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Dual-Trajectory Analysis of Psychological Resilience and Frailty After Surgery in Older Patients With Osteoporotic Thoracolumbar Vertebral Compression Fractures

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Abstract

Objective

To characterize the longitudinal trajectories of psychological resilience and frailty after surgery in older patients with osteoporotic vertebral compression fractures (OVCFs), identify joint recovery patterns and their associated factors, and provide evidence for individualized rehabilitation care.

Methods

In this longitudinal observational study, psychological resilience and frailty were assessed at four time points (T1-T4) after surgery. A total of 280 patients were included in the analysis. Group-based trajectory modeling (GBTM) was used to identify trajectories of psychological resilience and frailty. Group-based dual trajectory modeling (GBDTM) was then applied to characterize joint recovery patterns, and multinomial logistic regression was used to identify associated factors.

Results

Psychological resilience generally increased during follow-up, whereas frailty decreased. GBTM identified four psychological resilience trajectories and three frailty trajectories. Their joint distribution yielded three recovery patterns: good recovery (32.1%), intermediate recovery (47.5%), and poor recovery (20.4%). Changes in psychological resilience and frailty differed significantly across the three patterns (all $P < 0.001$). Older age, female sex, a greater number of comorbidities, and non-use of anti-osteoporosis medications were associated with the poor-recovery pattern, whereas the ability to live independently was protective.

Conclusion

Postoperative trajectories of psychological resilience and frailty are heterogeneous among older patients with OVCFs and form distinct joint recovery patterns. Patients at risk of poor recovery should be identified early, and stratified rehabilitation nursing should be guided by dynamic changes in psychological resilience and frailty to promote long-term recovery.

1. Introduction

Osteoporotic vertebral compression fractures (OVCFs) are among the most common fragility fractures in older adults with osteoporosis [1]. With accelerated population aging, the incidence and disease burden of vertebral fractures among older adults in China are increasing [2]. Although current treatments can alleviate pain and improve functional status to some extent [3], some patients experience delayed recovery, impaired quality of life, and persistent rehabilitation needs. These findings suggest that

postoperative recovery is a dynamic process influenced by psychological status, functional capacity, and physiological reserve [4]. Psychological resilience is an important resource that enables patients to cope with disease-related stress and adapt positively and is closely related to rehabilitation behaviors and illness adaptation. Frailty reflects diminished physiological reserve and reduced resistance to stressors in older adults and is an important determinant of postoperative recovery and long-term prognosis. Thus, psychological resilience and frailty represent psychological adaptability and physical recovery capacity, respectively, and may jointly shape the postoperative rehabilitation process [5, 6]. Nevertheless, previous studies have generally examined psychological or functional changes separately and evaluated their individual associations with rehabilitation outcomes. The dynamic evolution of psychological resilience and frailty and their coordinated recovery patterns remain insufficiently understood [7, 8]. To address this gap, we used group-based trajectory modeling to identify longitudinal trajectories of psychological resilience and frailty and subsequently applied group-based dual trajectory modeling to characterize their joint recovery patterns and associated factors. The findings may inform individualized rehabilitation care and dynamic risk management for older patients with OVCFs.

2. Methods

2.1 Participants

Using convenience sampling, we recruited older patients with OVCFs who were admitted to the Department of Minimally Invasive Spine Surgery at Luoyang Orthopedic-Traumatological Hospital of Henan Province between January 2025 and February 2026.

The inclusion criteria were as follows:
1 aged ≥ 65 years;

2 osteoporosis diagnosed according to internationally recommended clinical criteria [];

3 an acute thoracolumbar vertebral compression fracture confirmed by magnetic resonance imaging or computed tomography;

4 treatment with percutaneous vertebroplasty (PVP) or percutaneous kyphoplasty (PKP);

5 clear consciousness, normal cognitive function, and adequate reading and verbal communication abilities; and

6 voluntary participation and provision of written informed consent.

The exclusion criteria were as follows:

1 pathological fractures caused by conditions such as metastatic tumors, spinal tuberculosis, or osteomyelitis;

2 severe physical illness (such as decompensated heart failure or end-stage renal disease) or a severe psychiatric disorder;

3 preoperative severe paralysis or other neurological deficits likely to affect rehabilitation; and

4 long-term use of antidepressants or potent sedatives within the preceding 3 months.

Withdrawal and attrition criteria were as follows:

1 withdrawal from the study;

2 loss to follow-up or death; and

3 missing data that could not be imputed.

The study was approved by the Medical Ethics Committee of Luoyang Orthopedic-Traumatological Hospital of Henan Province (approval no. 2023KYKT0045-01). All participants provided written informed consent before enrollment.All methods were performed in accordance with the relevant guidelines and regulations.

2.2 Measures

2.2.1 General Information Questionnaire

Data were collected on age, sex, educational attainment, place of residence, comorbidity burden, marital status, fracture level, surgical procedure, bone mineral density T-score, anesthesia type, ability to live independently, and use of anti-osteoporosis medications.

