

A Nomogram for Identifying Poor Sleep Quality in Community- Dwelling Middle-Aged and Older Adults with Abdominal Obesity Based on Psychological and Physical Fitness Indicators

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Abstract

Background

Poor sleep quality is common in middle-aged and older adults, and abdominal obesity may coexist with psychological symptoms and impaired functional fitness. We developed and internally validated a model integrating psychological status and functional fitness to identify current poor sleep quality in adults with abdominal obesity and compared its performance with a routine-information model.

Methods

This cross-sectional study included 212 adults aged ≥ 45 years with abdominal obesity from Beijing. Poor sleep quality was defined as Pittsburgh Sleep Quality Index (PSQI) > 5 . Ten candidate predictors were evaluated using least absolute shrinkage and selection operator logistic regression with repeated stratified 10-fold cross-validation, followed by multivariable logistic regression. Performance was assessed using the area under the receiver operating characteristic curve (AUC), calibration, Brier score, and decision curve analysis. Separate 1,000-resample bootstrap procedures assessed selection stability and optimism in the fixed seven-predictor model.

Results

Among 212 participants, 117 (55.2%) had poor sleep quality. The final model included age, 9-item Patient Health Questionnaire, 7-item Generalized Anxiety Disorder scale, grip strength, 30-s chair stand, chair sit-and-reach, and 2-min step test. The apparent AUC was 0.779 (95% confidence interval [CI], 0.718–0.840); optimism-corrected AUC, calibration slope, and Brier score were 0.751, 0.858, and 0.206. Compared with the routine-information model (AUC, 0.648), the final model increased AUC by 0.131 (95% CI, 0.050–0.213; $P = 0.002$) and showed greater theoretical net benefit at thresholds of 13%–80% in the development sample.

Conclusions

The model integrating psychological status and functional fitness showed moderate discrimination and outperformed routine information for identifying current poor sleep quality. External validation is required before application.

1 Introduction

Poor sleep quality is common among middle-aged and older adults. A systematic review and meta-analysis of 995,544 community-dwelling older adults from 36 countries estimated a pooled prevalence of approximately 40% [1]. Middle-aged and older adults with poor sleep quality are more likely to have

concurrent depression, anxiety, functional limitations, reduced quality of life, and a greater burden of chronic disease [2–5]. Sleep disturbances are also associated with obesity, particularly abdominal obesity. Short sleep duration has been associated with central obesity in adults and obesity in older adults [6, 7], and an association between poor sleep quality and abdominal obesity has also been reported in Chinese populations [8]. Among older adults with obesity, poor sleep quality is accompanied by lower muscle strength and lean body mass and more pronounced anxiety and depressive symptoms [3]. These findings support the need for a simple community-based tool that integrates psychological status and physical function to identify current poor sleep quality in middle-aged and older adults with abdominal obesity.

Previous studies have developed prediction models for sleep quality or sleep disorders in different middle-aged and older populations [9, 10]. However, the selected predictors vary substantially, and most studies have focused on general older populations or patients with specific chronic diseases. Du et al. developed a sleep quality model in older adults using demographic, health, psychosocial, depressive-symptom, and cognitive variables [9]. Zhang et al. developed a sleep disturbance model for older adults with hypertension using variables including depressive symptoms, education, asthma, overweight status, arthritis, and work limitations [10]. Models have also been developed in patients with inflammatory bowel disease and systemic lupus erythematosus [11, 12]. These models rely mainly on demographic, disease-related, and psychosocial information, with less emphasis on physical function. However, lower muscle strength [13], grip strength and physical performance [14, 15], and multiple dimensions of functional fitness [16] have been associated with sleep quality in older adults. We therefore developed and internally validated a nomogram for identifying current poor sleep quality among community-dwelling middle-aged and older adults with abdominal obesity using readily obtainable measures of psychological status and functional fitness, and compared its performance with that of a routine-information model.

2 Methods

2.1 Study Design and Participants

This study employed a cross-sectional study design and was conducted in June 2026 at the Huayuan Road Community in Haidian District, Beijing. A total of 308 middle-aged and older adults underwent initial assessment. Inclusion criteria were: age ≥ 45 years; meeting the criteria for abdominal obesity, i.e., waist circumference ≥ 90 cm for men and ≥ 85 cm for women [17]; possession of complete Pittsburgh Sleep Quality Index (PSQI) data; and the ability to complete the questionnaire assessments and primary physical fitness tests required for the study. Participants aged < 45 years, those who did not meet the criteria for abdominal obesity, or those for whom abdominal obesity could not be determined due to missing sex or waist circumference data, as well as those with missing PSQI data, duplicate records, or unverifiable key information, were excluded from the analysis.

2.2 Ethics

This study was approved by the Sports Science Experiment Ethics Committee of Beijing Sport University (Approval No. 2026354H) and was conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent before the survey. Direct identifiers were removed, and study data were managed using unique participant identifiers.

2.3 Assessment of Poor Sleep Quality

This study used the Pittsburgh Sleep Quality Index (PSQI) to assess sleep quality over the previous month [18]. The PSQI comprises seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Each component is scored from 0 to 3, yielding a total score of 0–21; higher scores indicate poorer sleep quality. According to the threshold proposed by Buysse et al. [18], a PSQI score > 5 was classified as poor sleep quality and a score ≤ 5 as better sleep quality. The model outcome was current poor sleep quality (PSQI > 5) at the time of the survey.

2.4 General Characteristics

Participant characteristics were collected using a structured questionnaire and included age, sex, education, marital status, smoking, alcohol consumption, exercise status, physical activity level, number of disease categories, and medication use. Height, weight, and waist circumference were measured by trained assessors, and body mass index (BMI) was calculated as weight (kg)/height (m)². Abdominal obesity was defined using the commonly applied waist-circumference thresholds for Chinese adults [17]. Waist circumference defined the study population but was not considered as a candidate predictor in the main model.

2.5 Measurement of Physical and Mental Function

2.5.1 Depressive Symptoms

Depressive symptoms were assessed using the 9-item Patient Health Questionnaire (PHQ-9) [19], which assesses the frequency of depressive symptoms during the previous 2 weeks. Each item is scored from 0 to 3, yielding a total score of 0–27; higher scores indicate more severe depressive symptoms. The PHQ-9 total score was analyzed as a continuous variable.

2.5.2 Anxiety Symptoms

Anxiety symptoms were assessed using the 7-item Generalized Anxiety Disorder scale (GAD-7) [20], which assesses symptom frequency during the previous 2 weeks. Each item is scored from 0 to 3, yielding a total score of 0–21; higher scores indicate more severe anxiety symptoms. The GAD-7 total score was analyzed as a continuous variable.

2.5.3 Cognitive Function

Cognitive function was assessed using the Mini-Mental State Examination (MMSE) [21], which covers orientation, memory, attention and calculation, recall, and language. Total scores range from 0 to 30, with

higher scores indicating better global cognitive function. The MMSE total score was analyzed as a continuous variable.

2.5.4 Grip Strength

Grip strength was used to assess upper-limb muscle strength [22]. During testing, participants used a standard grip dynamometer to measure grip strength on their dominant side. Two measurements were taken with an adequate rest period between each, and the higher of the two values was recorded in kilograms (kg). A higher grip strength value indicates better upper-limb muscle strength.

2.5.5 Lower-Limb Muscle Strength

Lower-limb muscle strength was assessed using the 30-s chair stand test [23]. Participants sat in the center of a chair and repeatedly performed the movement from a seated position to a fully standing position and back to a seated position without using their arms for support. The number of correct repetitions completed within 30 seconds was recorded. A higher number of repetitions indicates better lower-limb muscle strength and functional performance.

2.5.6 Flexibility

Lower-body flexibility was assessed using the chair sit-and-reach test [24]. During the test, participants sat on the front edge of a chair, extended one leg forward while keeping the heel on the ground, and slowly reached forward with both hands toward the toes; the distance between the fingertips and the toes was recorded. The test was performed twice on each side, and the maximum value among the measurements was used for analysis, with units in cm; a higher value indicates better flexibility.

