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# Development and validation of a nomogram for predicting cognitive frailty in patients on cancer

Hui Wang[1,2†], Yu Xia Wu[1†], Su Yun Dong[1], Yan Qian[1] and Hai Ou Yan[1,3*]

## Abstract

**Objective** To investigate the current status of cognitive frailty in older cancer patients and construct a risk prediction model for cognitive frailty in older cancer patients.

**Methods** Using convenience sampling, 308 older cancer patients from four wards in the oncology department of a grade-A tertiary hospital in Jiangsu Province from November 2023 to May 2024 were selected as the research subjects, including a training set of 215 cases (70%) and a validation set of 93 cases (30%). Data were collected through a general information questionnaire, Activities of Daily Living Scale, Mini-Nutritional Assessment Scale, Geriatric Depression Rating Scale, Pittsburgh Sleep Quality Index, Fried Frailty Scale, and Mini-Mental State Examination. A prediction model was established using Logistic regression, and a visual nomogram was constructed using R software. The model's discriminative ability and calibration were evaluated using the receiver operating characteristic (ROC) curve and calibration curve, respectively, and the clinical effectiveness was assessed using the clinical decision curve (DCA).

**Results** The incidence of cognitive frailty in older cancer patients was 26.7%. Logistic regression analysis revealed that education level, depression, sleep disorders, and malnutrition were influencing factors for cognitive frailty ($P<0.05$). The Hosmer-Leme-show test of the nomogram model showed $\chi^2=10.342$, $P=0.242$. The area under the ROC curve was 0.934, with a sensitivity and specificity of 81.1% and 94.1%, respectively.

**Conclusions** Older cancer patients are at risk of cognitive frailty. The risk prediction model constructed in this study can conveniently and accurately predict the risk of cognitive frailty in older cancer patients, providing an important reference for clinical medical staff to conduct early assessment, screening, and intervention.

**Keywords** Cancer, Elderly, Cognitive frailty, Influencing factors, Prediction model, Nomogram

## Introduction

Statistics indicate that by 2035, about 60% of new cancer cases worldwide will occur in people aged 65 or older, a disease closely related to aging [1]. According to a systematic review [2], 46% to 86% of older cancer patients are frail. During cancer treatment and radiotherapy/chemotherapy, cognitive dysfunction has become a significant yet often overlooked adverse reaction. Chemotherapy patients suffer from cognitive impairment at a rate between 16 and 70%, with 35% continuing to experience it years after treatment ends [3]. There is often

†Hui Wang and Yu-Xia Wu contributed equally to this work.

*Correspondence:
Hai Ou Yan
yho0704@163.com
[1] Department of Oncology, Affiliated Hospital of Nantong University, Nantong 226001, China
[2] Present Address: Department of Nursing, Nantong Stomatological Hospital, Nantong 226001, China
[3] Department of Nursing, Affiliated Hospital of Nantong University, Nantong 226001, China

a vicious cycle formed between frailty and cognitive impairment in older cancer patients [4].

Experts first proposed the concept of cognitive frailty (CF) in 2013, defining it as a decline in physical frailty and cognitive function without a diagnosis of Alzheimer's disease or other specific dementias [5]. Cognitive frailty can lead to a decrease in self-care ability, dementia, disability, and other adverse health outcomes [6].The development of cognitive frailty in older cancer patients is the result of a combination of multiple factors. Ho et al. [7]. found that lack of regular exercise, longer treatment completion time, overall health status, physical and social functioning, and fatigue symptoms contribute to cognitive frailty. Another study further indicated that age, education, nutritional status, diabetes, sarcopenia, and insomnia may also lead to cognitive frailty in cancer patients [8]. The development of cognitive frailty is reversible [9]. Therefore, strengthening the management of cognitive frailty in older cancer patients, early identification of risk factors for cognitive frailty, and the adoption of effective intervention measures are crucial for reducing the readmission rate of older cancer patients and preventing, delaying, or reversing the progression of frailty.

Currently, the focus of cognitive frailty research in our country focuses primarily on the elderly population, with insufficient attention to the high-incidence cancer group. Nomogram models are extensively utilized in clinical research to quantify indicators influencing outcomes, thereby creating predictive models for prognostic evaluation to aid clinical decision-making [10]. Consequently, this study explores the risk factors for cognitive frailty in older cancer patients, establishes a nomogram model, and provides a basis for early detection and prevention of cognitive frailty in older cancer patients.

## Methods

### Study population and design

From November 2023 to May 2024, 308 older cancer patients from four wards in the oncology department of a certain three-level A-grade affiliated hospital of Jiangsu Province were selected as the research subjects. Among them, 215 cases (70%) were trained, and 93 cases (30%) were validated. Inclusion criteria: ① Age ≥ 60 years; ② Pathologically confirmed malignant tumor; ③ In treatment phase, with a three-month treatment duration; ④ Physical condition allows participation in the survey. Exclusion criteria: ① Individuals with communication difficulties; ② Individuals with symptoms of dementia or severe mental illness. The study has been approved by the hospital's ethics committee (approval number: 2023-K141-01). Based on the sample size calculation method for logistic regression [11], the sample size should be at least 5 to 10 times the number of independent variables. Considering a 20% rate of invalid questionnaires, the required sample size for modeling is 138 to 276 cases.

