who received care from the Department of Neurology of the First Hospital of Shanxi Medical University in Taiyuan, Shanxi Province, China between September 2018 and September 2020. The diagnostic criteria will follow the China Parkinson's Disease Diagnostic Criteria (2016 edition), using the Unified Parkinson's Disease Rating Scale (UPDRS), supplemented by black mole ultrasound examination and clinical imaging for confirmed cases. Exclusion criteria include: participants who refuse to participate; patients with severe aphasia due to the severity of their illness; patients with extremely missing unit data; patients with severe cognitive impairment or serious psychiatric and psychological disorders; patients who, due to critical illness, lose their ability to act and are treated by family members on their behalf; patients who present Parkinson's Disease-like symptoms due to anxiety or other mental states but are not actually diagnosed with Parkinson's Disease; and patients initially diagnosed with Parkinson's Disease but later re-diagnosed with another disease after multiple visits due to unresolved symptoms. The study adhered to the ethical standards set forth in the Declaration of Helsinki. Ethical approval for our study was also obtained from the Shanxi Medical University Ethics Committee, and informed consent was obtained from all participants. Clinical trial number is not applicable. Face-to-face interviews were used to collect data, and the researchers monitored and assisted participants while completing the questionnaires. Patients were

asked to provide demographic and background health information regarding sex, age, marital status, educational attainment, family unit, smoking status, and drinking behavior.

Clinical measurements

ADL was assessed using the Unified Parkinson's Disease Rating Scale-II (UPDRS-II)^[31]. This scale has shown good reliability and validity in patients with PD^[32], and is a useful index to monitor disease progression^[33]. The UPDRS-II contains 13 items pertaining to difficulties performing ADL symptom interference. Scores range from 0 to 52, with higher scores indicating greater impairment.

The Mini-Mental State Examination (MMSE)^[34] was used to assess cognitive function. Scores range from 0 to 30, with scores ≤ 23 typically considered indicative of cognitive impairment. The MMSE has shown satisfactory predictive validity and is a sufficient cognitive screening measure.

The Geriatric Depression Scale (GDS)^[35] was utilized to assess depression. The GDS is a self-administered, 30-item yes/no questionnaire. It performs well distinguishing patients with depression from those without depression and is a reliable, valid self-report screening measure for depression in the elderly^[36]. Higher scores indicate more severe depression.

The MOS 36-item Short-Form Health Survey (SF-36)^[37] was used to measure QOL. This scale was modified from the Medical Outcome Study-Short Form (MOS SF) to assess eight dimensions of QOL. Each dimension is scored out of 100, with higher scores indicating greater QOL^[38].

The Mini Nutritional Assessment (MNA)^[39] was used to assess nutritional status. It consists of 18 items, with a total possible score of 30. Normal nutrition is defined as an MNA score ≥ 24 , potential malnutrition as a score of 17 to 23.5, and malnutrition as a score < 17 . (See the attachment)

Modeling

The moderated mediation model, also known as conditional process analysis, conditional process model, or mixed model, was formally described by Hayes and Andrew^[40] in 2019. The essence of moderated mediation is that a moderating variable regulates the paths within a mediation model. If a variable regulates the degree of mediation, then that variable is considered to moderate the mediation. Hayes and Andrew proposed 92 different models for conducting conditional process analysis. To construct a regulated mediating model for this study, MMSE score was treated as the independent variable, SF-36 and GDS scores as the moderating variables, MNA score as the mediating variable, and UPDRS-II score as the dependent variable. A total of 24 paths were constructed, and four key models were screened (Fig. 1).

Models 1 and 2 were conditional process models with univariate moderating variables. In Model 1, depression was treated as a moderator of the relationship between the independent variable (cognitive function) and the mediator (nutritional status). In Model 2, we considered QOL as a moderator of the relationship between the mediator (nutritional status) and the dependent variable (ADLs).

In Models 3 and 4, we treated depression and QOL as simultaneous moderating variables. In Model 3, we entered these variables as joint moderators of the relationship between the independent variable and the mediator. However, in Model 4, we considered depression as a moderator of the relationship between the independent variable and the mediator, and, at the same time, we treated QOL as the moderator of the relationship between the mediator and the dependent variable.