2.5.7 Cardiorespiratory Endurance

Cardiorespiratory endurance was assessed using the 2-min step test [25, 26]. During the test, participants performed continuous stepping in place for 2 minutes while raising their knees to a specified height; the number of correctly completed steps within the specified time was recorded. A higher number of completed steps indicates better cardiorespiratory endurance.

2.5.8 Functional Mobility

Functional mobility was assessed using the 8-Foot Up-and-Go test (8UG), a modified version of the conventional TUG [27]. Participants stood up from a chair, walked as quickly and safely as possible around a cone placed 2.44 m from the chair, turned around, walked back, and sat down again; the time required to complete the entire process was recorded. The test was conducted twice, and the shorter time was used for analysis, with results reported in seconds; a shorter completion time indicates better functional mobility.

2.6 Statistical Analysis

Statistical analyses were performed using R version 4.6.1. Categorical variables were summarized as frequencies and percentages, and continuous variables as means with standard deviations or medians

with interquartile ranges, as appropriate. Between-group comparisons used Welch's independent-samples t-test or the Mann–Whitney U test for continuous variables and Pearson's χ^2 test or Fisher's exact test for categorical variables.

The definitions and coding of the 10 candidate predictors are summarized in Supplementary Table S1. LASSO logistic regression was used to select candidate predictors [28]. Continuous variables were standardized before modeling. The penalty parameter was selected using 100 repetitions of stratified 10-fold cross-validation. The primary rule was λ_{1se} , which minimizes the cross-validated binomial deviance; the predictor set at λ_{1min} was also examined. Variable-selection stability was evaluated by repeating LASSO in 1,000 bootstrap resamples. Predictors with nonzero coefficients at λ_{1se} were entered simultaneously into an unpenalized multivariable logistic regression model, from which the nomogram was constructed.

Discrimination was evaluated using the area under the receiver operating characteristic curve (AUC). The Youden index determined the apparent optimal cutoff and corresponding sensitivity and specificity [29]. Calibration was evaluated using a calibration plot, calibration intercept, and calibration slope [30, 31], and overall prediction error was quantified using the Brier score. After the seven-predictor structure was fixed, a separate 1,000-resample bootstrap procedure estimated optimism-corrected model performance [32]. Decision curve analysis (DCA) evaluated theoretical net benefit across threshold probabilities.

A routine-information model including age, sex, number of disease categories, current alcohol consumption, and exercise status was compared with the final model in the same participants. Apparent AUCs were compared using a paired DeLong test [33], and 95% confidence intervals for other performance differences were estimated using 1,000 paired bootstrap resamples. LASSO was implemented with glmnet, the nomogram and calibration analyses with rms, ROC analysis with pROC, and DCA with dcurves. All tests were two-sided, and $P < 0.05$ was considered statistically significant. Further modeling details are provided in Supplementary Methods S1.

3 Results

3.1 Study Population Selection

A total of 308 middle-aged and older adults were surveyed in this study. Of these, 9 were excluded because they were younger than 45 years old, 86 were excluded because they did not meet the criteria for abdominal obesity or could not be classified as such, and 1 was excluded due to missing PSQI data. Ultimately, 212 participants were included in the analysis. The participant selection process is shown in Fig. 1. The mean age of the included participants was 65.81 ± 6.86 years; 152 were female, accounting for 71.7%. Among them, 117 participants were classified as having poor sleep quality (PSQI > 5), accounting for 55.2%. A comparison of the baseline characteristics of participants with different sleep quality is shown in Table 1.

Table 1
Baseline characteristics according to sleep quality status.

Characteristic	Total (n = 212)	PSQI ≤ 5 (n = 95)	PSQI > 5 (n = 117)	P
Demographic and lifestyle characteristics				
Age, years	65.81 ± 6.86	64.59 ± 7.41	66.79 ± 6.25	0.022
Sex				0.517
Male	60 (28.3)	29 (30.5)	31 (26.5)	
Female	152 (71.7)	66 (69.5)	86 (73.5)	
Education level				0.565
Elementary school or below	6 (2.8)	2 (2.1)	4 (3.4)	
Junior high school	41 (19.3)	18 (18.9)	23 (19.7)	
High school/college	105 (49.5)	45 (47.4)	60 (51.3)	
Bachelor's degree	50 (23.6)	23 (24.2)	27 (23.1)	
Postgraduate	10 (4.7)	7 (7.4)	3 (2.6)	
Marital status				0.112
Unmarried	5 (2.4)	0 (0.0)	5 (4.3)	
Married	197 (92.9)	91 (95.8)	106 (90.6)	
Divorced/widowed	10 (4.7)	4 (4.2)	6 (5.1)	
Smoking status				0.221
Never smoked	185 (87.3)	80 (84.2)	105 (89.7)	
Former smoker	21 (9.9)	13 (13.7)	8 (6.8)	
Current smoker	6 (2.8)	2 (2.1)	4 (3.4)	
Alcohol consumption				0.193
Never drinker	141 (66.5)	68 (71.6)	73 (62.4)	
Former drinker	3 (1.4)	0 (0.0)	3 (2.6)	
Current drinker	68 (32.1)	27 (28.4)	41 (35.0)	

Note. Data are presented as mean ± standard deviation, median (Q1, Q3), or n (%), as appropriate. *P* values were calculated using Welch's independent-samples *t*-test or the Mann–Whitney *U* test for continuous variables and Pearson's χ^2 test or Fisher's exact test for categorical variables, as appropriate. PSQI, Pittsburgh Sleep Quality Index; PHQ-9, Patient Health Questionnaire-9; GAD-7, Generalized Anxiety Disorder-7; MMSE, Mini-Mental State Examination; BMI, body mass index.

Characteristic	Total (n = 212)	PSQI ≤ 5 (n = 95)	PSQI > 5 (n = 117)	P
Demographic and lifestyle characteristics				
Exercise status				0.106
No exercise	60 (28.3)	20 (21.1)	40 (34.2)	
Occasional exercise	74 (34.9)	36 (37.9)	38 (32.5)	
Regular exercise	78 (36.8)	39 (41.1)	39 (33.3)	
Physical activity level				0.523
High	43 (20.3)	19 (20.0)	24 (20.5)	
Moderate	117 (55.2)	56 (58.9)	61 (52.1)	
Low	52 (24.5)	20 (21.1)	32 (27.4)	
Number of disease categories				0.233
0 diseases	10 (4.7)	7 (7.4)	3 (2.6)	
1 disease	28 (13.2)	11 (11.6)	17 (14.5)	
≥2 diseases	174 (82.1)	77 (81.1)	97 (82.9)	
Number of medication categories				0.765
0 medications	51 (24.1)	24 (25.3)	27 (23.1)	
1–4 medications	135 (63.7)	61 (64.2)	74 (63.2)	
≥5 medications	26 (12.3)	10 (10.5)	16 (13.7)	
Psychological and cognitive characteristics				
PHQ-9 score	3.00 (1.00, 5.00)	2.00 (1.00, 3.00)	4.00 (2.00, 6.00)	<0.001
GAD-7 score	3.00 (1.00, 5.00)	2.00 (1.00, 3.00)	4.00 (2.00, 6.00)	<0.001
MMSE score	27.00 (25.00, 28.00)	27.00 (25.00, 28.00)	27.00 (25.00, 28.00)	0.387
Anthropometric and physiological characteristics				
<i>Note.</i> Data are presented as mean ± standard deviation, median (Q1, Q3), or n (%), as appropriate. <i>P</i> values were calculated using Welch's independent-samples t-test or the Mann–Whitney <i>U</i> test for continuous variables and Pearson's χ^2 test or Fisher's exact test for categorical variables, as appropriate. PSQI, Pittsburgh Sleep Quality Index; PHQ-9, Patient Health Questionnaire-9; GAD-7, Generalized Anxiety Disorder-7; MMSE, Mini-Mental State Examination; BMI, body mass index.				