### Data collection

#### *Research instrument*

*General situation questionnaire* After reviewing the literature, researchers developed the following general information survey questionnaire: (1) Demographic information: gender, age, education, economic status, insurance type, residence, smoking history, etc.; (2) Disease-related information: type of tumor, stage, duration of illness, polypharmacy, comorbidities, etc.

*Activities of daily living scale* The Activities of Daily Living (ADL) scale was developed by Lawton et al. [12] as a tool to assess an individual's ability to care for themselves in daily life. The scale consists of two parts: physical and instrumental ADL, with a total of 14 items. Each item is scored using a Likert 4-point scale (1 to 4 points). The total score ranges from 0 to 56 points. A total score of ≤ 14 points indicates normal ADL, 15 to 21 points indicates mild impairment in ADL, and a total score of ≥ 22 points indicates severe impairment. A higher score indicates a more severe degree of impairment. The Cronbach's alpha coefficient for this scale is 0.894.

*Mini nutrition assessment-shortform scale* The mini nutrition assessment-shortform (MNA-SF) was developed by Rubenstein et al. [13] and is used to screen for the risk of malnutrition in the elderly. It consists of 6 items: Body Mass Index (BMI), weight loss, acute disease or stress, physical activity, mental state, and appetite. The total score ranges from 0 to 14 points, with a lower score indicating a poorer nutritional status. A total score of less than 11 points is indicative of malnutrition. The Cronbach's alpha coefficient for this scale is 0.711.

*Geriatric depression scale* The Geriatric Depression Scale-15 (GDS-15) was revised by Sheikhnj et al. [14] based on the original version and is used to assess depressive symptoms and psychological status in the elderly over the past week. It consists of 15 items, mainly related to mood, interest, weight, sleep, fatigue, feelings of guilt, and suicidal tendencies. The total score ranges from 0 to 15 points, with a higher score indicating a higher degree of depression. A total score of 5 or more is indicative of a depressive state. The Cronbach's alpha coefficient for this scale is 0.793.

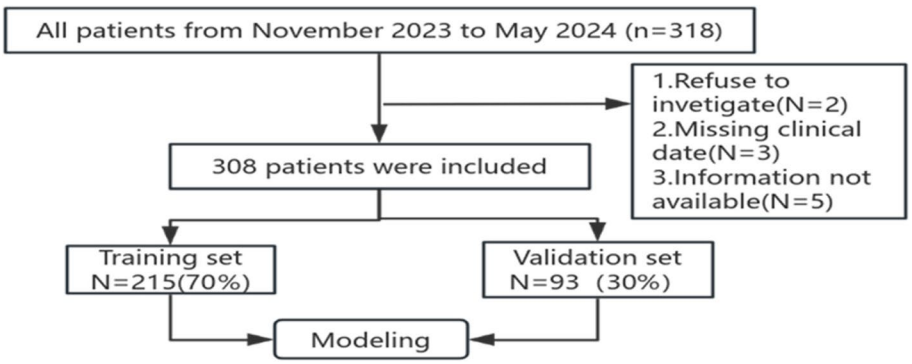


**Fig. 1** Flowchart of research participant recruitment

*Pittsburgh sleep quality index* The Pittsburgh Sleep Quality Index (PSQI) was developed by Buysse et al. [15] and is primarily used to assess the sleep quality of patients over the past month. The scale includes seven dimensions such as sleep quality and sleep latency, with a total of 18 items. The total score ranges from 0 to 21 points, with a higher score indicating poorer sleep quality. The Cronbach's alpha coefficient for this scale is 0.843.

*Cognitive frailty assessment* In this study, cognitive frailty is defined as a condition where the participant's Fried Frailty Scale (FP) score is in the frail (≥3 points) or pre-frail (1–2 points) range, accompanied by cognitive dysfunction (MMSE≤26 points), while excluding Alzheimer's disease or other types of dementia [16]. The FP scale was developed by Fried et al. [14] and includes five aspects: weight loss, self-reported fatigue, reduced physical activity, slowed walking speed, and decreased grip strength. The total score ranges from 0 to 5 points, with less than 1 point indicating no frailty, 1–2 points indicating pre-frailty, and≥3 points indicating frailty. The Mini-mental state examination (MMSE) scale, developed by Folstein et al. [17]. The Chinese version was translated and cross-culturally adapted by Li Ge in 1988 for the assessment of urban elderly residents [18], is used to assess cognitive function. The MMSE scale evaluates cognitive status through five sections: recall, orientation, attention and calculation, language ability, and memory. The total score ranges from 0 to 30 points, with a total score of≤26 points indicating the presence of cognitive dysfunction.

### Research methods

Researchers were trained on the standard use of research tools before conducting the study. Participants signed the informed consent form, completed the questionnaire individually, and submitted it immediately. When participants were unable to complete the questionnaire on their own, the researchers assisted them by asking questions. After collecting the questionnaires, they were immediately checked for any omissions, which were corrected on the spot. In this study, 318 questionnaires were distributed, of which 308 were valid, resulting in a 96.9% effective recovery rate.