Statistical analysis

We used EpiData 3.1^[41] to record data twice to ensure data accuracy and reliability. We used SPSS version 26.0^[42] for computing summary statistics, t-tests, and one-way analyses of variance. Spearman's rank correlation coefficients were used to explore the associations among the factors affecting ADL. A two-sided p-value < 0.05 was considered significant.

A moderated mediation model was constructed with MMSE score as the independent variable, SF-36 and GDS scores as moderators, MNA score as the mediator, and UPDRS-II score as the dependent variable. The Process Selection Model (SPSS 26.0) was used for conditional process analysis. Moderated one-path and two-path mediation tests were performed using Mplus version 8.3^[43]. Moderator variables were classified into different levels based on Mean $\pm$ 1SD. Mean + 1SD represents a high level, Mean represents a medium level, and Mean - 1SD

represents a low level. The bias-corrected confidence interval method was used for statistical inference, with 5,000 bootstrap resamples. The moderated mediation effect was considered significant if the CI did not include zero. A significance level of $\alpha = 0.05$ was adopted.

Results

Descriptive statistics and correlational analysis

In this study, 347 patients with PD were examined, including 206 males (59.37%) and 141 females (40.63%). The average education level was below that of junior high school. There were significant differences in UPDRS-II score as a function of age, marital status, and family population. Therefore, these factors were included as covariates in the conditional process analysis (Table 1).

Cognitive function, ADL, depression, nutritional status, and QOL significantly intercorrelated ($p < 0.001$). ADL negatively correlated with cognitive function ($r = -0.331$), QOL ($r = -0.423$), and nutritional status ($r = -0.421$), and positively correlated with depression ($r = 0.304$). Depression negatively correlated with QOL ($r = -0.282$), whereas nutritional status positively correlated with QOL ($r = 0.270$) (Fig. 2).

Table 1
Demographic characteristics by UPDRS-II score (N = 347)

Age (years)	N(%)	Mean (SD)	t/F	p
< 60	77 (22.19)	10.76 (8.76)	0.78	0.047
≥ 60	270 (77.81)	11.65 (8.28)		
Gender				
Male	206 (59.37)	11.83 (8.43)	1.29	0.256
Female	141 (40.63)	10.81 (8.37)		
Marital status				
Widowed	26 (7.49)	11.12 (8.20)	5.7	0.018
Married	321 (92.51)	15.04 (10.08)		
Education				
No formal education	220 (63.40)	10.95 (7.87)	2.27	0.105
High school and below	78 (22.48)	13.15 (10.38)		
Junior college and above	49 (14.12)	10.77 (6.89)		
Family population				
1–3	120 (34.58)	11.07 (7.53)	3.74	0.025
4–6	204 (58.79)	11.12 (8.48)		
7–9	23 (6.63)	15.92 (10.85)		
Smoking				
Yes	71 (20.46)	13.05 (8.58)	3.61	0.058
No	276 (79.54)	10.99 (8.32)		
Drinking				
Yes	51 (14.70)	12.57 (8.66)	1.20	0.274
No	296 (85.30)	11.21 (8.36)		
SD: standard deviation				

Conditional process analysis of univariate moderating variables

Table 2 shows that, in Model 1, depression positively moderated the relationship between cognitive function and nutritional status ($\beta = 0.006$, $p = 0.049$). However, moderation occurred only in the context of medium ($\beta = -0.057$, 95% CI: $-0.127 - -0.003$) and high ($\beta = -0.112$, 95% CI: $-0.202 - -0.040$) levels of depression (Table 4). Low levels of depression had no significant moderating effect ($\beta = -0.002$, 95% CI: $-0.097 - 0.075$). Figure 3a shows that, at medium and high levels of depression, with the enhancement of cognitive function, patients with PD have stronger ADLs. However, the increasing trend of ADL in patients is not obvious in the low depressive state, with improved cognitive function.