Characteristic	Total (n = 212)	PSQI ≤ 5 (n = 95)	PSQI > 5 (n = 117)	P
Demographic and lifestyle characteristics				
Body mass index, kg/m ²	25.65 ± 2.98	25.68 ± 2.94	25.62 ± 3.02	0.871
Waist circumference, cm	91.95 (87.00, 96.53)	92.00 (87.00, 97.75)	91.50 (87.00, 96.50)	0.959
Mean arm circumference, cm	27.94 ± 2.42	28.20 ± 2.45	27.73 ± 2.38	0.168
Body fat percentage, %	33.07 ± 6.93	32.66 ± 7.78	33.39 ± 6.18	0.456
Systolic blood pressure, mmHg	133.21 ± 18.56	133.87 ± 16.45	132.67 ± 20.17	0.633
Diastolic blood pressure, mmHg	79.24 ± 10.29	78.58 ± 9.57	79.78 ± 10.85	0.394
Functional fitness				
Grip strength, kg	28.76 ± 7.99	30.00 ± 8.70	27.74 ± 7.25	0.045
30-second chair stand, repetitions	16.14 ± 4.40	16.99 ± 4.21	15.44 ± 4.45	0.010
30-second arm curl, repetitions	26.00 (22.75, 29.00)	27.00 (23.00, 30.50)	24.00 (22.00, 27.00)	0.002
Back scratch, cm	-5.78 ± 10.35	-5.76 ± 9.34	-5.80 ± 11.15	0.975
Chair sit-and-reach, cm	5.84 ± 12.17	7.90 ± 11.81	4.17 ± 12.25	0.026
One-leg stance with eyes closed, s	3.21 (2.27, 4.81)	3.44 (2.63, 4.83)	3.13 (2.01, 4.48)	0.033
2-minute step test, steps	100.61 ± 17.17	103.77 ± 14.27	98.04 ± 18.88	0.013
8UG, s	6.87 (6.16, 7.63)	6.83 (6.06, 7.49)	6.98 (6.19, 7.77)	0.174
<i>Note.</i> Data are presented as mean ± standard deviation, median (Q1, Q3), or n (%), as appropriate. <i>P</i> values were calculated using Welch's independent-samples <i>t</i>-test or the Mann–Whitney <i>U</i> test for continuous variables and Pearson's χ^2 test or Fisher's exact test for categorical variables, as appropriate. PSQI, Pittsburgh Sleep Quality Index; PHQ-9, Patient Health Questionnaire-9; GAD-7, Generalized Anxiety Disorder-7; MMSE, Mini-Mental State Examination; BMI, body mass index.				

Compared with participants with better sleep quality, those with poor sleep quality were older (66.79 ± 6.25 vs. 64.59 ± 7.41 years) and had higher PHQ-9 and GAD-7 scores. They also had lower grip strength, fewer 30-s chair stand and 30-s arm curl repetitions, shorter chair sit-and-reach distance and eyes-closed single-leg stance time, and a lower 2-min step count (all $P < 0.05$).

3.2 Selection of Predictors

The 10 candidate predictors were age, sex, PHQ-9 score, GAD-7 score, MMSE total score, grip strength, 30-s chair stand repetitions, chair sit-and-reach distance, 2-min step count, and 8UG time. LASSO selected seven predictors. At $\lambda_{0.5}$, age, PHQ-9 score, GAD-7 score, grip strength, 30-s chair stand repetitions, chair sit-and-reach distance, and 2-min step count had nonzero coefficients; the same predictors were retained at $\lambda_{1.0}$ (Figs. 2 and 3). Selection frequencies and coefficient-direction consistency across 1,000 bootstrap resamples are reported in Table 2, with additional details provided in Supplementary Figure S1 and Supplementary Table S2.

Table 2
Variable selection using LASSO and bootstrap stability analysis.

Variables	β at $\lambda_{0.5}$	β at $\lambda_{1.0}$	bootstrap selection, %	Direction consistency, %
Demographic characteristics				
Age	0.014	0.012	72.8	96.6
Sex	0	0	34.6	—
Mental and physical functioning variables				
PHQ-9	0.282	0.276	100.0	100.0
GAD-7	0.062	0.054	83.8	99.9
MMSE	0	0	50.3	83.9
Grip strength	-0.010	-0.008	68.3	99.0
30-second chair stand	-0.012	-0.010	62.3	96.0
Chair sit-and-reach	-0.009	-0.007	73.2	98.4
2-minute step test	-0.003	-0.002	59.9	92.5
8UG	0	0	36.7	59.9
<i>Note.</i> At $\lambda_{0.5}$ ($\lambda = 0.0222$), seven variables had non-zero coefficients: age, PHQ-9, GAD-7, grip strength, 30-second chair stand, chair sit-and-reach, and 2-minute step test. The same seven variables were retained at $\lambda_{1.0}$ ($\lambda = 0.0267$). The bootstrap selection frequency was calculated from 1,000 resamples. Direction consistency refers to the proportion of selected bootstrap samples in which the coefficient had the same direction as in the full-sample model; it is not reported for sex because the categorical term was not retained in the full-sample model. GAD-7, Generalized Anxiety Disorder-7; MMSE, Mini-Mental State Examination; PHQ-9, Patient Health Questionnaire-9.				

The seven LASSO-selected predictors were entered simultaneously into the multivariable logistic regression model. PHQ-9 score was associated with current poor sleep quality: each 1-point increase corresponded to a 37.4% increase in the odds (OR = 1.374, 95% CI, 1.164–1.621; $P < 0.001$). Associations for age, GAD-7 score, grip strength, 30-s chair stand repetitions, chair sit-and-reach distance, and 2-min step count did not reach statistical significance (Table 3). No substantial multicollinearity was detected;

supporting correlation and model-diagnostic results are provided in Supplementary Figure S2 and Supplementary Table S3.

Table 3
Multivariable logistic regression analysis of factors associated with poor sleep quality.

Variables	β	SE	Wald χ^2	OR	95% CI	P	VIF
Demographic characteristic							
Age, per 5-year increase	0.115	0.123	0.874	1.122	0.882–1.428	0.348	1.103
Mental and functioning variables							
PHQ-9, per 1-point increase	0.318	0.085	13.996	1.374	1.164–1.621	<0.001	1.265
GAD-7, per 1-point increase	0.110	0.072	2.334	1.116	0.969–1.286	0.127	1.242
Grip strength, per 5-kg increase	−0.114	0.104	1.202	0.892	0.728–1.093	0.270	1.147
30-second chair stand, per 1-repetition increase	−0.023	0.040	0.331	0.977	0.903–1.057	0.564	1.298
Chair sit-and-reach, per 5-cm increase	−0.082	0.070	1.372	0.921	0.803–1.057	0.241	1.143
2-minute step test, per 10-repetition increase	−0.063	0.107	0.347	0.939	0.761–1.159	0.559	1.295
<i>Note.</i> Poor sleep quality was defined as a PSQI score greater than 5 (coded as 1), with a PSQI score of 5 or less coded as 0. All seven variables selected by LASSO were included simultaneously. CI, confidence interval; GAD-7, Generalized Anxiety Disorder-7; OR, odds ratio; PHQ-9, Patient Health Questionnaire-9; PSQI, Pittsburgh Sleep Quality Index; VIF, variance inflation factor.							

3.3 Construction of the Nomogram Model

A nomogram for estimating the probability of current poor sleep quality was constructed from the final multivariable logistic regression model (Fig. 4). It included age, PHQ-9 score, GAD-7 score, grip strength, 30-s chair stand repetitions, chair sit-and-reach distance, and 2-min step count. Predictor-specific points are summed to obtain a total score, which corresponds to the estimated probability of current poor sleep quality.

For example, a 65-year-old participant with a PHQ-9 score of 8, a GAD-7 score of 8, a grip strength of 30 kg, 16 30-s chair stands, a chair sit-and-reach distance of 0 cm, and a 2-min step test with 100 steps has scores of approximately 6.8, 50.0, 17.3, 9.0, 5.5, 9.7, and 4.9, respectively, for a total score of approximately 103.2. The estimated probability of poor sleep quality for this participant is approximately 91% (Fig. 4).