### Statistical analysis

Data analysis and graphing were conducted using SPSS 26.0 and R software. In this study, after normality testing, the quantitative data did not meet the normal distribution and were represented by M (Q1, Q3), with intergroup comparisons using the Mann–Whitney U test; qualitative data were presented as frequency and percentage (%) and compared between groups using the χ^2 test. Logistic regression was used to construct the cognitive frailty prediction model and to draw the nomogram, with internal validation performed using the validation set data. The area under the receiver operating characteristic (ROC) curve (AUC) was used to evaluate the model's discriminative ability; the Hosmer-Lemeshow test and calibration curve were used to evaluate the model's goodness of fit; and the decision curve analysis (DCA) was used to evaluate the clinical benefit of the model. The significance level was set at $\alpha = 0.05$.

## Results

### Participant characteristics

The enrollment process for the research participants, involving 308 patients in this study, is depicted in Fig. 1. There were 207 males and 101 females; 82 cases of cognitive frailty and 226 cases of non-cognitive frailty, with a detection rate of cognitive frailty of 26.7%.

### Prevalence of frailty and related variables

In the modeling group, univariate analysis revealed that education level, place of residence, disease stage,

comorbidities, malnutrition, depression, sleep disorders, and ADL were significant influencing factors ($P<0.05$). See Table 1.

#### Logistic regression of patients with cancer

Logistic regression analysis was conducted using cognitive frailty (no = 0, yes = 1) as the dependent variable and variables with statistical significance in the univariate analysis as independent variables. Table 2 outlines the assignment method. The study identifies education level, depression, sleep disorders, and malnutrition as significant factors influencing cognitive frailty in older cancer patients (all $P<0.05$). The results are shown in Table 3.

#### Model development

The logistic regression results were used to construct a nomogram prediction model for cognitive frailty in older cancer patients (Fig. 2). In practical application, healthcare professionals first locate the corresponding scores for each predictive indicator on the first row (Points) of the nomogram based on the patient's specific conditions. Then, they sum the scores and draw a vertical line intersecting the last row of the nomogram from the marked total score (Total Points). At this intersection point, the value represents the patient's cognitive frailty risk probability.

#### Validation and evaluation of the predictive model

The prediction model achieved an AUC of 0.934 (95% CI: 0.896 to 0.971) in the training set, with an optimal cut-off value of 0.148, a specificity of 0.941, and a sensitivity of 0.811; in the validation set, the AUC was 0.971 (95% CI: 0.942 to 1.000), with an optimal cut-off value of 0.148, a specificity of 1.000, and a sensitivity of 0.758, all demonstrating good predictive performance, as shown in Fig. 3. The Hosmer-Leme-show test yielded a χ^2 value of 10.342 and a *P*-value of 0.242; in the validation set, the Hosmer-Leme-show test resulted in a χ^2 value of 4.507 and a *P*-value of 0.809, indicating that the model's fit is good, as shown in Fig. 4. From the clinical decision curve, when the model's threshold is set between 10 and 95%, the model's decision curve is superior to the None and All lines, suggesting that the model has a high level of net benefit and clinical predictive value, as shown in Fig. 5.

## Discussion

#### Elevated cognitive frailty risk in older cancer patients

The study found that 26.7% of older cancer patients had cognitive frailty, which is higher than Ho MH et al. [7] (8.2%). Examining the underlying causes, cancer patients are susceptible to frailty due to the intricate effects of the cancer and the extensive treatments involved, including surgery and chemotherapy, which deplete physiological reserves [19]. Factors such as neurotoxicity, neuroinflammatory reactions, DNA damage from chemotherapeutic agents that penetrate the blood–brain barrier, and host-specific elements like genetic predisposition can contribute to additional cognitive decline [20]. This cognitive decline, in turn, can precipitate the onset of cognitive frailty. Additionally, cancer patients and their families often prioritize the tumor and its treatment efficacy, frequently overlooking cognitive care, which exacerbates cognitive issues in patients. Therefore, medical staff should be aware of the risk of cognitive frailty among older cancer patients, screen and identify high-risk groups early on, and implement effective intervention measures in a timely manner to prevent or delay the occurrence and progression of cognitive frailty.

#### Analysis of cognitive frailty risk factors

The study finds that a low education level, elementary school or below, is a risk factor for cognitive frailty in older cancer patients ($P<0.05$), aligning with Bai et al. [21]. Zahodne et al.'s research has similarly found that higher levels of education are associated with enhanced cognitive abilities and a slower decline in cognitive function [22]. Typically, patients with less education have a limited cognitive reserve, reducing their ability to adapt cognitively to cancer. The reduced mental stimulation may reduce the activity of brain cells, reducing brain synapse and neuron density, accelerating brain aging, and causing cognitive impairment [23]. As well, these patients often lack health literacy and access to health information and resources, which can impede their understanding and adherence to treatment [24], resulting in poorer outcomes. Hence, medical staff should provide clear health education to older cancer patients during hospitalization to ensure they understand their condition and follow treatment advice, helping to manage disease progression and potentially reduce cognitive frailty risk.