2.2.2 Psychological Resilience [10]

Psychological resilience was assessed using the Chinese version of the 25-item Connor-Davidson Resilience Scale (CD-RISC). The conventional Chinese version comprises three domains: tenacity, strength, and optimism. Items are rated on a 5-point scale, with higher total scores indicating greater psychological resilience. The Chinese version has demonstrated good reliability and validity in different populations, with a Cronbach's α of 0.89 .x

2.2.3 Frailty Assessment [11]

Frailty was assessed using the Chinese version of the Tilburg Frailty Indicator (TFI), which contains 15 items across physical, psychological, and social domains. Total scores range from 0 to 15, and a total score of ≥ 5 indicates frailty. The Chinese version of the TFI has demonstrated acceptable reliability and validity in older adults, with a Cronbach's α of 0.75 and a test–retest reliability coefficient of 0.76.

2.3 Data Collection

After consideration of clinical feasibility and expert discussion, data were collected at four time points: T1 (1–2 days before discharge), using paper questionnaires administered in the ward; T2 (1 month after surgery), through online or telephone follow-up; T3 (3 months after surgery), online or during an outpatient visit; and T4 (6 months after surgery), online or during an outpatient visit. All investigators received standardized training in questionnaire administration and follow-up procedures. During telephone follow-up, investigators read each item aloud and entered the participant's response. Paper questionnaires completed during outpatient visits were checked immediately for missing items.

2.4 Statistical Analysis

Statistical analyses were performed using R software. Continuous variables were compared using one-way analysis of variance, whereas categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. GBTM was used to identify trajectories of psychological resilience and frailty. Competing models with different numbers of trajectory classes were compared using the Akaike information criterion (AIC), Bayesian information criterion (BIC), entropy, average posterior probability (AvePP), class size, and clinical interpretability. The optimal model was selected based on lower AIC and BIC values, higher entropy, an AvePP > 0.70 for each trajectory class, a minimum class size of > 5% of the total sample, and clinically interpretable trajectory patterns [12]. GBDTM was subsequently used to characterize the joint longitudinal changes in psychological resilience and frailty.

2.5 Sample Size

This was an exploratory longitudinal trajectory study. The sample size was determined primarily according to the stability requirements of GBTM. Previous studies have shown that class identification in latent trajectory models is influenced by sample size, class proportions, and model complexity, and that fit indices can be used to compare competing class solutions [13]. Considering reporting recommendations for latent class analysis, previous research experience [14], and an anticipated attrition rate of approximately 20%, we planned to recruit at least 250 participants. Ultimately, 280 patients completed all four assessments and were included in the trajectory analyses.

2.6 Follow-up and Questionnaire Completion

Psychological resilience and frailty were assessed at T1, T2, T3, and T4. At these four time points, 315, 298, 288, and 284 questionnaires were returned, respectively; of these, 315, 294, 286, and 280 were considered valid.During follow-up, 35 participants did not complete all assessments: 12 could not be contacted because their telephone numbers had been discontinued or changed or because repeated contact attempts were unsuccessful; 7 patients or family members declined further participation; 6 were hospitalized for stroke or other serious cardiovascular or cerebrovascular events and were unable to complete telephone assessments; 5 died; and 5 were hospitalized for a new osteoporotic fracture. Thus, 280 patients completed all four assessments and were included in the trajectory analyses.

3. Results

3.1 Identification of Psychological Resilience and Frailty Trajectories

During follow-up, psychological resilience generally increased, with mean CD-RISC scores rising from 54.04 ± 15.01 at T1 to 76.77 ± 16.59 at T4. Linear mixed-effects modeling showed a significant effect of time on psychological resilience (F = 764.32, P < 0.001). Conversely, frailty generally decreased, with mean TFI scores declining from 7.38 ± 3.65 at T1 to 3.74 ± 2.23 at T4; the effect of time on frailty was also significant (F = 677.71, P < 0.001). However, substantial between-patient heterogeneity was observed in both outcomes, prompting further identification of distinct trajectory classes using GBTM.

The GBTM fit indices are presented in Table 1. For psychological resilience, the four-class solution provided the best fit (AIC = 7205.058, BIC = 7248.675, entropy = 0.861). The AvePP values for the four classes were 0.91, 0.98, 0.92, and 0.90; therefore, the four-class model was selected.