3.4 Evaluation of the Nomogram Model

The apparent AUC was 0.779 (95% CI, 0.718–0.840), and the optimism-corrected AUC after 1,000 bootstrap resamples was 0.751, indicating moderate discrimination (Fig. 5A). The optimism-corrected calibration intercept, calibration slope, and Brier score were 0.002, 0.858, and 0.206, respectively (Fig. 5B and Supplementary Table S4). In the development sample, the model provided greater theoretical net benefit than the “Treat all” and “Treat none” strategies across threshold probabilities of 13%–80% (Fig. 6).

3.5 Comparison of Model Performance

Compared with the routine-information model, the final model had higher apparent and optimism-corrected AUCs and a lower Brier score (Table 4). Coding and coefficient estimates for the routine-information model are provided in Supplementary Table S5. The apparent AUCs were 0.648 (95% CI, 0.574–0.722) and 0.779 (95% CI, 0.718–0.840), respectively, with a difference of 0.131 (95% CI, 0.050–0.213; $P = 0.002$). The corresponding optimism-corrected AUCs were 0.608 and 0.751, and the optimism-corrected Brier scores were 0.245 and 0.206. In the development sample, the final model showed greater theoretical net benefit than the routine-information model across threshold probabilities of 13%–80% (Fig. 7 and Supplementary Table S6).

Table 4

Comparison of predictive performance between the routine-information model and the final model.

Performance measure	Routine-information model	Final model	Difference (Final – Routine)	95% CI for difference	<i>P</i>
Discrimination					
AUC, apparent	0.648 (0.574–0.722)	0.779 (0.718–0.840)	0.131	0.050–0.213	0.002
AUC, optimism-corrected	0.608	0.751	0.143	0.063–0.222	—
Overall prediction error					
Brier score, apparent	0.230	0.190	–0.040	–0.067 to –0.016	—
Brier score, optimism-corrected	0.245	0.206	–0.039	–0.069 to –0.006	—
Scaled Brier score, apparent	0.070	0.230	0.160	0.063–0.274	—
Scaled Brier score, optimism-corrected	0.014	0.172	0.158	0.020–0.280	—
Calibration					
Calibration intercept, optimism-corrected	0.000	0.002	0.002	–0.185–0.185	—
Calibration slope, optimism-corrected	0.723	0.858	0.135	–0.374–0.726	—
Explained variation					
Nagelkerke R ² , apparent	0.098	0.309	0.211	0.084–0.343	—
Nagelkerke R ² , optimism-corrected	–0.010	0.235	0.245	0.033–0.884	—
Model fit					
AIC	289.5	251.9	–37.6	—	—
BIC	313.0	278.8	–34.3	—	—

4 Discussion

This study developed a nomogram for identifying current poor sleep quality using measures of psychological status and functional fitness from 212 community-dwelling middle-aged and older adults

with abdominal obesity; 55.2% had a PSQI score > 5. LASSO retained age, PHQ-9 score, GAD-7 score, grip strength, 30-s chair stand repetitions, chair sit-and-reach distance, and 2-min step count. PHQ-9 score was associated with current poor sleep quality in the multivariable model. The apparent AUC was 0.779, and the optimism-corrected AUC was 0.751. Overall performance exceeded that of the routine-information model.

In this study, 55.2% of participants had poor sleep quality, exceeding the pooled prevalence reported among community-dwelling older adults. Canever et al. [1] estimated a prevalence of approximately 40% in a meta-analysis of nearly one million older adults from 36 countries, while Fu et al. [2] also reported that sleep disturbances were common but heterogeneous across studies. The higher detection rate in our sample may partly reflect its composition. All participants had abdominal obesity, and 71.7% were women. Chinese population-based research has associated poor sleep quality with abdominal obesity, with possible sex-specific differences [8], while systematic reviews have linked shorter sleep duration with central obesity in adults and obesity in older adults [6, 7]. The observed 55.2% should therefore be interpreted as the burden within this specific sample rather than as a prevalence estimate for the general community. Because existing sleep-quality models mainly concern general older populations or specific patient groups, including people with hypertension [9, 10], the present population remains relevant for targeted risk identification.

Psychological symptoms provided substantial information in the model. Participants with a PSQI score > 5 had higher PHQ-9 and GAD-7 scores, and both were retained by LASSO. In the multivariable model, each 1-point increase in PHQ-9 score was associated with higher odds of current poor sleep quality (OR = 1.374), whereas the adjusted association with GAD-7 score was not statistically significant. Previous studies have likewise associated depressive symptoms [34], anxiety symptoms [4], and obesity accompanied by anxiety and depression [3] with poorer sleep quality. Emotional arousal, altered stress regulation, and inflammatory responses may contribute to the observed overlap, while impaired sleep may also coexist with worsening negative affect [35, 36]. The contribution of PHQ-9 should therefore be interpreted as a marker of current poor sleep quality, not evidence that depressive symptoms are an independent cause. Moreover, PHQ-9 Item 3 assesses sleep disturbance, creating content overlap with the PSQI [18, 19]. This overlap may inflate the predictive information attributed to PHQ-9. Future studies with item-level data should examine models excluding the sleep item or use mood measures without sleep-related content.

Physical function constituted another dimension of the predictor set. Participants with poor sleep quality performed worse in grip strength, 30-s chair stand, chair sit-and-reach, and 2-min step tests, and all four measures were retained by LASSO. This pattern is consistent with evidence linking poorer sleep with lower muscle strength [13], poorer physical performance [14], grip strength [15], and multiple dimensions of functional fitness [16]. Potential explanations include daytime fatigue, lower physical activity, impaired muscle recovery, and altered metabolic or circadian regulation. Exercise interventions have also improved subjective sleep quality in middle-aged and older adults [37–39]. Nevertheless, the 95% CIs for all four physical fitness measures crossed 1 in the multivariable model. The findings therefore do not

establish any single measure as an independent risk factor; rather, the measures collectively capture complementary aspects of physical function relevant to identifying current poor sleep quality.

Not all seven LASSO-selected predictors reached conventional statistical significance in the multivariable logistic regression model. Except for PHQ-9, the 95% CIs for age, GAD-7, and the four physical fitness measures crossed 1. This does not imply that these predictors contain no model information. LASSO retains variables according to their contribution to penalized model fit and prediction error rather than an individual $P < 0.05$ criterion [28]; variable selection and coefficient testing therefore address different questions. Across 1,000 bootstrap resamples, PHQ-9, GAD-7, age, and chair sit-and-reach were selected in more than 70% of samples, and the other retained physical fitness measures in more than 50%, with generally consistent coefficient directions. Age may provide limited independent information after accounting for mood, muscle strength, and functional capacity, despite its association with sleep problems in previous research [2]. The seven variables should therefore be interpreted as a combined predictor set rather than as seven independent risk factors. For prediction models, overall discrimination, calibration, and prediction error are more informative than individual P values [40], consistent with the present focus on risk identification rather than causal inference.

Integrating psychological status and functional fitness measures improved identification of current poor sleep quality compared with routine information alone. The final model had an apparent AUC of 0.779 versus 0.648 for the routine-information model; the optimism-corrected AUCs were 0.751 and 0.608, respectively. The final model also had a lower Brier score and a calibration slope closer to 1, indicating advantages beyond discrimination [30, 40]. Because the final model combines psychological status and functional fitness dimensions, the comparison cannot isolate the independent contribution of either dimension. The required information comes from brief questionnaires and field-based fitness tests rather than laboratory testing. Where such assessments are already available in community health programs, the model may help identify individuals who warrant further sleep assessment. It is not intended to replace the PSQI or a clinical diagnosis, but to translate multidimensional information into an estimated probability of current poor sleep quality. In the development sample, the final model showed greater theoretical net benefit across threshold probabilities of 13%–80%. This range should not be interpreted as a community screening or intervention cutoff because DCA depends on the sample and assumed decision weights [41–43]. Until independent external validation and a specific use context are established, the nomogram should be regarded as a research tool for community risk stratification rather than a basis for individual clinical decisions [44].