Current research has shown that comorbidities are associated with a higher risk of cognitive frailty [25]. When cancer patients are afflicted with multiple diseases simultaneously, their multi-organ functions are in a state of long-term depletion, leading to an imbalance in the body's homeostasis, weakening the patient's ability to resist external stress, and increasing the risk of cognitive function frailty [26]. Additionally, studies have found that advanced cancer stages (III-IV) are linked to higher frailty rates [27], likely due to tumor progression, increased chemotherapy, and its neurotoxic effects crossing the blood–brain barrier. Medical staff should promptly screen for frailty and cognitive issues in patients with varying tumor stages and implement early interventions to lower cognitive frailty incidence.

**Table 1** Univariate analysis of cognitive frailty in older cancer patients

| Variables | Total ($n=215$) | Non-CF ($n=164$) | CF ($n=51$) | Statistic | *P* |
|---|---|---|---|---|---|
| Disease duration, M ($Q_1$, $Q_3$) | 2.00 (2.00, 4.00) | 2.00 (2.00, 4.00) | 2.00 (2.00, 4.00) | $Z=-1.003$ | 0.316 |
| Gender, n (%) | | | | $\chi^2=0.416$ | 0.519 |
| Male | 147 (68.37) | 114 (69.51) | 33 (64.71) | | |
| Female | 68 (31.63) | 50 (30.49) | 18 (35.29) | | |
| Education, n (%) | | | | $\chi^2=18.317$ | < 0.001 |
| Primary school and below | 127 (59.07) | 110 (67.07) | 17 (33.33) | | |
| Junior high school and above | 88 (40.93) | 54 (32.93) | 34 (66.67) | | |
| Marital status n (%) | | | | $\chi^2=0.068$ | 0.795 |
| Single | 21 (9.77) | 17 (10.37) | 4 (7.84) | | |
| Cohabitation | 194 (90.23) | 147 (89.63) | 47 (92.16) | | |
| Type of medical insurance, n (%) | | | | $\chi^2=0.378$ | 0.828 |
| Medical insurance | 111 (51.63) | 83 (50.61) | 28 (54.90) | | |
| Rural medical insurance | 29 (13.49) | 22 (13.41) | 7 (13.73) | | |
| Self-payment | 75 (34.88) | 59 (35.98) | 16 (31.37) | | |
| Residence, n (%) | | | | $\chi^2=4.863$ | 0.027 |
| Urban | 66 (30.70) | 44 (26.83) | 22 (43.14) | | |
| Rural | 149 (69.30) | 120 (73.17) | 29 (56.86) | | |
| Cancer site, n (%) | | | | $\chi^2=2.502$ | 0.644 |
| Upper GI | 55 (25.58) | 40 (24.39) | 15 (29.41) | | |
| Lower GI | 46 (21.40) | 33 (20.12) | 13 (25.49) | | |
| Liver | 22 (10.23) | 16 (9.76) | 6 (11.76) | | |
| Other | 51 (23.72) | 42 (25.61) | 9 (17.65) | | |
| Breast | 41 (19.07) | 33 (20.12) | 8 (15.69) | | |
| Tumor metastasis, n (%) | | | | $\chi^2=2.555$ | 0.110 |
| No | 122 (56.74) | 98 (59.76) | 24 (47.06) | | |
| Yes | 93 (43.26) | 66 (40.24) | 27 (52.94) | | |
| Cancer stage, n (%) | | | | $\chi^2=6.869$ | 0.009 |
| I-II | 75 (34.88) | 65 (39.63) | 10 (19.61) | | |
| III-IV | 140 (65.12) | 99 (60.37) | 41 (80.39) | | |
| Treatment modality, n (%) | | | | $\chi^2=4.597$ | 0.331 |
| Immunity | 93 (43.26) | 74 (45.12) | 19 (37.25) | | |
| Targeted therapy | 22 (10.23) | 16 (9.76) | 6 (11.76) | | |
| Chemotherapy | 62 (28.84) | 48 (29.27) | 14 (27.45) | | |
| Chemoradiotherapy | 28 (13.02) | 21 (12.80) | 7 (13.73) | | |
| Other | 10 (4.65) | 5 (3.05) | 5 (9.80) | | |
| Comorbidity, n (%) | | | | $\chi^2=4.579$ | 0.032 |
| No | 104 (48.37) | 86 (52.44) | 18 (35.29) | | |
| Yes | 111 (51.63) | 78 (47.56) | 33 (64.71) | | |
| Age(years), n (%) | | | | $\chi^2=2.997$ | 0.223 |
| 60–70 | 89 (41.40) | 67 (40.85) | 22 (43.14) | | |
| 70–80 | 86 (40.00) | 70 (42.68) | 16 (31.37) | | |
| > 80 | 40 (18.60) | 27 (16.46) | 13 (25.49) | | |
| Polypharmacy, n (%) | | | | $\chi^2=3.428$ | 0.064 |
| No | 200 (93.02) | 156 (95.12) | 44 (86.27) | | |
| Yes | 15 (6.98) | 8 (4.88) | 7 (13.73) | | |
| ADL, n (%) | | | | $\chi^2=30.970$ | < 0.001 |
| Normal | 87 (40.47) | 81 (49.39) | 6 (11.76) | | |
| Minor impairment | 65 (30.23) | 49 (29.88) | 16 (31.37) | | |
| Severe impairment | 63 (29.30) | 34 (20.73) | 29 (56.86) | | |