Table 1
Comparison of Fit Indices for Group-Based Trajectory Models

Variable	Number of class	AIC	BIC	Entropy	AvePP	Class proportion (%)
Psychological resilience	1	7936.014	7946.918	—	1.00	100.0%
Psychological resilience	2	7533.494	7555.302	0.804	0.94; 0.94	53.9%; 46.1%
Psychological resilience	3	7307.778	7340.492	0.869	0.94; 0.94; 0.96	48.6%; 38.2%; 13.2%
Psychological resilience	4	7205.058	7248.675	0.861	0.91; 0.98; 0.92; 0.90	14.3%; 37.5%; 30.4%; 17.9%
Frailty	1	5654.990	5665.900	—	1.00	100.0%
Frailty	2	4356.601	4378.410	0.840	0.962; 0.949	50.7%; 49.3%
Frailty	3	4098.137	4130.850	0.880	0.945; 0.956; 0.940	21.4%; 53.6%; 25.0%
Frailty	4	3987.501	4031.118	0.861	0.894; 0.932; 0.961; 0.932	33.2%; 16.1%; 15.7%; 35.0%
Frailty	5	3948.506	4003.028	0.855	0.873; 0.860; 0.939; 0.935; 0.882	32.5%; 6.4%; 30.7%; 15.4%; 15.0%

Table 1 note. Lower AIC and BIC values and higher entropy indicate better fit. AvePP >0.70 and class size >5% were considered acceptable. AIC, Akaike information criterion; AvePP, average posterior probability; BIC, Bayesian information criterion.

Based on their shapes, the four psychological resilience trajectories were labeled low resilience with slow improvement (R1), moderate resilience with rapid improvement (R2), moderately high resilience with improvement (R3), and high resilience with sustained improvement (R4) (Fig. 1).

Considering model fit, class proportions, and clinical interpretability, a three-class frailty model was selected (AIC = 4098.137, BIC = 4130.850, entropy = 0.880). The AvePP values were 0.945, 0.956, and 0.940. The trajectories were labeled persistently high frailty, moderate frailty with improvement, and stable low frailty (Fig. 2).

3.2 Joint Psychological Resilience-Frailty Recovery Patterns and Dynamic Validation

GBDTM was applied to the four psychological resilience trajectories and three frailty trajectories. Although 12 combinations were theoretically possible, six joint trajectory combinations were observed. Conditional and joint probabilities were calculated to characterize their joint longitudinal changes (Table 2). On the basis of the combined trajectory profiles, patients were classified into good, intermediate, and poor recovery patterns. The highest joint probability was observed for moderate resilience with rapid improvement combined with moderate frailty with improvement (30.36%), followed by moderately high resilience with improvement combined with moderate frailty with improvement (23.21%). High resilience with sustained improvement combined with stable low frailty accounted for 17.86%.

Linear mixed-effects models were used to validate differences in longitudinal change across the joint recovery patterns. Significant time-by-pattern interactions were observed for psychological resilience ($F = 22.351$, $P < 0.001$) and frailty ($F = 17.585$, $P < 0.001$), indicating that changes in both outcomes differed across the recovery patterns (Fig. 3).

Table 2
Conditional and Joint Probabilities of Psychological Resilience and Frailty Trajectory Classes (n = 280)

Psychological resilience trajectory	Frailty trajectory		
	Persistently high frailty	Moderate frailty with improvement	Stable low frailty
Conditional probability of resilience trajectory given frailty trajectory			
Low resilience with slow improvement	40 (66.67)	0 (0.00)	0 (0.00)
Moderate resilience with rapid improvement	20 (33.33)	85 (56.67)	0 (0.00)
Moderately high resilience with improvement	0 (0.00)	65 (43.33)	20 (28.57)
High resilience with sustained improvement	0 (0.00)	0 (0.00)	50 (71.43)
Conditional probability of frailty trajectory given resilience trajectory			
Low resilience with slow improvement	40 (100.00)	0 (0.00)	0 (0.00)
Moderate resilience with rapid improvement	20 (19.05)	85 (80.95)	0 (0.00)
Moderately high resilience with improvement	0 (0.00)	65 (76.47)	20 (23.53)
High resilience with sustained improvement	0 (0.00)	0 (0.00)	50 (100.00)
Joint probability of resilience and frailty trajectories			
Low resilience with slow improvement	40 (14.29)	0 (0.00)	0 (0.00)
Moderate resilience with rapid improvement	20 (7.14)	85 (30.36)	0 (0.00)
Moderately high resilience with improvement	0 (0.00)	65 (23.21)	20 (7.14)
High resilience with sustained improvement	0 (0.00)	0 (0.00)	50 (17.86)

Table 2 note. Values are n (%). The three sections show conditional probabilities by frailty class, conditional probabilities by resilience class, and joint probabilities, respectively.

3.3 Participant Characteristics and Baseline Comparisons

A total of 280 older patients who underwent surgery for osteoporotic thoracolumbar vertebral compression fractures completed all four assessments and were included in the longitudinal trajectory

analysis. According to the joint psychological resilience-frailty patterns, 90 patients (32.1%) were classified as having good recovery, 133 (47.5%) as having intermediate recovery, and 57 (20.4%) as having poor recovery. Baseline characteristics are compared in Table 3.