5 Strengths and Limitations

This study has several strengths. It focuses on middle-aged and older adults with abdominal obesity, an understudied population with a substantial burden of poor sleep quality, and integrates psychological measures and objectively assessed functional fitness within one risk-identification framework. Candidate predictors balanced evidence, clinical plausibility, community feasibility, and measurement burden. Repeated cross-validation and bootstrap resampling assessed selection stability, while a

separate bootstrap procedure quantified optimism in the fixed seven-predictor model for discrimination, calibration, and prediction error; DCA assessed theoretical net benefit in the development sample. Comparison with a routine-information model in the same sample further quantified the added performance of the multidimensional model.

This study also has limitations. First, its cross-sectional design captures associations with poor sleep quality at the time of assessment and cannot establish temporality, causality, or future sleep outcomes. Second, only internal validation was performed. Bootstrap optimism correction re-estimated coefficients after the seven-predictor structure had been fixed and did not repeat the full selection process. Although a separate bootstrap analysis assessed LASSO selection stability, optimism from the overall development process cannot be excluded; independent external validation is required before application. Third, participants came from one Beijing community, and the sample was relatively small. Generalizability to other regions, sex and age distributions, and other populations with abdominal obesity remains uncertain. Fourth, the PSQI measured self-reported sleep quality and was not supplemented by actigraphy or polysomnography. PHQ-9 Item 3 contains sleep-related content and overlaps conceptually with the PSQI, potentially inflating the PHQ-9 association and model performance. Because item-level PHQ-9 data were unavailable, a sensitivity analysis excluding this item could not be performed [19]. Finally, obstructive sleep apnea, chronic pain, menopausal status, and detailed medication use were unavailable and may contain additional predictive information. Larger multicenter prospective studies should evaluate external calibration, discrimination, and potential use with objective sleep measures and more comprehensive health information.

6 Conclusions

This study developed and internally validated a nomogram that integrates measures of psychological status and functional fitness to estimate the probability of current poor sleep quality among community-dwelling middle-aged and older adults with abdominal obesity. The seven-predictor model showed moderate discrimination and acceptable internal performance and outperformed a routine-information model. The combined psychological status and functional fitness information may support the identification of individuals who warrant further sleep assessment. External validation in independent populations is required before practical application.

Declarations

Ethics approval and consent to participate

This study was approved by the Sports Science Experiment Ethics Committee of Beijing Sport University (approval No. 2026354H) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before data collection.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Supplementary Information

Supplementary Material contains Supplementary Methods S1 (detailed model-development and internal-validation procedures); Supplementary Figures S1–S2 (bootstrap variable-selection frequency and Spearman correlations among candidate predictors); and Supplementary Tables S1–S6 (candidate-predictor definitions and coding, LASSO tuning and selection stability, final-model diagnostics, bootstrap optimism correction, the routine-information benchmark model, and decision-curve results).

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Author Contribution

CYQ and SLY conceptualized the study, developed the methodology, conducted the investigation, curated and formally analyzed the data, managed the software and resources, administered and supervised the project, validated the results, prepared the visualizations, and drafted and critically revised the manuscript. CYQ additionally acquired funding. YW contributed to study conceptualization, funding acquisition, project administration, supervision, validation, and critical revision of the manuscript. CWY, YHH, and SYZ contributed to data curation and critical revision of the manuscript. All authors read and approved the final manuscript. CYQ and SLY contributed equally to this work and share first authorship.

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Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