**Table 1** (continued)

| Variables | Total (*n* = 215) | Non-CF (*n* = 164) | CF (*n* = 51) | Statistic | *P* |
|---|---|---|---|---|---|
| Fatigue, n (%) | | | | $\chi^2 = 0.799$ | 0.371 |
| No | 96 (44.65) | 76 (46.34) | 20 (39.22) | | |
| Yes | 119 (55.35) | 88 (53.66) | 31 (60.78) | | |
| Depression, n (%) | | | | $\chi^2 = 11.106$ | < 0.001 |
| No | 85 (39.53) | 75 (45.73) | 10 (19.61) | | |
| Yes | 130 (60.47) | 89 (54.27) | 41 (80.39) | | |
| Smoking, n (%) | | | | $\chi^2 = 1.810$ | 0.179 |
| No | 127 (59.07) | 101 (61.59) | 26 (50.98) | | |
| Yes | 88 (40.93) | 63 (38.41) | 25 (49.02) | | |
| Drinking alcohol, n (%) | | | | $\chi^2 = 1.026$ | 0.311 |
| No | 89 (41.40) | 71 (43.29) | 18 (35.29) | | |
| Yes | 126 (58.60) | 93 (56.71) | 33 (64.71) | | |
| Monthly family income (RMB), n (%) | | | | $\chi^2 = 0.458$ | 0.795 |
| < 3000 | 75 (34.88) | 58 (35.37) | 17 (33.33) | | |
| 3000–5000 | 110 (51.16) | 82 (50.00) | 28 (54.90) | | |
| > 5000 | 30 (13.95) | 24 (14.63) | 6 (11.76) | | |
| Malnutrition, n (%) | | | | $\chi^2 = 40.546$ | < 0.001 |
| No | 109 (50.70) | 103 (62.80) | 6 (11.76) | | |
| Yes | 106 (49.30) | 61 (37.20) | 45 (88.24) | | |
| Sleep Disorder, n (%) | | | | $\chi^2 = 35.539$ | < 0.001 |
| No | 120 (55.81) | 110 (67.07) | 10 (19.61) | | |
| Yes | 95 (44.19) | 54 (32.93) | 41 (80.39) | | |

**Table 2** Assignment methods for independent variables

| Variables | Assignment |
|---|---|
| Education | Junior high school and above = 1; Primary school and below = 2 |
| Cancer stage | III-IV = 1; I-II = 0 |
| Comorbidity | Yes; No = 0 |
| ADL | Severe impairment = 2; Minor impairment = 1; Normal = 0 |
| Depression | Yes = 1; No = 0 |
| Malnutrition | Yes = 1; No = 0 |
| Sleep Disorder | Yes = 1; No = 0 |

The results of this study indicate that impairment in ADL increases the risk of cognitive frailty in older cancer patients. A previous cross-sectional study has uncovered the association between functional impairment and both frailty and cognitive function, further confirming that the ADL score is an indicator for predicting cognitive frailty [28]. The possible reason is that as people age, they generally face a natural decline in muscle strength, balance, and coordination, which directly affects the elderly's ability to care for themselves in daily life. The side effects of cancer and its treatment, such as fatigue and decreased immunity, further exacerbate the functional impairment and activity restrictions in older cancer patients. These conditions not only reduce the effective activity and necessary cognitive stimulation of the brain but also have a negative impact on cognitive function [29]. Therefore, nursing staff should encourage patients to engage in daily exercises within their capabilities, explore new things, and actively participate in social activities to delay the decline of physical functions and the progression of cognitive frailty.

The results of this study indicate that malnutrition is associated with cognitive frailty in older cancer patients ($P < 0.05$), which is consistent with Kocyigit's findings [30]. Previous research has indicated that inadequate protein consumption is among the nutritional factors contributing to frailty, and a lack of energy and protein nutrition in elderly individuals is linked to impaired cognitive function [31]. Cancer-related malnutrition, often due to decreased intake and increased energy needs, not only leads to muscle loss and weakness, raising the risk of frailty [32], but also impairs brain neuron renewal and neurotransmitter balance, contributing