Table 3
Baseline Characteristics According to Joint Psychological Resilience-Frailty Recovery Pattern (n = 280)

Variable	Good recovery (n = 90)	Intermediate recovery(n = 133)	Poor recovery (n = 57)	χ^2/F	P
Age, years	73.36 ± 5.49	75.99 ± 6.64	78.89 ± 5.88	14.439	< 0.001
Bone mineral density T-score	-3.13 ± 0.34	-3.25 ± 0.44	-3.20 ± 0.38	2.398	0.093
No. of comorbidities	1.98 ± 1.38	3.06 ± 1.84	4.47 ± 1.91	36.798	< 0.001
Sex				7.046	0.030
Male	57 (63.3)	61 (45.9)	33 (57.9)		
Female	33 (36.7)	72 (54.1)	24 (42.1)		
Educational attainment				4.325	0.115
Junior high school or below	68 (75.6)	99 (74.4)	50 (87.7)		
Senior high school or above	22 (24.4)	34 (25.6)	7 (12.3)		
Place of residence				4.522	0.104
Urban	38 (42.2)	61 (45.9)	34 (59.6)		
Rural	52 (57.8)	72 (54.1)	23 (40.4)		
Marital status				1.309	0.860
Widowed	29 (32.2)	41 (30.8)	22 (38.6)		
Married	56 (62.2)	85 (63.9)	33 (57.9)		
Unmarried/divorced	5 (5.6)	7 (5.3)	2 (3.5)		
Fracture location				0.367	0.985
Thoracic	20 (22.2)	29 (21.8)	12 (21.1)		
Thoracolumbar	41 (45.6)	60 (45.1)	24 (42.1)		
Lumbar	29 (32.2)	44 (33.1)	21 (36.8)		
Surgical procedure				1.392	0.499
PVP	31 (34.4)	53 (39.8)	25 (43.9)		
PKP	59 (65.6)	80 (60.2)	32 (56.1)		

Variable	Good recovery (n = 90)	Intermediate recovery(n = 133)	Poor recovery (n = 57)	χ^2/F	P
Anesthesia type				1.965	0.374
Local infiltration anesthesia	60 (66.7)	100 (75.2)	40 (70.2)		
General anesthesia	30 (33.3)	33 (24.8)	17 (29.8)		
Ability to live independently				4.257	0.119
No	30 (33.3)	43 (32.3)	27 (47.4)		
Able to live independently	60 (66.7)	90 (67.7)	30 (52.6)		
Use of anti-osteoporosis medication				7.864	0.020
No	34 (37.8)	61 (45.9)	35 (61.4)		
Yes	56 (62.2)	72 (54.1)	22 (38.6)		

Table 3 note. Data are mean ± standard deviation or n (%). BMD, bone mineral density; PKP, percutaneous kyphoplasty; PVP, percutaneous vertebroplasty.

Age, sex, number of comorbidities, and anti-osteoporosis medication use differed significantly across the three joint recovery patterns ($P < 0.05$). Compared with patients in the good-recovery group, those in the poor-recovery group were older, had more comorbidities, were more likely to be female, and were less likely to use anti-osteoporosis medications. Educational attainment, place of residence, marital status, fracture location, surgical procedure, anesthesia type, bone mineral density, and ability to live independently did not differ significantly among the groups ($P > 0.05$).

3.4 Factors Associated With Joint Recovery Patterns

Using the good-recovery pattern as the reference category, multinomial logistic regression was performed to identify factors associated with joint recovery patterns. Variables with $P < 0.10$ in univariable analyses were entered into the multivariable model. The results are presented in Table 4 and Fig. 4.

Table 4
Multinomial Logistic Regression of Factors Associated With Joint Recovery Patterns

Variable	Intermediate vs good recovery OR (95% CI)	P value	Poor vs good recovery OR (95% CI)	P value
Age, years	1.07 (1.02–1.13)	0.006	1.15 (1.08–1.23)	< 0.001
Female sex	6.30 (2.39–16.62)	< 0.001	13.13 (3.19–53.99)	< 0.001
Senior high school or above	0.47 (0.19–1.17)	0.105	0.28 (0.08–1.02)	0.053
No. of comorbidities	1.49 (1.23–1.81)	< 0.001	2.19 (1.70–2.81)	< 0.001
Able to live independently	0.50 (0.22–1.14)	0.100	0.22 (0.06–0.78)	0.019
No anti-osteoporosis medication	1.47 (0.80–2.69)	0.218	2.29 (1.01–5.21)	0.048

Table 4 note. The good-recovery pattern was the reference outcome. CI, confidence interval; OR, odds ratio.

Age, sex, number of comorbidities, ability to live independently, and anti-osteoporosis medication use were associated with joint recovery patterns. Compared with the good-recovery pattern, the intermediate-recovery pattern was associated with older age (OR = 1.07, 95% CI 1.02–1.13; P = 0.006), female sex (OR = 6.30, 95% CI 2.39–16.62; P < 0.001), and a greater number of comorbidities (OR = 1.49, 95% CI 1.23–1.81; P < 0.001).