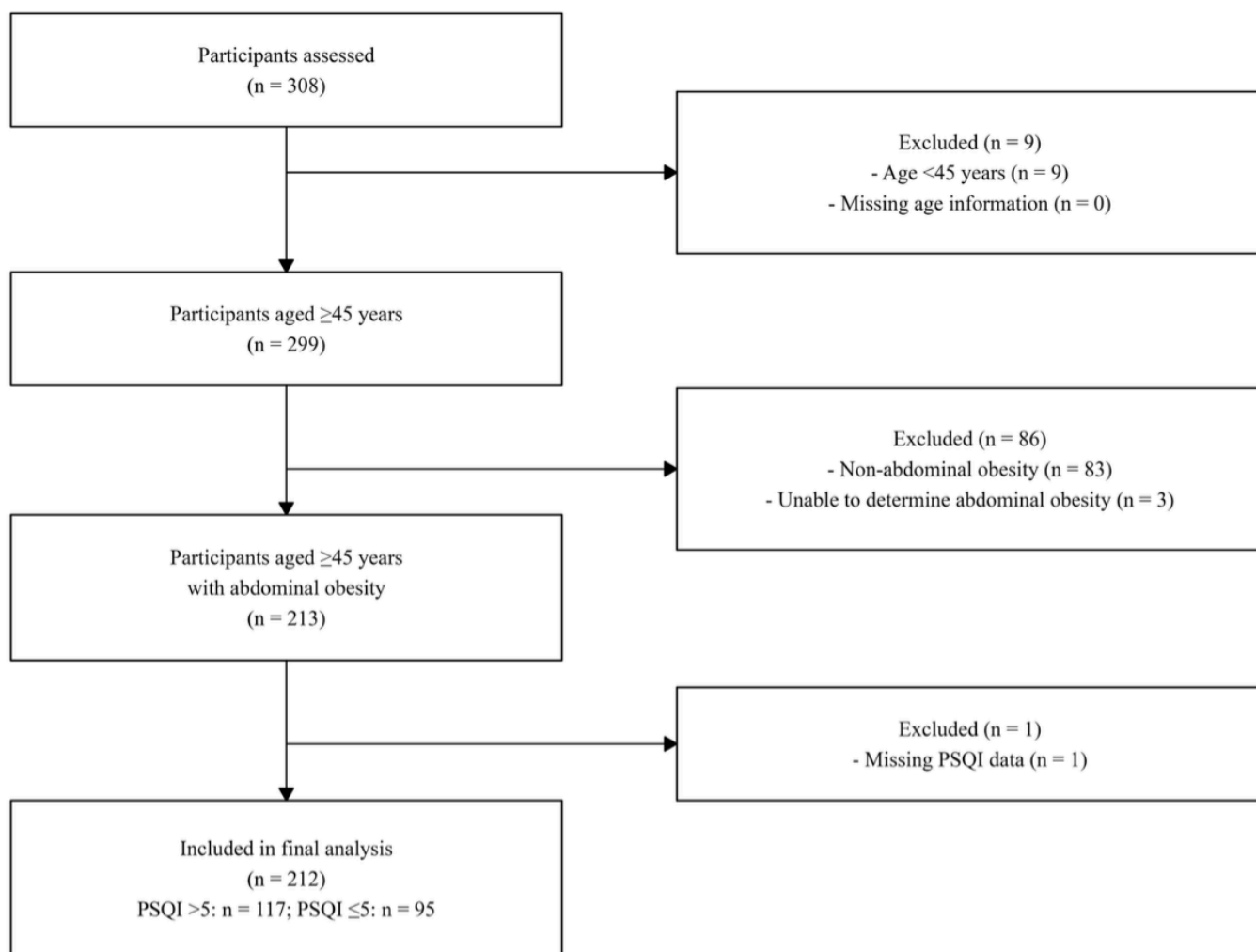


Figure 1

Flowchart of participant selection

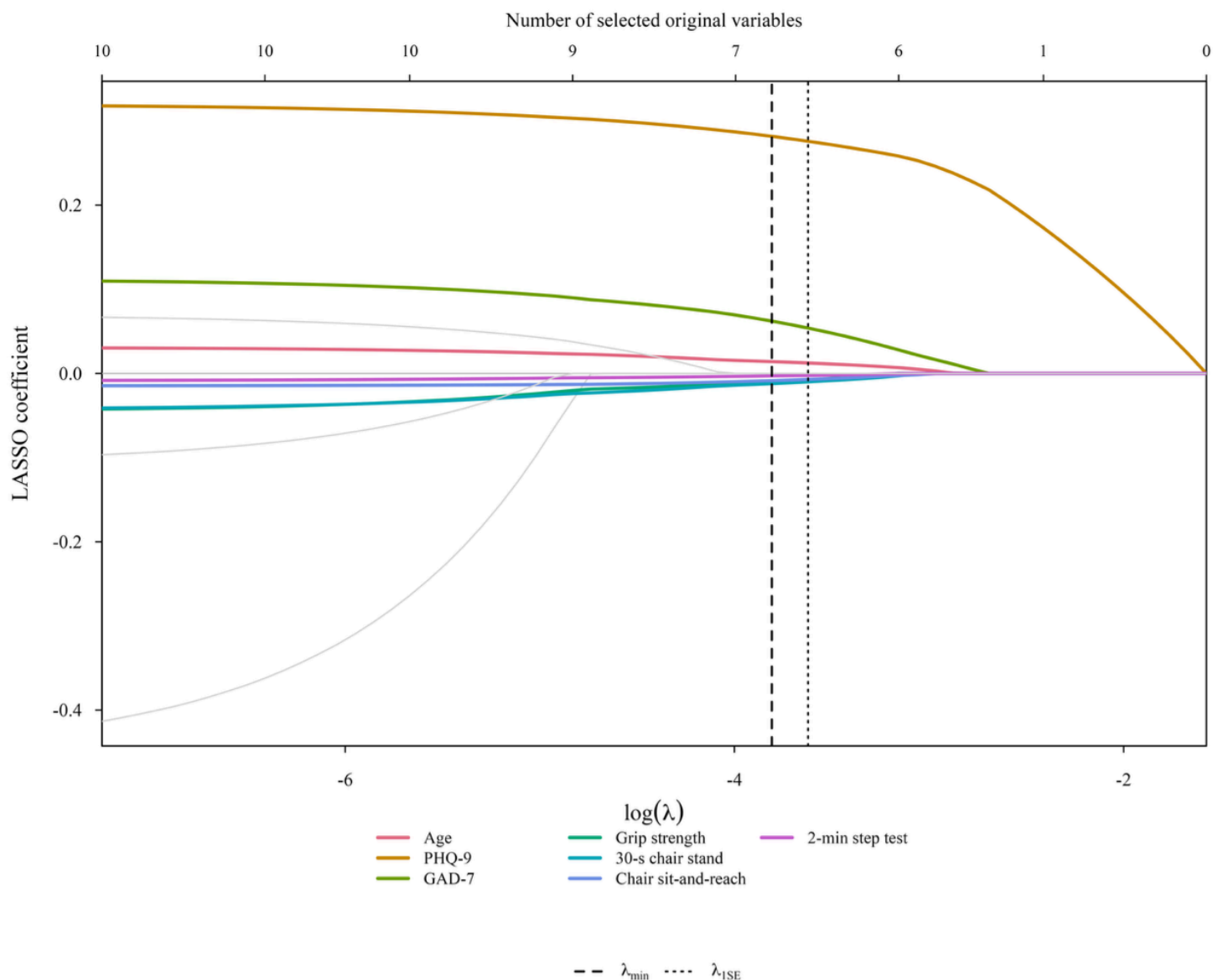


Figure 2

LASSO coefficient profiles of the 10 candidate predictors.

Each curve represents the change in the standardized coefficient of a candidate predictor as the penalty parameter (λ) increases. Vertical dashed lines indicate $\lambda_{\min}$ and λ_{1SE} . LASSO, least absolute shrinkage and selection operator; $\lambda_{\min}$, the value of λ that minimizes the cross-validated binomial deviance; λ_{1SE} , the largest value of λ within one standard error of the minimum.

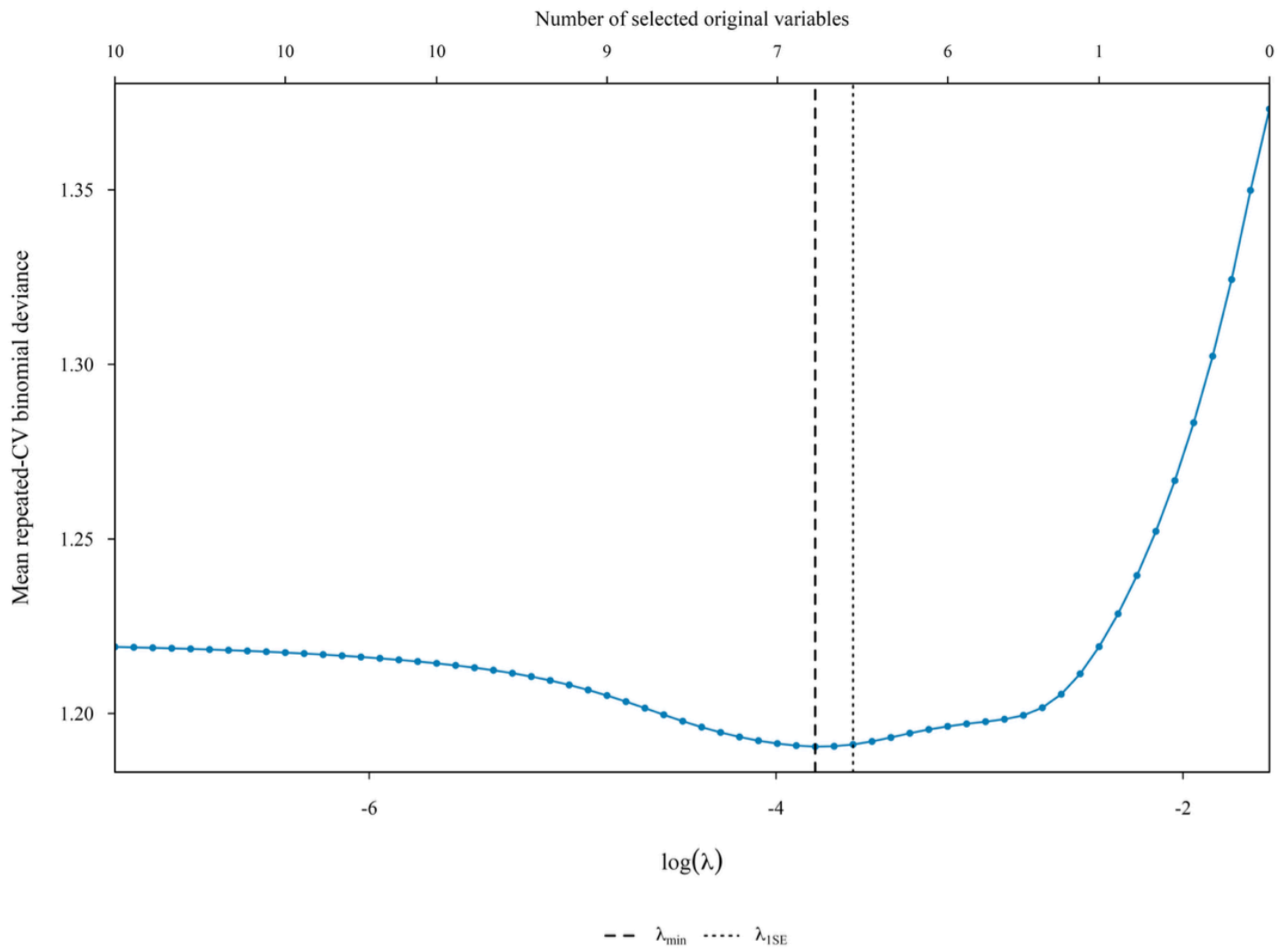


Figure 3

Selection of the optimal penalty parameter using repeated stratified 10-fold cross-validation.

The optimal penalty parameter was determined using the minimum-error criterion ($\lambda_{\min}$), with λ_{1SE} additionally examined as a more parsimonious criterion. Seven predictors were retained under both criteria. $\lambda_{\min}$, the value of λ that minimizes the cross-validated binomial deviance; λ_{1SE} , the largest value of λ within one standard error of the minimum.