**Table 3** Logistic regression analysis of cognitive frailty in older cancer patients predictive model development

| Variables | | *SE* | *Wald χ2* | *P* | *OR* (95%CI) |
|---|---|---|---|---|---|
| Constant | | 1.086 | −6.181 | < 0.001 | 0.001 (0.000 ~ 0.010) |
| Education | | | | | |
| | Junior high school and above[a] | | | | |
| | Primary school and below | 0.538 | 3.932 | < 0.001 | 8.284 (2.888 ~ 23.765) |
| Cancer stage | | | | | |
| | I-II[a] | | | | |
| | III-IV | 0.576 | 1.563 | 0.118 | 2.462 (0.796 ~ 7.620) |
| Comorbidity | | | | | |
| | No[a] | | | | |
| | Yes | 0.524 | 1.635 | 0.102 | 2.357 (0.843 ~ 6.590) |
| ADL | | | | | |
| | Minor impairment[a] | | | | |
| | Normal | 0.682 | −1.912 | 0.056 | 0.271 (0.071 ~ 1.034) |
| | Severe impairment | 0.587 | 1.853 | 0.064 | 2.969 (0.939 ~ 9.386) |
| Depression | | | | | |
| | No[a] | | | | |
| | Yes | 0.568 | 2.256 | 0.024 | 3.598 (1.183 ~ 10.945) |
| Sleep Disorder | | | | | |
| | No[a] | | | | |
| | Yes | 0.528 | 3.289 | 0.001 | 5.679 (2.017 ~ 15.986) |
| Malnutrition | | | | | |
| | No[a] | | | | |
| | Yes | 0.611 | 4.012 | < 0.001 | 11.589 (3.501 ~ 38.360) |

[a] indicates the control group

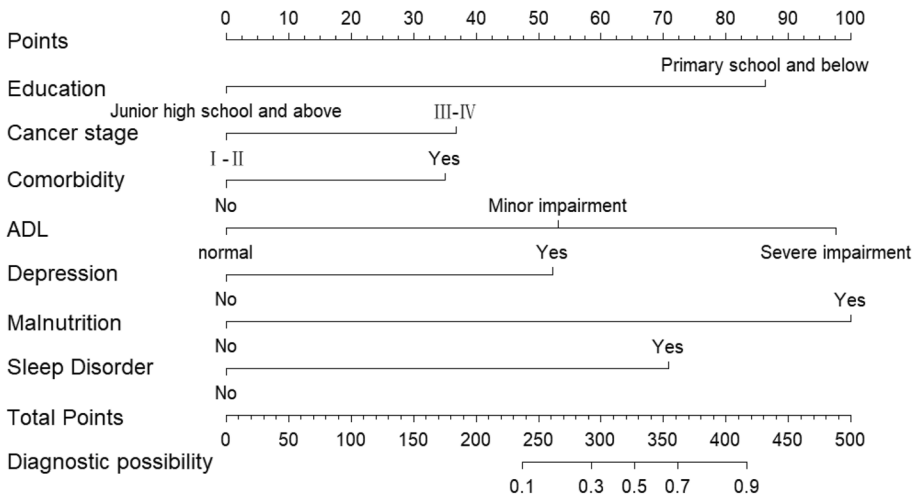


**Fig. 2** Nomogram for predicting cognitive frailty risk in older cancer patients

to cognitive decline [33]. Appropriate nutritional support is vital for enhancing cognitive function in these patients. Guidelines suggest a protein intake of 1.2 to 1.5 g/(kg/d) for frail elderly patients, with each meal containing 20 to 40 g of protein to stimulate muscle protein synthesis [34]. However, due to individual variations, these recommendations may not suit all patients. Healthcare providers should evaluate the nutritional status of older cancer patients early on and,

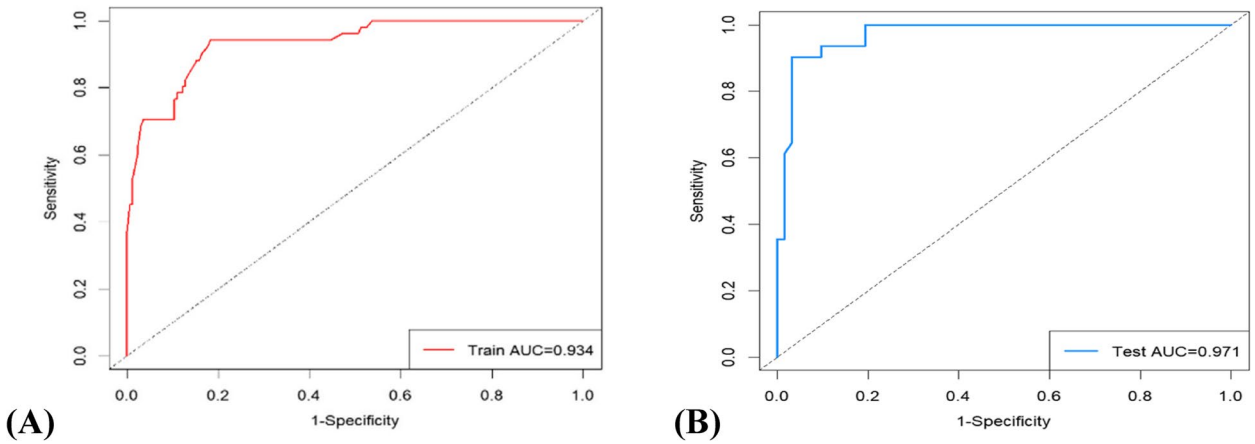


**Fig. 3** Receiver operating characteristic curve (ROC) of the predictive nomogram for the risk of cognitive frailty in older cancer patients. **A** training set. **B** validation set