4. Discussion

4.1 Longitudinal Psychological Resilience Trajectories Reveal Heterogeneity in Psychological Recovery

This study found that postoperative psychological resilience among older patients with OVCFs did not follow a uniform pattern but exhibited substantial heterogeneity, with four distinct recovery trajectories identified. This finding is broadly consistent with the study by Shan et al. [7],who identified distinct psychological resilience trajectories among patients undergoing joint arthroplasty. Unlike previous studies that assessed psychological resilience at a single time point, the present study used group-based trajectory modeling (GBTM) to characterize dynamic variations in psychological recovery, suggesting that conventional analyses based on mean scores may overlook individual rehabilitation needs. Patients in the high-resilience sustained-improvement group may have had greater psychological self-regulation, better adaptation to illness, and stronger engagement in rehabilitation. Pain relief, functional recovery, and changes in illness perceptions may have jointly facilitated their positive

psychological adaptation. In contrast, patients in the low-resilience slow-improvement group may have been adversely affected by postoperative pain, activity limitations, and difficulties adapting to illness, indicating a greater need for psychological rehabilitation. Previous evidence also suggests that psychological resilience is a dynamic psychological resource that may change in response to illness experiences, functional recovery, and social support [15]. Therefore, postoperative psychological rehabilitation for older patients with OVCFs should focus on changes in recovery trajectories rather than relying solely on assessments conducted at a single time point. Nurses should identify psychological resilience trajectories through repeated assessments and provide stratified interventions to promote long-term psychological recovery.

4.2 Longitudinal Frailty Trajectories Reveal Heterogeneity in Physical Recovery

GBTM identified three postoperative frailty trajectories, demonstrating substantial individual variation in frailty recovery. This finding is consistent with the distinct frailty trajectories identified by Tchalla et al. in older adults [16]. Frailty gradually decreased in some patients, possibly because of better baseline function, greater physiological recovery capacity, and stronger adaptation to rehabilitation. By contrast, persistently high frailty may reflect advanced age, greater disease burden, and restricted mobility, all of which may constrain functional recovery. Previous evidence has also linked insufficient physical activity to frailty in older adults [17]. The gradual improvement observed in some patients suggests that frailty is potentially modifiable. Exercise, nutritional support, and comprehensive rehabilitation management may facilitate functional recovery [18]. Frailty management after OVCF surgery should therefore focus on longitudinal change rather than a single assessment. Trajectory-based risk stratification may help nurses deliver targeted rehabilitation to patients with inadequate functional recovery.

4.3 Joint Psychological Resilience-Frailty Patterns Reveal Coordinated Heterogeneity During Recovery

GBDTM showed that psychological resilience and frailty did not change independently after surgery; instead, they formed three distinct joint recovery patterns. This finding indicates coordinated heterogeneity between psychological adaptation and physical recovery in older patients with OVCFs. Compared with separate assessments of psychological or functional status, joint trajectory analysis provides a more comprehensive representation of how these domains align over time. Patients with good recovery showed greater improvement in resilience and a lower frailty burden, suggesting relatively coordinated psychological and physical recovery. In contrast, those with poor recovery exhibited insufficient improvement in resilience together with a high frailty burden, indicating that psychological and physical recovery may be impaired simultaneously. These patients should be prioritized in postoperative rehabilitation. Previous studies indicate that recovery in middle-aged and older populations is jointly related to psychological resilience, frailty, functional capacity, and disease burden [19, 20]. Accordingly, nursing practice should integrate longitudinal assessments of resilience and frailty to support risk stratification and individualized rehabilitation management.

4.4 Factors Associated With Joint Recovery Patterns and Implications for Precision Nursing

Age, sex, and number of comorbidities were associated with joint recovery patterns, whereas the ability to live independently and anti-osteoporosis medication use were primarily associated with the poor-recovery pattern. These findings are consistent with those reported by Scheyerer et al. [21] and indicate that postoperative recovery in older patients with OVCFs is jointly influenced by demographic characteristics, disease burden, and functional status. Older patients, women, and those with more comorbidities were more likely to exhibit a less favorable recovery pattern, possibly because of diminished physiological reserve, greater disease burden, and limited rehabilitation capacity. The ability to live independently was associated with a lower likelihood of poor recovery, suggesting that functional autonomy may be protective [22].In addition, adherence to anti-osteoporosis therapy may reduce the risks of subsequent fractures and adverse long-term outcomes after surgical treatment for OVCFs [23, 24].Nurses should prioritize older patients, women, those with multiple comorbidities, and those with limited functional independence. Early risk identification and stratified management should incorporate dynamic changes in psychological resilience and frailty, together with education and support for anti-osteoporosis treatment, to promote coordinated psychological and physical recovery.

