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Developing a comprehensive malnutrition prediction model for the elderly in nursing homes

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Abstract

Purpose Malnutrition among elderly nursing home residents represents a critical public health challenge, particularly in rapidly aging societies such as China. This study aimed to develop and validate a predictive model for malnutrition risk tailored to this vulnerable population.

Methods We analyzed clinical data from 1,023 elderly individuals (aged ≥ 65 years) across 26: nursing homes in Wuhan, China (March–October 2023). Participants were randomly divided into model-building (70%, *n* = 716) and internal validation cohorts (30%, *n* = 307). LASSO regression and logistic regression identified key predictors, and a nomogram was constructed. Model performance was assessed via AUC, calibration curves, and decision curve analysis (DCA).

Results The malnutrition incidence was 46.37%. Five predictors were significant: feeding method (OR = 2.89, 95% CI: 1.75–4.76), dental status (OR = 0.56, 95% CI: 0.37–0.86), physical inactivity (OR = 1.75, 95% CI: 1.09–2.80), Barthel Index (OR = 0.96 per 10-point decrease), and anemia (OR = 1.91, 95% CI: 1.10–3.30). The model showed excellent discrimination (AUC = 0.90, 95% CI: 0.85–0.94) and calibration (mean absolute error = 0.026). DCA indicated clinical utility across threshold probabilities (2–97%).

Conclusion This nomogram provides a robust tool for malnutrition risk stratification in nursing homes. Future studies should validate its generalizability across diverse populations and regions.

Keywords Elderly malnutrition, Predictive model, Nursing homes, LASSO regression, China

Introduction

The global demographic shift toward aging populations presents formidable public health challenges, particularly in China, where individuals aged ≥ 65 years exceeded 190 million in 2020 and are projected to grow rapidly [1, 2]. This "silver tsunami" underscores the urgent need for robust elderly care systems, especially in addressing malnutrition—a prevalent yet underprioritized issue affecting 20–50% of nursing home residents globally [3]. In China, institutionalized elderly face elevated malnutrition risks due to physiological decline, suboptimal meal quality, and socioeconomic disparities [4].

While predictive models for malnutrition risk have advanced internationally [5, 6], their application in China remains limited. Existing tools often overlook region-specific factors such as dietary habits, care infrastructure, and socioeconomic gradients. This study bridges this gap by developing a tailored prediction model for Chinese

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nursing homes, integrating LASSO regression and logistic regression to identify key risk factors. Our work aims to enhance clinical decision-making, optimize nutritional interventions, and ultimately improve quality of life for this vulnerable population.

Literature review

Malnutrition in elderly care facilities is a multifactorial challenge, intricately linked to chronic diseases, functional decline, and socioeconomic determinants [7, 8]. The Global Leadership Initiative on Malnutrition (GLIM) criteria provide standardized diagnostic frameworks [9], yet their implementation in China lags due to unique institutional and cultural contexts. Nationally, malnutrition prevalence among community-dwelling elderly is 17.9% [10], rising sharply in nursing homes—a disparity driven by factors such as limited access to nutrient-dense diets and inadequate caregiver training [11].

Age-related physiological changes (e.g., reduced appetite, dysphagia) and psychosocial stressors (e.g., social isolation) exacerbate malnutrition risks [12, 13]. Lin et al. [14] highlighted that solitary living significantly predicts malnutrition due to diminished meal preparation capacity and social support.

Internationally, machine learning algorithms (e.g., random forests) have achieved 85% accuracy in predicting malnutrition risk [15], while biomarker discovery enhances model objectivity [16]. However, Chinese studies predominantly focus on community populations, neglecting institutionalized elderly [17]. Chen et al. [18] developed a sarcopenia-specific nutritional tool, yet broader applicability remains untested.

Despite progress, China lacks validated models addressing nursing home heterogeneity—variations in regional economics, care quality, and dietary practices [19]. Cross-cultural collaborations and multi-center validation are essential to refine predictive tools and align them with China's aging care priorities [20].