In Model 2, QOL positively moderated the relationship between nutritional status and ADL ($\beta = 0.097$, $p = 0.002$) (Table 2). However, moderation occurred in the specific contexts of low ($\beta = -0.103$, 95% CI: $-0.198 - -0.028$) and medium ($\beta = -0.067$, 95% CI: $-0.133 - -0.017$) levels of QOL (Table 4). A high QOL level had no significant moderating effect ($\beta = -0.030$, 95% CI: $-0.087 - 0.007$). At the same time, Fig. 3b shows that the moderating effect of QOL in the path from nutritional status to ADL is more evident at lower QOL levels.

Table 2
Regression results for the univariate moderating variables

Variables	MNA (Dependent variable)						UPDRS-II (Dependent variable)					
	Model 1			Model 2			Model 1			Model 2		
β	SE	t	β	SE	t	β	SE	t	β	SE	t	
Constant	7.896	0.766	10.312***	-0.294	0.921	-0.319	19.71	3.866	5.098***	0.006	0.043	0.135
Age	-0.011	0.01	-1.07	-0.011	0.011	-1.088	0.065	0.045	1.446	-2.154	0.738	-2.919**
Marital status	-0.047	0.114	-0.412	-0.075	0.118	-0.64	1.028	0.505	2.034*	0.087	0.345	0.254
Education	0.089	0.082	1.089	0.076	0.085	0.889	0.247	0.364	0.678	0.006	0.043	0.135
MMSE	0.031	0.017	1.829	0.051	0.017	2.978***	-0.488	0.074	-6.625***	-0.454	0.069	-6.630***
GDS	-0.08	0.017	-4.805***									
MNA							-1.829	0.226	-8.087***	-1.316	0.22	-5.983***
SF-36										-0.353	0.05	-7.080***
MMSE*GDS	0.006	0.003	1.977									
MNA*SF-36										0.097	0.031	3.116**
R^2	0.111			0.041			0.291			0.395		
F	6.395***			3.065**			24.451***			29.064***		
MMSE: Mini-Mental State Examination, MNA: Mini Nutritional Assessment, UPDRS-II: Unified Parkinson's Disease Rating Scale-II, GDS: Geriatric Depression Scale, SF-36: MOS 36-item Short-Form Health Survey												
** $p < 0.01$, *** $p < 0.001$												

Table 3
Regression results for the two-factor moderating variables

Variables	MNA (Dependent variable)						UPDRS-II (Dependent variable)					
	Model 3			Model 4			Model 3			Model 4		
β	SE	t	β	SE	t	β	SE	t	β	SE	t	
Constant	7.389	0.764	9.675***	0.655	0.766	0.855	19.71	3.866	5.098***	10.935	3.203	3.414***
Age	0.000	0.01	-0.041	-0.011	0.01	-1.07	0.065	0.045	1.446	0.006	0.043	0.135
Marital status	-0.077	0.112	-0.687	-0.047	0.114	-0.412	1.028	0.505	2.034*	1.137	0.468	2.429*
Education	0.044	0.082	0.53	0.089	0.082	1.089	0.247	0.364	0.678	0.087	0.345	0.254
MMSE	0.037	0.018	2.080*	0.031	0.017	1.829	-0.488	0.074	-6.625***	-0.454	0.069	-6.63***
GDS	-0.061	0.017	-3.636***	-0.08	0.017	-4.805***				0.355	0.061	5.778***
MNA							-1.829	0.226	-8.087***	-1.316	0.22	-5.983***
SF-36	0.044	0.012	3.684***							-0.353	0.05	-7.08***
MMSE*GDS	0.008	0.003	2.603**	0.006	0.003	1.977*				0.008	0.045	0.167
MNA*SF-36	0.005	0.003	1.842							0.097	0.031	3.116**
R^2	0.154			0.111			0.291			0.395		
F	7.174***			6.395***			24.451***			29.064***		
MMSE: Mini-Mental State Examination, MNA: Mini Nutritional Assessment, UPDRS-II: Unified Parkinson's Disease Rating Scale-II, GDS: Geriatric Depression Scale, SF-36: MOS 36-item Short-Form Health Survey												
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$												

Table 4
Moderated mediating effect estimated results (Bootstrap = 5000)