5. Conclusions

Dual-trajectory analysis identified distinct postoperative trajectories of psychological resilience and frailty and three joint recovery patterns in older patients with OVCFs, demonstrating substantial individual variation in rehabilitation. The distinct profiles of resilience and frailty across these patterns may support postoperative risk identification and stratified nursing care. Because this was a single-center longitudinal observational study, the stability and clinical utility of the joint recovery patterns require validation in larger multicenter cohorts. Future studies should incorporate objective functional measures and long-term clinical outcomes to refine precision rehabilitation strategies.

Declarations

Author Contribution

 Qin Shengnan: Conceptualization, Data curation, Investigation, Writing – original draft.

 Hu Siying: Formal analysis, Visualization, Writing – review & editing.

 Zhangfan: Methodology, Software, Validation.

 Fu Ruihui: Resources, Project administration.

 Chenrui: Investigation, Data curation, Writing – review & editing.

 Guan Miaoyan: Validation, Supervision, Writing – review & editing.

 Liyang (corresponding author): Conceptualization, Supervision, Funding acquisition, Writing – review & editing.

 Xing Linbo (corresponding author): Conceptualization, Supervision, Methodology, Writing – review & editing.

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Data Availability

The authors confirm that the data supporting the findings of this study are available within the article.

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Figures

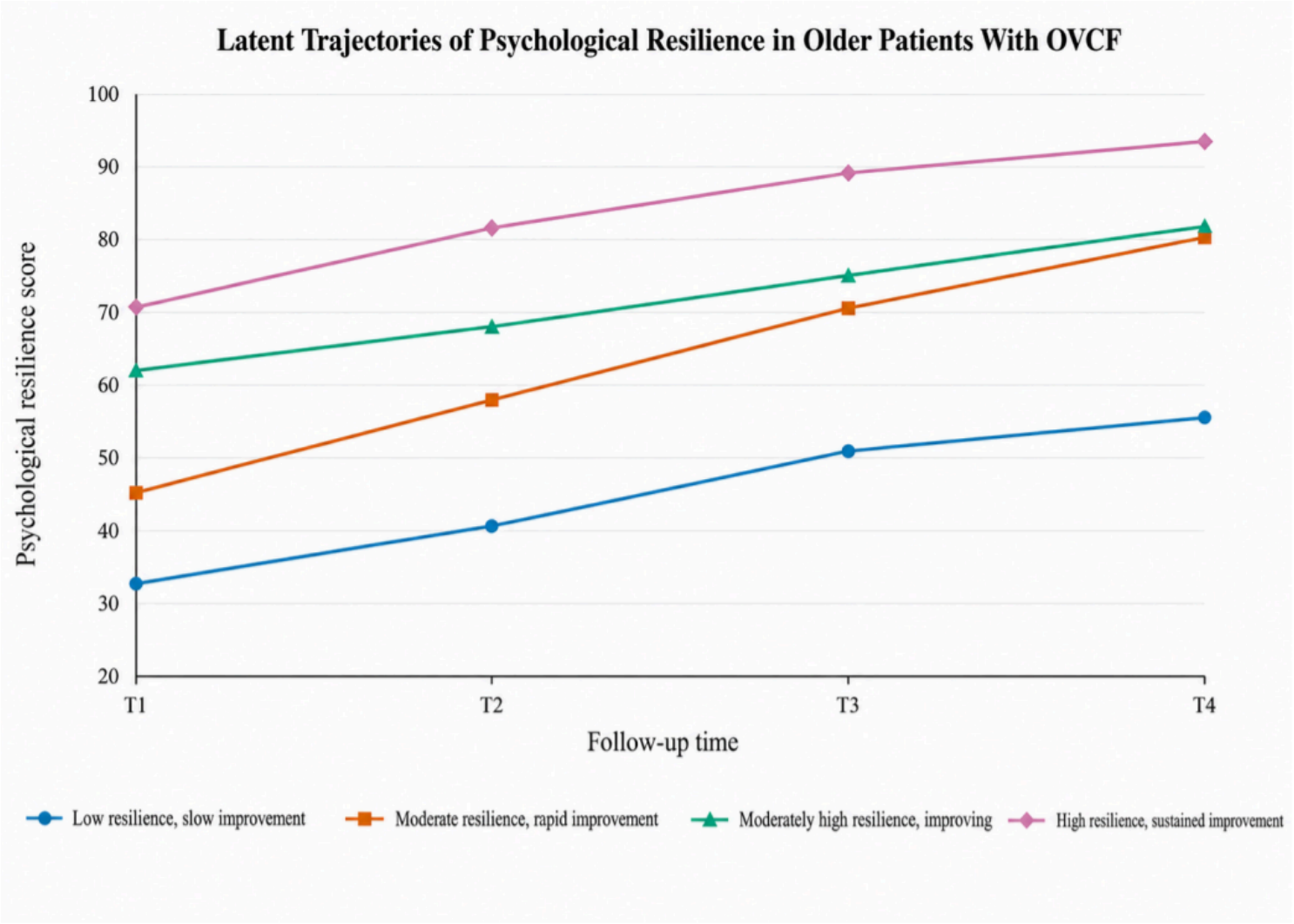


Figure 1

Latent trajectories of psychological resilience. Higher scores indicate greater resilience. T1, before discharge; T2, 1 month; T3, 3 months; T4, 6 months after surgery.