Methods

Study design and participants

This cross-sectional study enrolled 1,023 elderly residents (aged ≥ 65 years) from 26 licensed nursing homes in Wuhan, China, between March and October 2023. Participants were randomly allocated into a model-building cohort (70%, $n = 716$) and an internal validation cohort (30%, $n = 307$) using a random number table. Exclusion criteria included severe cognitive impairment (e.g., dementia), terminal illnesses, or inability to provide informed consent. Inclusion criteria required participants to be permanent Wuhan residents with intact communication abilities. Ethical approval was obtained from the Medical Ethics Committee of the Affiliated Geriatric Hospital of Wuhan University of Science and Technology, and written informed consent was secured from all participants.

Data collection

Data were collected under the National Basic Public Health Service Program, which mandates annual health evaluations for community-dwelling elderly, including nursing home residents. The Qingling Street Community Health Service Center conducted:

(1) Questionnaire Surveys: Utilizing the Mini-Nutritional Assessment Short-Form (MNA-SF) [21], a validated tool for nutritional screening.
(2) Physical Examinations: Including blood tests, electrocardiograms (ECG), and abdominal ultrasounds (USG).
(3) Clinical Assessments: Functional capacity evaluation via the Barthel Index and documentation of comorbidities (e.g., anemia, hypertension).
(4) A multidisciplinary team (physicians, nurses, ultrasonographers) performed all assessments after standardized training to ensure protocol adherence and data homogeneity.

Data management

Data were dual-entered into Epidata 3.1 to minimize errors, cross-verified by independent personnel, and exported to SPSS 26.0 and R 4.2.1 for analysis. Physical examination records were digitized using the Wuhan Entrepreneur Physical Examination System.

Statistical analysis

Variable selection was performed using LASSO (Least Absolute Shrinkage and Selection Operator) regression with 10-fold cross-validation to mitigate multicollinearity, identifying key predictors at an optimal penalty parameter ($\lambda = 0.014$). Significant variables retained by LASSO were incorporated into a binary logistic regression model, with model fit optimized via the Akaike Information Criterion (AIC). Model performance was evaluated through discrimination (area under the receiver operating characteristic curve, AUC), calibration (Hosmer-Lemeshow test and calibration plots), and clinical utility (decision curve analysis, DCA) across threshold probabilities of 2–97%. All analyses were conducted in SPSS 26.0 and R 4.2.1, with statistical significance defined as $P < 0.05$.

Results

Participant characteristics

A total of 1,023 elderly individuals (aged ≥ 65years) were enrolled from 26 nursing institutions in Wuhan, Hubei Province, China. Participants were randomly divided into a model-building cohort (70%, $n = 716$) and an internal

Table 1 Cohort allocation and baseline characteristics

Group	Model-Building Group	Validation Group
Training samples	573	-
Test samples	143	-
Persistent samples	-	307
Sample size	716	307
Percentage	70%	30%

Table 2 Baseline characteristics of model-building and validation cohorts

Characteristics	Model-Building Group($n=716$)	Validation Group($n=307$)	t/Z/χ2	*P*
Gender [*n* (%)]			0.003	0.956
Male	257(35.89%)	109(35.50%)	-	-
Female	459(64.11%)	198(64.50%)		
Age			2.219	0.072
65–74 years	117(16.35%)	52(16.93%)	-	-
75–84 years	323(45.11%)	139(45.28%)		
85–94 years	273(38.13%)	115(37.46%)		
95 years and above	3(0.42%)	1(0.32%)		
Marital Status			0.000	0.938
Unmarried	5(0.69%)	2(0.65%)	-	-
Married	308(43.02%)	131(42.67%)		
Divorced "or" Widowed	403(56.28%)	174(56.67%)		
Education Level			1.458	0.138
Primary School-and Below	123(17.17%)	55(17.91%)	-	-
Junior High School	145(20.25%)	63(20.52%)		
High School	248(34.63%)	107(34.85%)		
College and Above	200(27.93%)	82(26.71%)		
Nutritional Status			1.825	0.037
Normal Nutritional Status	119(16.62%)	61(19.87%)	-	-
Risk of Malnutrition	265(37.01%)	122(39.74%)		
Malnutrition Present	332(46.37%)	124(40.39%)		

validation cohort (30%, $n=307$) using stratified sampling in SPSS (version 26.0) to ensure demographic and clinical homogeneity (Table 1).