Model	Intensity of effect		Effect	SE	95% CI
	GDS	SF-36			
Model 1	Low		-0.002	0.042	(-0.097, 0.075)
	Medium		-0.057	0.031	(-0.127, -0.003)
	High		-0.112	0.042	(-0.202, -0.040)
Model 2		Low	-0.103	0.044	(-0.198, -0.028)
		Medium	-0.067	0.029	(-0.133, -0.017)
		High	-0.030	0.024	(-0.087, 0.007)
Model 3	Low	Low	0.073	0.064	(-0.046, 0.215)
	Low	Medium	0.008	0.044	(-0.087, 0.095)
	Low	High	-0.057	0.051	(-0.170, 0.035)
	Medium	Low	-0.003	0.043	(-0.082, 0.092)
	Medium	Medium	-0.067	0.033	(-0.139, -0.011)
	Medium	High	-0.132	0.056	(-0.255, -0.035)
	High	Low	-0.078	0.043	(-0.167, 0.009)
	High	Medium	-0.142	0.050	(-0.250, -0.054)
	High	High	-0.207	0.076	(-0.372, -0.074)
Model 4	Low	Low	-0.002	0.047	(-0.105, 0.086)
	Low	Medium	-0.001	0.030	(-0.065, 0.057)
	Low	High	-0.001	0.016	(-0.037, 0.030)
	Medium	Low	-0.063	0.035	(-0.140, -0.001)
	Medium	Medium	-0.041	0.023	(-0.093, -0.001)
	Medium	High	-0.019	0.017	(-0.060, 0.005)
	High	Low	-0.125	0.050	(-0.234, -0.040)
	High	Medium	-0.081	0.034	(-0.157, -0.024)
	High	High	-0.037	0.029	(-0.106, 0.007)
GDS: Geriatric Depression Scale, SF-36: MOS 36-item Short-Form Health Survey					

Conditional process analysis of two-factor moderating variables

In Model 3, depression and QOL were treated as moderating variables that regulate cognitive function and nutritional status simultaneously. Table 3 shows that, while depression had a moderating effect on the path from cognitive function to nutritional status ($\beta = 0.008$, $p = 0.010$), the moderating effect of QOL was not significant ($\beta = 0.005$, $p = 0.066$). Table 4 shows that the moderating effect of QOL is not significant at low levels of depression. However, at medium levels of depression, medium QOL ($\beta = -0.067$, 95% CI: -0.139– -0.011) and high QOL ($\beta = -0.132$, 95% CI: -0.255– -0.035) had a significant moderating effect. At high levels of depression, medium QOL ($\beta = -0.142$, 95% CI: -0.250– -0.054) and high QOL ($\beta = -0.207$, 95% CI: -0.372– -0.074) had a significant moderating effect. On the other hand, medium ($\beta = -0.142$, 95% CI: -0.250– -0.054) and high ($\beta = -0.207$, 95% CI: -0.372– -0.074) levels of QOL had significant moderating effects on depression score. Figure 3c shows that the slope of high QOL in the high depression state was higher than that of low QOL in the high depression state. In other words, high depression and QOL exerted stronger regulatory effects on ADL, and the regulatory path was via cognitive function. However, in the low depression state, the moderating effect of high QOL was positive, and the moderating effect of low QOL was negative, indicating that, for low levels of depression, the moderating effect of higher QOL on ADL is stronger.

In Model 4, depression did not demonstrate a moderating effect on the path from cognitive function to nutritional status, whereas QOL had a significant positive moderating effect on the path from nutritional status to ADL (Table 3). The moderating effects of low and medium levels of QOL in the medium depression state, and low and medium levels of QOL in the high depression state, were significant (Table 4). This indicates that the strongest moderating effects of depression and QOL are observed when depression tends to be high and QOL tends to be low. As shown in Fig. 3d, the moderating effects of depression increase with depression severity. With improvement in cognitive function in patients, ADL increased more significantly at medium and high levels of depression, while the moderating effect of low levels of depression was weaker. In other words, the more severe the depression, the more obvious the adjustment in ADL, with this adjustment path between cognitive function and nutritional status. The effect of different QOL scores on ADLs showed a decreasing trend. At low and medium QOL levels, with the enhancement of cognitive function, ADL showed an obvious decreasing trend, while the moderating effect of high QOL levels was relatively flat. This indicates that, the lower the QOL level, the greater the regulation of ADL is in PD patients (Fig. 3e).