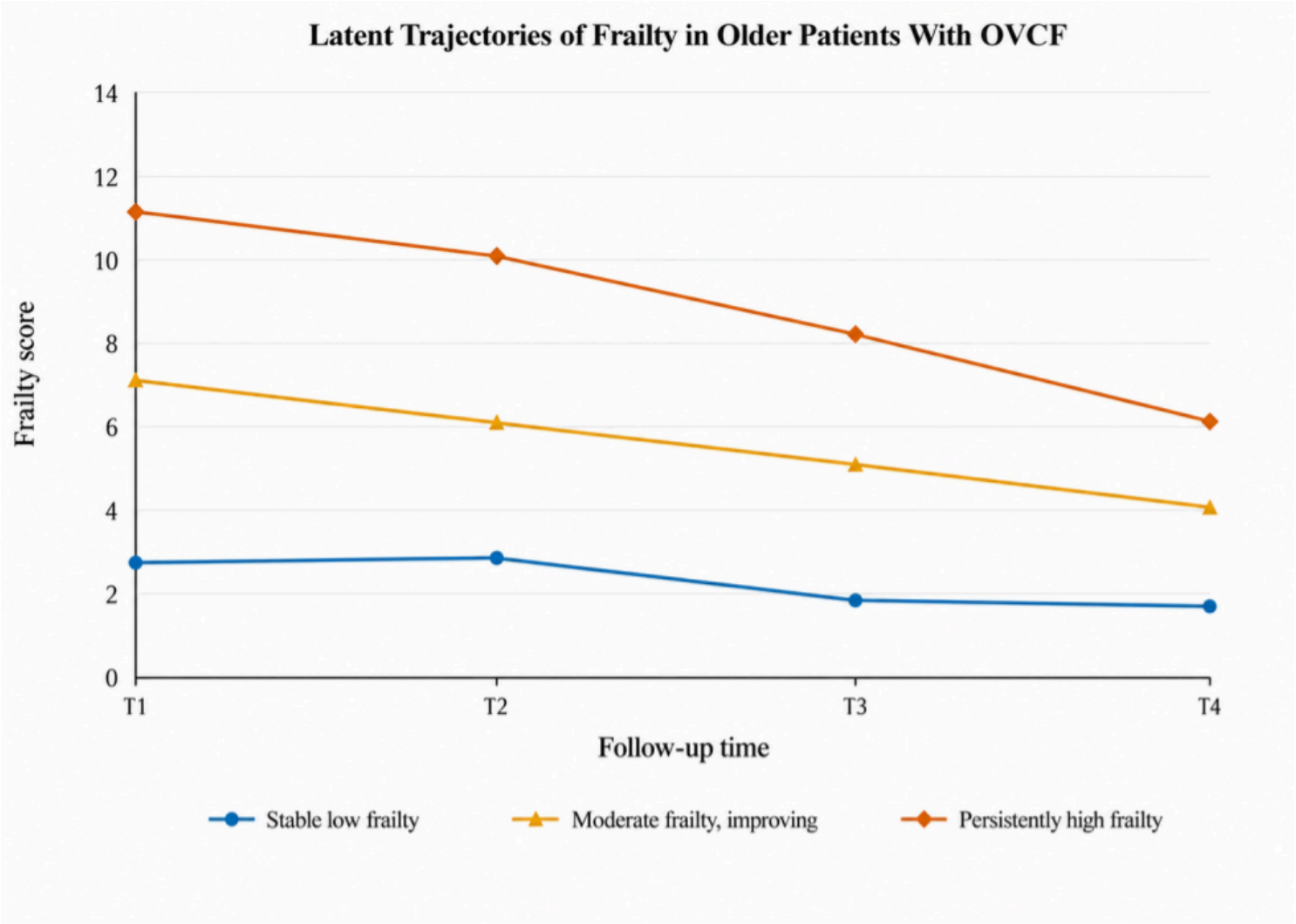


Figure 2

Latent trajectories of frailty. Higher scores indicate greater frailty. T1, before discharge; T2, 1 month; T3, 3 months; T4, 6 months after surgery.