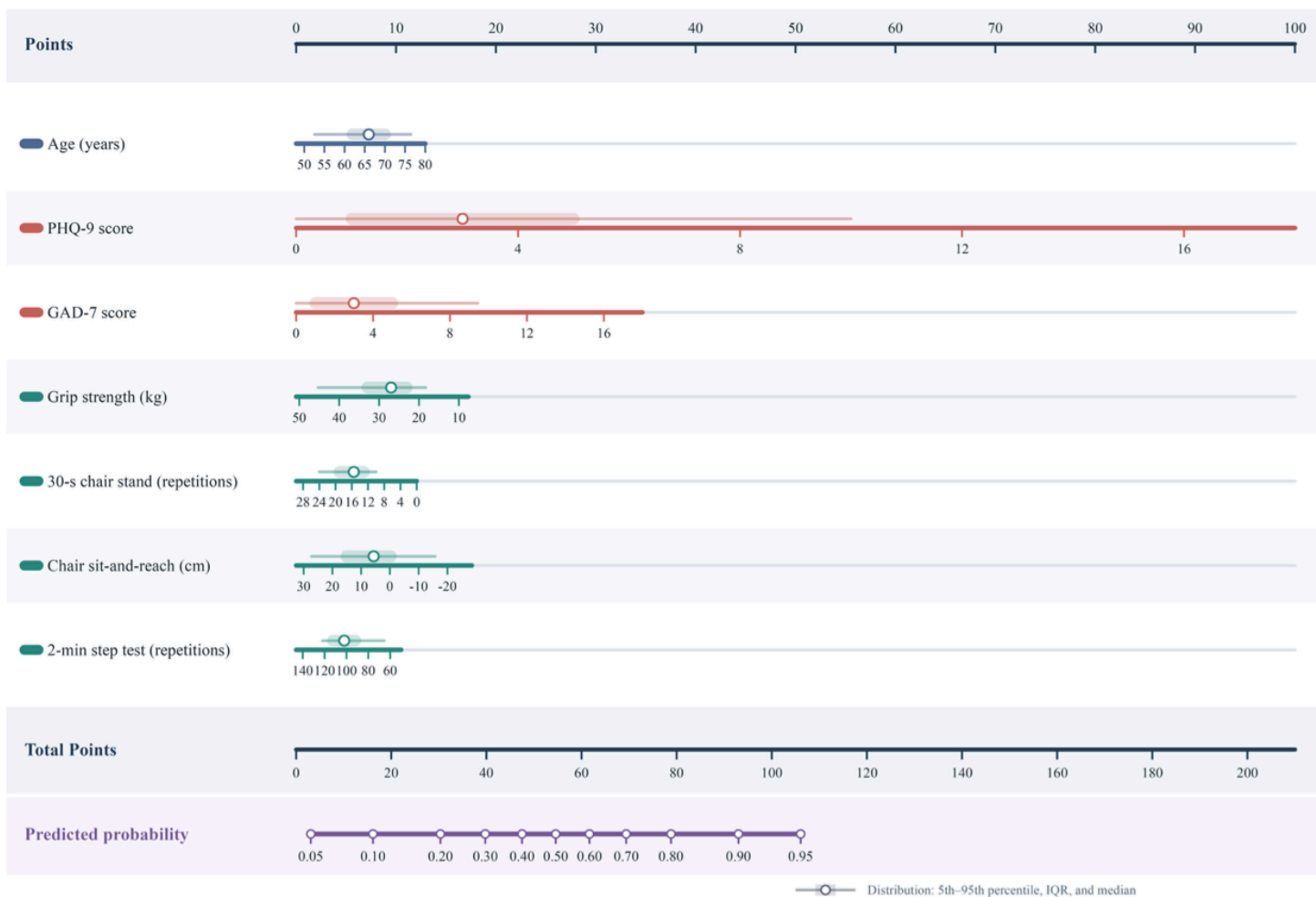


Figure 4

Nomogram for estimating the probability of current poor sleep quality in middle-aged and older adults with abdominal obesity.

For each predictor, a point value is assigned by projecting its observed value onto the “Points” scale. The individual point values are summed to obtain the total score, which corresponds to the estimated probability of current poor sleep quality. PHQ-9, Patient Health Questionnaire-9; GAD-7, Generalized Anxiety Disorder-7.

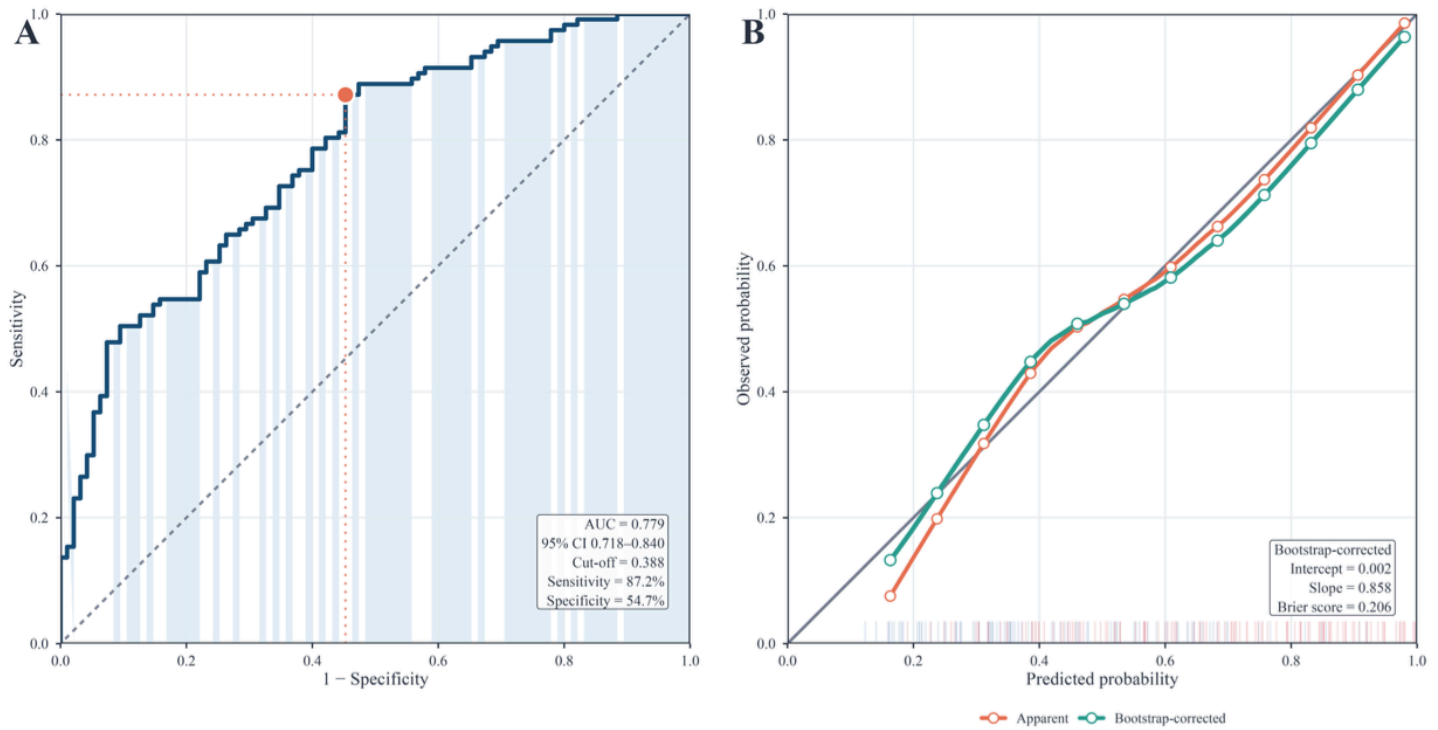


Figure 5

Discrimination and calibration of the final model for identifying current poor sleep quality.