We conducted a post hoc power analysis using G*Power software. The results indicated that the statistical power for all models exceeded 80% with the current sample size (N = 337). This suggests that the sample size meets the statistical requirements.

Discussion

We found that ADL correlated negatively with QOL and cognitive function but positively with depression. Patients with poorer cognitive function and more severe depressive symptoms tended to have greater ADL impairment and lower QOL, suggesting that declines in cognitive function and mood may be closely related to poorer functional status and well-being in patients with PD. Previous studies have reported that poorer ADL performance is associated with higher levels of depression in older adults^[44], which is consistent with our findings. This relationship may be explained by the fact that depressive symptoms are often accompanied by reduced motivation, psychomotor retardation, and impaired self-care, which are associated with poorer functional performance. Patients with PD commonly experience physical dysfunction, which is associated with greater ADL impairment and, in turn, poorer QOL^[45].

Multiple studies have shown a positive association between cognitive function and nutritional status^[46, 47]. Previous studies have shown that depressive symptoms are significantly negatively correlated with nutritional status^[48, 49, 50]; the present findings are consistent with previous results. Moreover, Bossola et al^[51] confirmed that depression is a risk factor for malnutrition in patients. In our conditional process model, depression and QOL were identified as key moderators. First, depression moderated the effect of cognitive function on nutritional status. In particular, medium and high levels of depression significantly moderated the relationship between cognitive functioning and nutritional status, consistent with the findings of Gong et al^[52]. This moderating effect may be explained by depression-related inflammatory activation and neurotransmitter dysregulation, which impair executive function and appetite regulation, while reduced motivation and self-care further hinder the translation of cognitive function into adequate nutritional intake^[53, 54]. In light of our results and those reported in the literature, it is important to emphasize routine screening for depressive symptoms, and integrated interventions targeting both cognitive function and nutritional intake may help prevent functional decline and preserve ADL performance in patients with PD.

Second, QOL played a moderating role in the association between nutritional status and ADL. Specifically, the association between nutritional status and ADL was significantly moderated at low and medium levels of QOL. This may be explained by functional reserve and psychosocial resource mechanisms, as lower QOL is often associated with reduced physical capacity, poorer symptom management, and limited social support, which may amplify the association between malnutrition and ADL performance^[55, 56]. In addition, poor QOL may reflect underlying physical frailty and reduced physiological resilience, which may be associated with greater functional limitations in the context of malnutrition^[27]. When patients with PD have low and medium levels of QOL, greater attention to their nutritional status may help reduce the risk of functional decline in ADL. Our moderated mediation analysis showed that QOL may not provide additional moderating value in the presence of depression, and vice versa. These findings highlight the importance of integrating QOL assessment into clinical practice and suggest that targeted nutritional and supportive interventions may help mitigate functional decline and preserve ADL performance in patients with PD.

While this study focused on depression and quality of life as moderators, anxiety—an often co-occurring yet underrecognized syndrome can significantly influence nutritional behaviors and motivation, thereby indirectly impairing ADL. Incorporating brief, culturally appropriate anxiety screening into routine assessments^[57, 58] may offer a more comprehensive understanding of patients' functional profiles and help identify those at higher risk of decline. This approach could inform more individualized care strategies aimed at preserving independence and quality of life in patients with Parkinson's disease. In future research, we aim to optimize the model by incorporating anxiety as a moderator or covariate, which may elucidate additional variance in functional outcomes.

Furthermore, patients with mild cognitive impairment in Parkinson's disease (PD-MCI) represent a high-risk group in whom neuropsychiatric symptoms, such as apathy and mood disturbances, already begin to affect daily and social functioning. These early interactions may impair social function before dementia onset^[59]. In future research, we will focus on the PD-MCI population to identify modifiable risk factors and develop timely, stage-specific interventions aimed at preserving independence and delaying functional decline^[60].