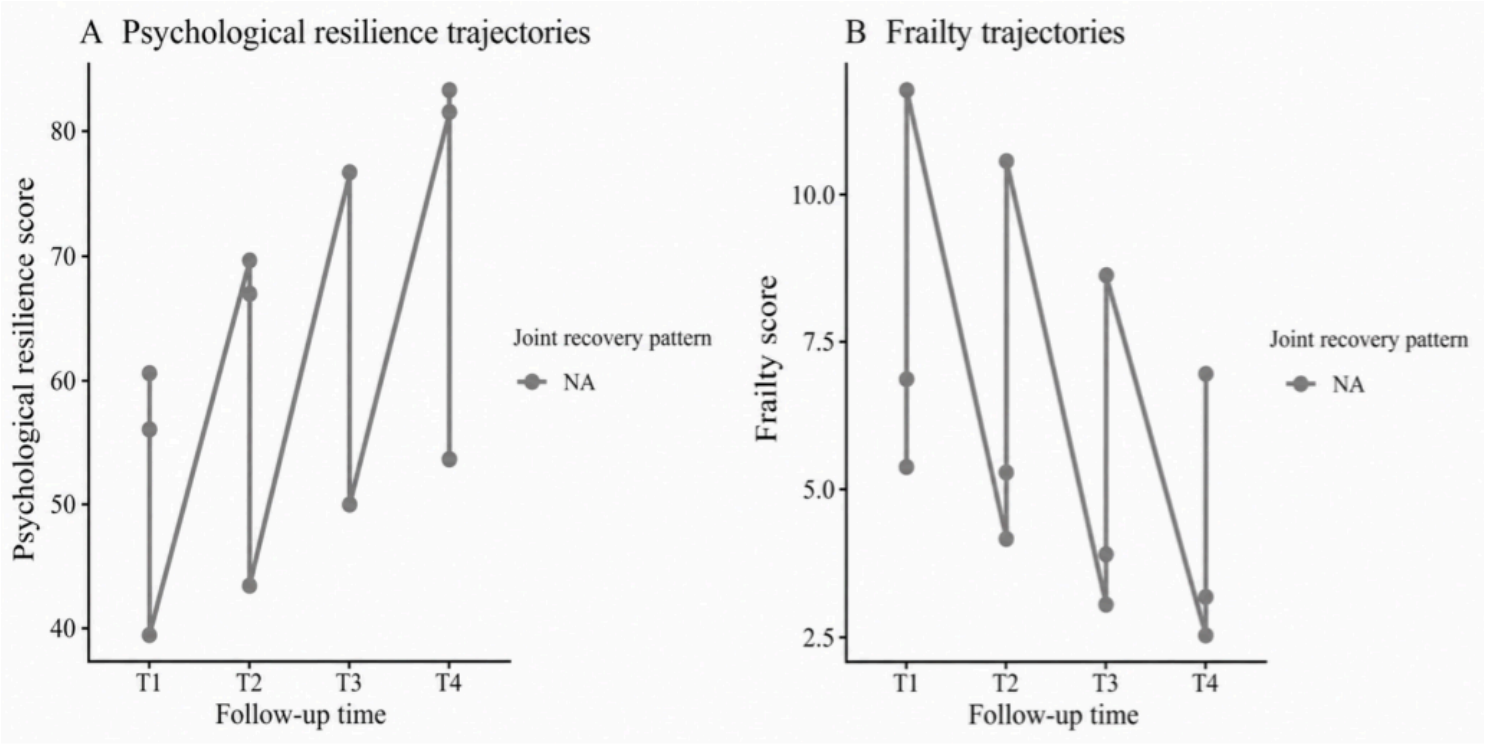


Figure 3

Psychological resilience (A) and frailty (B) trajectories across the good, intermediate, and poor recovery patterns.

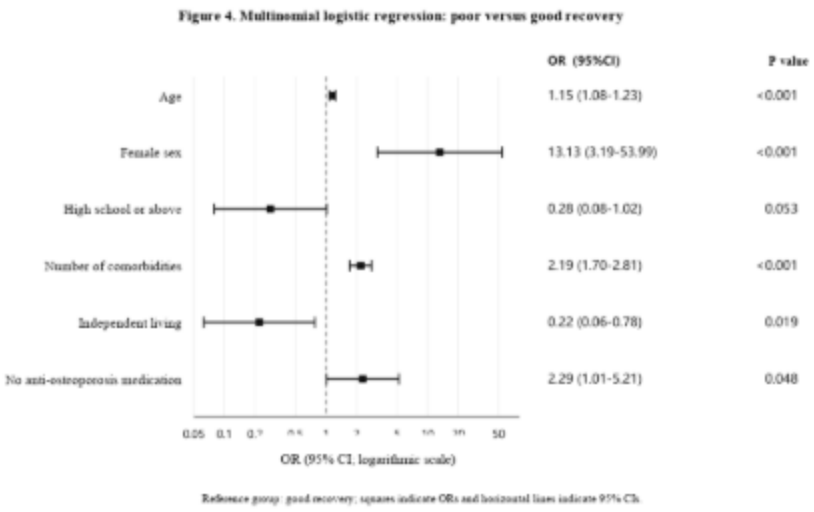


Figure 4

Forest plot comparing poor with good recovery. Squares indicate ORs, horizontal lines indicate 95% CIs, and the dashed line indicates OR=1