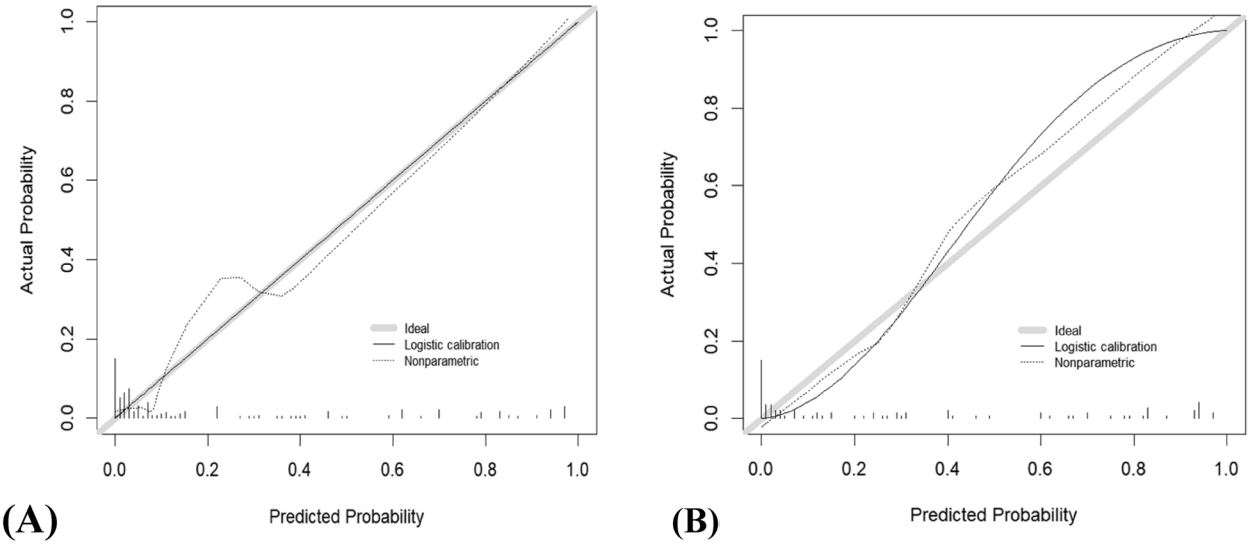


**Fig. 4** Calibration curve for predicting the risk of cognitive frailty in in older cancer patients by the predictive nomogram. **A** training set. **B** validation set

in collaboration with dietitians, tailor nutritional plans to prevent or mitigate cognitive frailty.

This study reveals that depression and sleep disorders are significant risk factors for cognitive frailty in older cancer patients ($P<0.05$), aligning with Jiranan et al. [35], who reported odds ratios of 5.003 (95% CI = 2.399–10.434) for depression and 1.613 (95% CI = 1.041–2.500) for poor sleep quality. Research indicates that these conditions in the elderly have a synergistic effect, heightening the risk of cognitive frailty, especially when both are present [36]. Depression, common in cancer patients, is linked to higher levels of inflammatory cytokines like C-reactive protein and interleukin-6, which are associated with muscle wasting and cognitive impairment [37, 38]. Cancer patients frequently experience sleep disorders, contributing to cognitive decline with age [39]. Sleep disorders not only disrupt circadian rhythms but also promote inflammation, elevate adipokine levels, and inhibit testosterone and insulin-like growth factor-1 synthesis, accelerating protein degradation and muscle protein hydrolysis, thus worsening frailty [40]. Sleep disorders can also indirectly impair cognitive function through inflammation, altered vascular status, and impaired beta-amyloid clearance with increased Tau protein levels [41]. Clinically, healthcare providers should address patients' overall well-being, with a focus on sleep assessment and management. Targeted