Our study has some limitations. Although this was a detailed investigation of ADL, the data were collected from a single center and focused on a local population of patients with PD, which may limit the generalizability of the findings. In addition, the cross-sectional design precludes any causal inferences regarding the observed associations. Potential measurement bias should also be considered, as several variables were assessed using self-reported scales. Furthermore, important PD-related confounders, such as disease severity and treatment information, were not included in the analysis, which may have influenced the results. There may also be unmeasured variables, including physical activity, caregiver support, and comorbidities, that could affect the relationships observed in this study. Additionally, cultural and linguistic factors may have influenced participants' understanding and responses to the questionnaires. Finally, the absence of sensitivity analyses limits the robustness of our findings. Therefore, future studies with multicenter designs, longitudinal data, and more comprehensive variable control are warranted to validate and extend these results.

Conclusions

In this study, we explored the mechanisms underlying the association between cognitive function and ADL using conditional process modeling. Nutritional status was identified as a mediator in the relationship between cognitive function and ADL. Depression moderated the association between cognitive function and nutritional status, while QOL moderated the association between nutritional status and ADL. These findings highlight the importance of a multidimensional clinical approach. Routine screening for cognitive function, depressive symptoms, and nutritional status should be incorporated into clinical practice to identify patients at higher risk of functional decline. In particular, patients with elevated depressive symptoms or poor QOL may benefit from targeted interventions, such as psychological support, nutritional management, and cognitive rehabilitation. Such integrated and individualized strategies may help maintain functional independence and improve ADL outcomes in patients with PD.

Declarations

Ethics approval and consent to participate

The study adhered to the ethical standards set forth in the Declaration of Helsinki. Ethical approval for our study was also obtained from the Shanxi Medical University Ethics Committee, and informed consent was obtained from all participants.

Consent for publication

Written informed consent was obtained from all participants or their authorized representatives.

Competing interests

The authors declare no conflict of interest.

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Authors' contributions

H.-M.Y. and J.C. raised new questions and ideas regarding this article. J.C., Y.C. and J.-Q.Z. performed the research design, statistical analysis and wrote the manuscript. Y.Q., D.-R.C. and H.-Y.C. contributed to the collection of the data and revised the manuscript. All authors reviewed the manuscript.

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Availability of data and materials

All data generated or analysed during this study are included in this published article.