(A) Receiver operating characteristic curve of the final model. The apparent area under the curve was 0.779 (95% confidence interval [CI], 0.718–0.840). The highlighted point indicates the optimal probability threshold determined using the Youden index. (B) Calibration curves of the final model. The gray diagonal line indicates perfect calibration, the coral curve indicates apparent calibration, and the teal curve indicates optimism-corrected calibration based on 1,000 bootstrap resamples. Short vertical ticks along the x-axis show the distribution of predicted probabilities: blue ticks represent participants with Pittsburgh Sleep Quality Index (PSQI) scores ≤ 5 , and red ticks represent those with PSQI scores > 5 . Abbreviation: AUC, area under the curve.

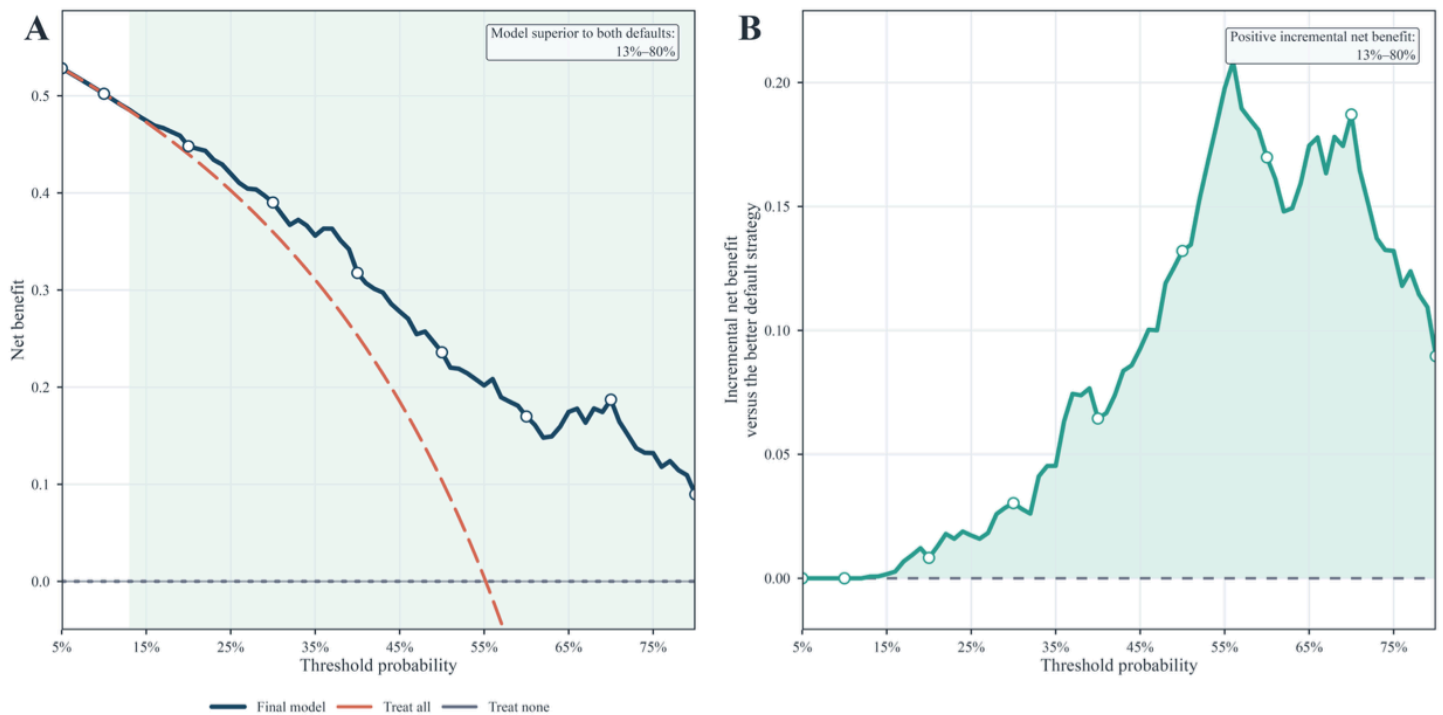


Figure 6

Decision curve analysis of the final prediction model.

(A) Net benefit of the final model, the “Treat all” strategy, and the “Treat none” strategy across threshold probabilities ranging from 5% to 80%. (B) Incremental net benefit of the final model relative to the better default strategy. The shaded region indicates the threshold range in the development sample in which the final model showed greater theoretical net benefit than both default strategies.

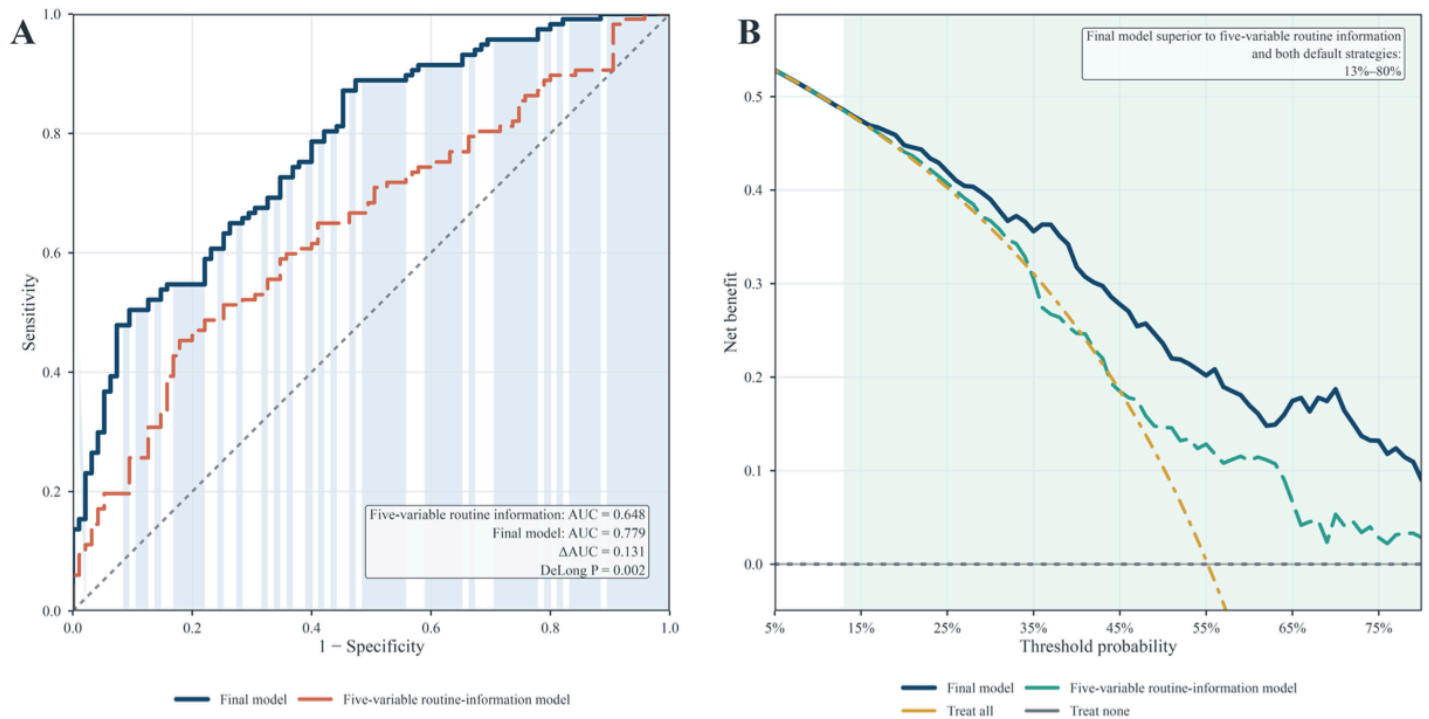


Figure 7

Comparison of predictive performance between the routine-information model and the final model. (A) Receiver operating characteristic (ROC) curves of the two models. (B) Decision curve analysis comparing the theoretical net benefits in the development sample of the two models with the “Treat all” and “Treat none” strategies. The routine-information model included age, sex, number of disease categories, alcohol consumption, and exercise status. AUC, area under the curve; CI, confidence interval.

Supplementary Files

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