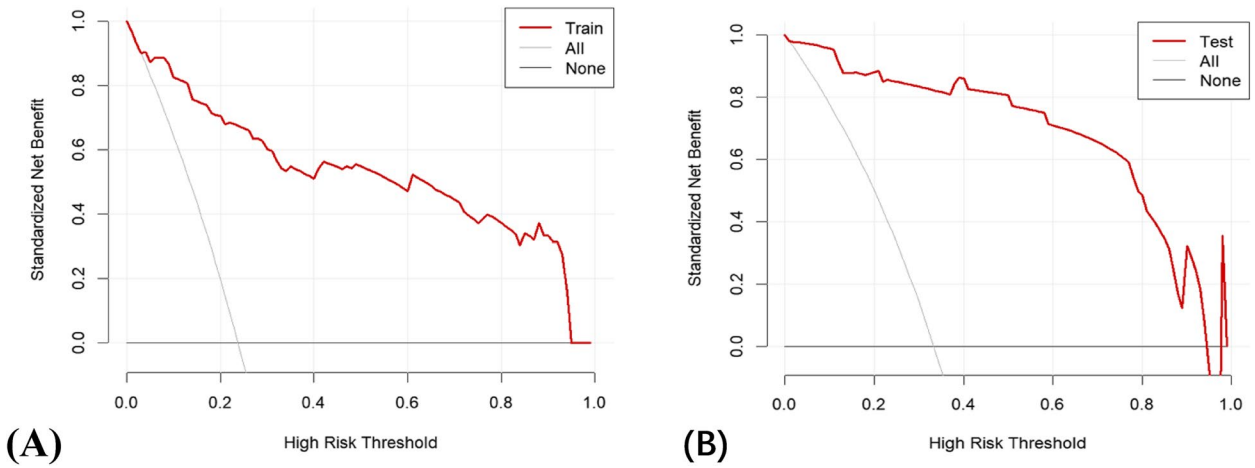


**Fig. 5** Decision curve analysis (DCA) of the prediction nomogram. **A** training set. **B** validation set

psychological support can help reduce negative emotions, enhance sleep quality, and slow cognitive frailty's progression.

In the present study, the nomogram prediction model demonstrated a high level of predictive capability, with an AUC of 0.934 (95% confidence interval [CI]: 0.896–0.971) for the training set and an AUC of 0.971 (95% CI: 0.942–1.000) for the validation set. The Hosmer-Leme-show test for both datasets, in conjunction with the calibration curves, indicated a satisfactory fit, affirming the model's appropriateness and accuracy. Additionally, DCA confirmed the model's substantial clinical utility. The nomogram model visualizes the results of logistic regression, making the predictive factors more straight forward and clear, which facilitates early screening for older cancer patients.

The model developed in this study effectively predicts the risk of cognitive frailty in elderly cancer patients, characterized by simplicity, cost-effectiveness, and practicality, offering guiding value for clinical practice. Based on easily accessible, non-invasive, and cost-effective predictors, the model ensures its practicality and reliability. The nomogram visually presents the risk ratios of predictors in the logistic regression model, allowing for the straightforward calculation of the probability of target events, facilitating early screening. Tailored interventions, such as distributing health education booklets and showing educational videos, can be implemented based on different risk levels of cognitive frailty to enhance patients' understanding, spark their interest in learning, and standardize health management behaviors. This approach aids in optimizing the allocation of medical resources and human resource management.

### Limitations

The limitations of this study are as follows: Firstly, this study is a single-center study with a small sample size, which may affect the precision and generalizability of the results. Future research should conduct multicenter studies with larger sample sizes to enhance the reliability of the findings. Secondly, the predictive factors involved in this study were limited and primarily based on self-reported data. Future research should include more objective measurement predictors to identify risk factors for cognitive frailty more comprehensively and objectively. Thirdly, the nomogram developed in this study was mainly based on data from elderly cancer patients in Nantong, Jiangsu Province, China, and its generalizability may be influenced by patient demographic characteristics, disease presentation, and regional differences in medical practice; hence, the model requires external validation in other regions. Fourthly, age is a risk factor for cognitive frailty, and there may be differences in risk factors between different age groups (older and young people). Future research should explore and predict cognitive frailty in cancer patients across different age groups. Fifthly, this study provides an initial predictive nomogram tool for cognitive frailty in elderly cancer patients. To enhance its practicality and convenience, future research could consider developing a dynamic nomogram or an online calculator to establish a predictive platform that facilitates the screening, prevention, and management of cognitive frailty in elderly cancer patients.

## Conclusion

The detection rate of cognitive frailty in older cancer patients is relatively high, with key predictive factors including education level at primary school or below, tumor stage at III-IV, presence of comorbidities, self-care ability impairment, depression, malnutrition, and sleep disorders. This prediction model provides important guidance for clinical work. Medical staff can use this model to screen for cognitive frailty in older cancer patients and develop individualized and comprehensive care plans based on the patients' different characteristics, including improving nutritional status, regularly engaging in physical exercise, promptly identifying and addressing negative emotions, and strengthening sleep management, with the aim of preventing or delaying the onset and progression of cognitive frailty. Simultaneously, since cognitive frailty involves aspects such as nutrition, exercise, disease, and psychological status, a multidisciplinary collaborative team management can be established for cancer patients.

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**Authors' contributions**
HW: Conceptualization, Methodology, Software Conceptualization, Methodology, Data Curation, Formal analysis, Investigation, Writing-original draft, Writing-review & editing. YXW: Data curation, Writing- Original draft preparation.SYD: Writing- Reviewing and Editing. Yan Qian: Visualization, Investigation. Hai-Ou Yan: Writing- Reviewing and Editing, Supervision.

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**Data availability**
The data that support the findings of this study are available from the corresponding author, Hai-Ou Yan, upon reasonable request.

## Declarations

**Ethics approval and consent to participate**
The Ethics Committee of Affiliated Hospital of Nantong University granted of approval for the study, on 9th October 2023, with the reference number 2023-K141-01. Prior to enrollment, all participants were thoroughly briefed on the study's objectives and provided their consent by signing an informed consent form. All methods were carried out in accordance with the Declaration of Helsinki.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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