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Figures

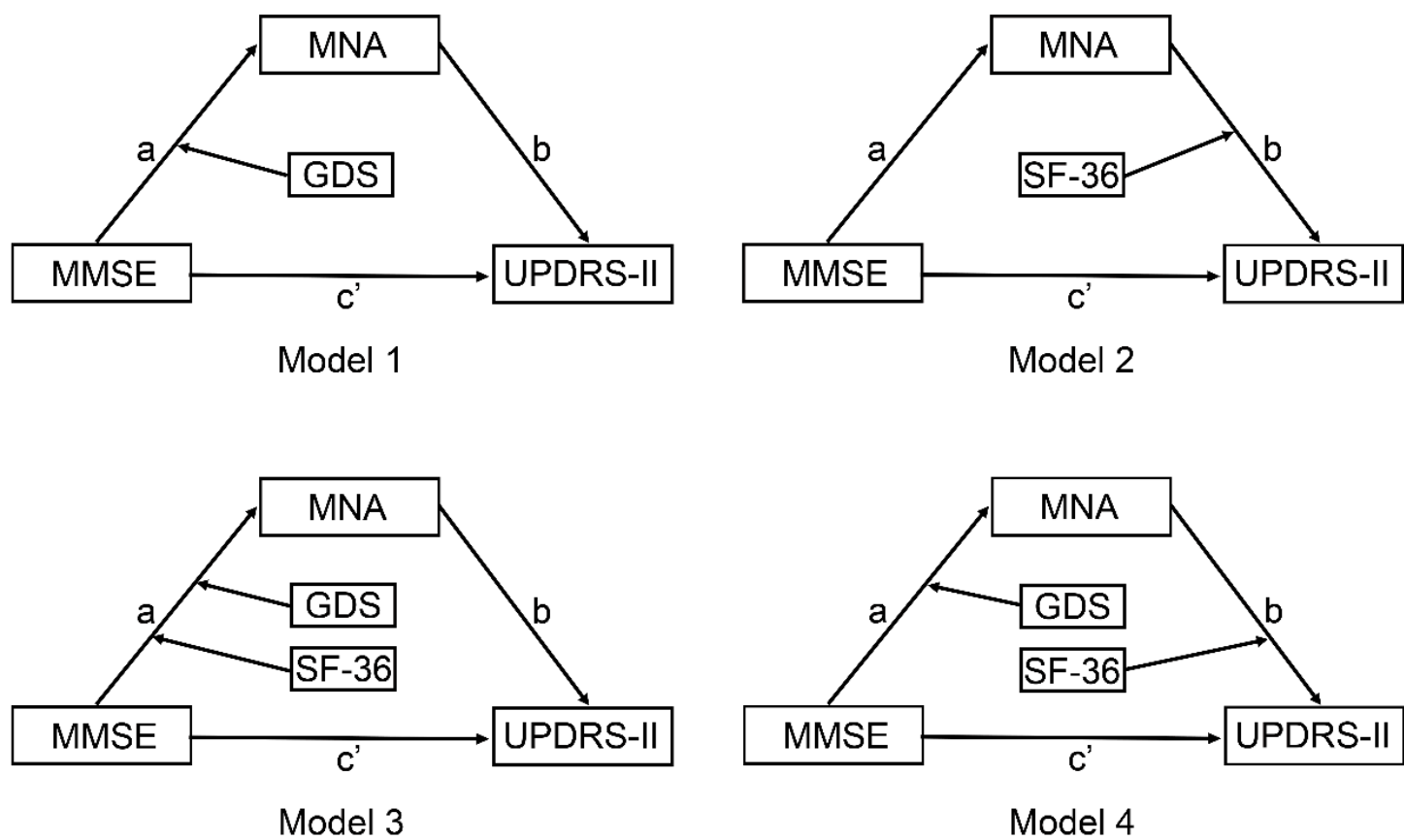


Figure 1

Conditional process model with depression score and quality of life score as moderator variables. MMSE: Mini-Mental State Examination, MNA: Mini Nutritional Assessment, UPDRS-II: Unified Parkinson's Disease Rating Scale-II, GDS: Geriatric Depression Scale, SF-36: MOS 36-item Short-Form Health Survey

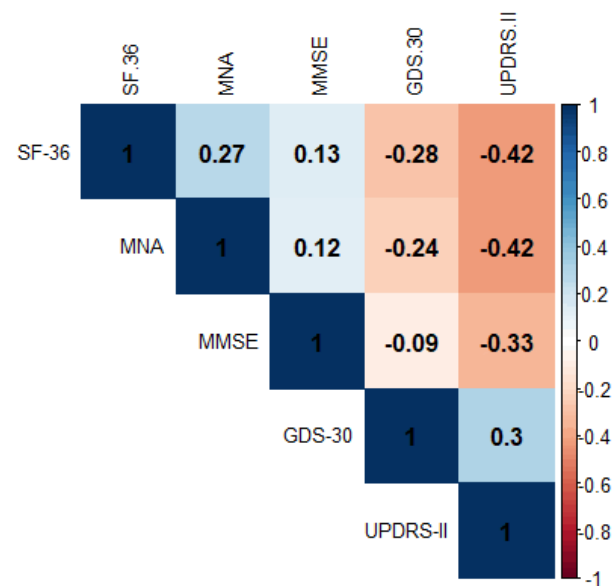


Figure 2

Correlations among the main variables. MMSE: Mini-Mental State Examination, MNA: Mini Nutritional Assessment, UPDRS-II: Unified Parkinson's Disease Rating Scale-II, GDS: Geriatric Depression Scale, SF-36: MOS 36-item Short-Form Health Survey

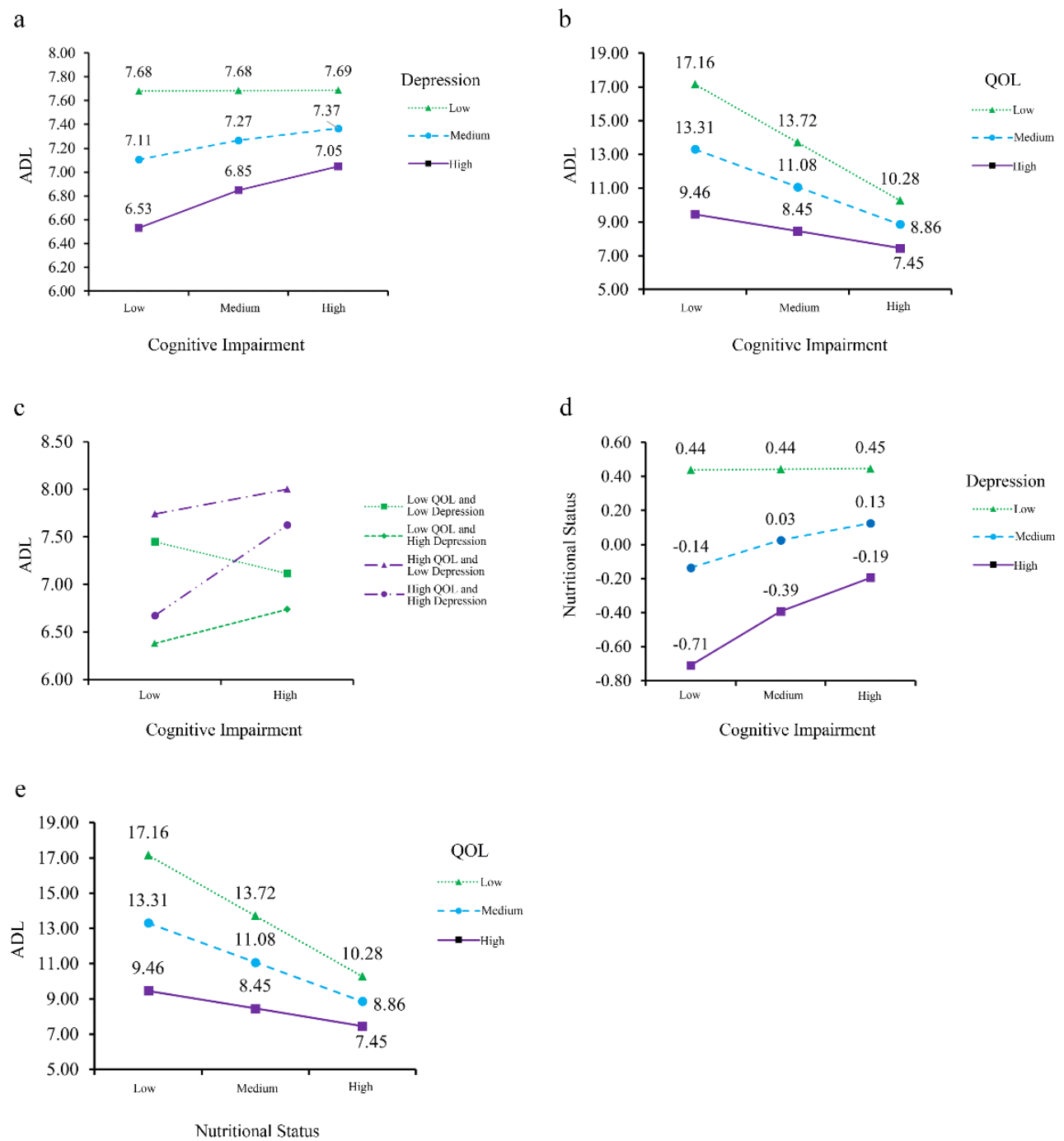


Figure 3

Moderating effects of depression and QOL on the associations among cognitive function, nutritional status, and ADL. (a) Diagram of the moderating effect of depressive state on the single path of ADL; (b) Diagram of the moderating effect of QOL on the single path of ADL; (c) Diagram of the moderating effects of depressive state and QOL on the single path of ADL: a two-factor model; (d) and (e) Diagram of the two-factor, two-path moderating effects of depressive state and QOL on ADL.