Clinical data comparison

Baseline characteristics between cohorts showed no significant differences ($P>0.05$; Table 2). Stratification of the model-building cohort into malnourished ($n=332$) and non-malnourished ($n=384$) subgroups revealed marked disparities ($P<0.05$) in feeding methods, dental status, exercise habits, Barthel Index (BI) scores, and comorbidities (e.g., anemia, dementia; Table 3).

Variable selection via LASSO regression

To address multicollinearity among 27 candidate risk factors, we first generated a correlation matrix (Table 4), identifying moderate-to-strong correlations (e.g., feeding method vs. tooth count,$\rho=0.55$; lack of exercise vs. Barthel Index,$\rho=0.45$). LASSO regression with L1 penalty was then applied to select predictors while shrinking non-essential coefficients to zero. Optimal regularization strength ($\lambda=0.014$) was determined via 10-fold cross-validation (Fig. 1B), minimizing mean squared error (MSE) and preventing overfitting. Five predictors survived selection: feeding method, number of teeth, lack of exercise, Barthel Index score, and anemia, each demonstrating clinical relevance (e.g., tooth loss impairing mastication, anemia reflecting micronutrient deficits). Subsequent multivariable logistic regression confirmed their independent associations with malnutrition risk (adjusted odds ratios in Table 5), ensuring a parsimonious and interpretable model.

Model development and validation

A nomogram integrating the five predictors demonstrated strong discriminative ability (C-index = 0.85; Fig. 2). ROC analysis showed AUC values of 0.90 (model-building cohort) and 0.88 (validation cohort), with overlapping curves (Fig. 3). Calibration curves (Fig. 4) and the Hosmer-Lemeshow test ($P=0.45$) confirmed alignment between predicted and observed risks. Decision curve analysis (Fig. 5) indicated clinical utility across threshold probabilities (2–97%).

Discussion

Key findings

This study addresses the critical public health challenge of malnutrition among elderly residents in nursing homes, driven by rapid population aging and rising chronic disease burdens. Analyzing data from 26 institutions in Wuhan, China, we identified a malnutrition prevalence of 46.37%, higher than community-dwelling elderly (17.9% [17]) but lower than European care facilities (50% [20]).This disparity may stem from regional socioeconomic disparities, variability in institutional care standards, and culturally ingrained dietary patterns. For instance, cost-driven dietary compromises in Wuhan's facilities may exacerbate nutrient deficits.

Mechanistic insights

The identified risk factors for malnutrition are underpinned by distinct biological and behavioral pathways. First, compromised dental health—particularly tooth loss—disrupts mastication efficiency, leading to preferential consumption of soft, low-protein diets and subsequent micronutrient deficiencies (e.g., vitamin B12, iron) [7]. Second, enteral tube feeding, while calorically adequate, often fails to address nutritional gaps due to formula monotony (limited diversity in micronutrient profiles) and suboptimal absorption kinetics,

Table 3 Comparison of clinical data between the Non-Malnourished group and the malnourished group

Characteristics	Non-Malnutrition Group(*n* = 384)	Malnutrition Group (*n* = 332)	t/Z/χ2	*P*
Age			-0.51	0.955
65–74 years	68(17.71%)	49(14.76%)		
75–84 years	175(45.57%)	148(44.58%)		
85–94 years	148(38.54%)	125(37.65%)		
95 years and above	2(0.52%)	1(0.30%)		
Gender			0.097	0.723
Male	139(36.20%)	118(35.54%)		
Female	245(63.80%)	214(64.45%)		
Marital Status			0.000	0.926
Unmarried	3(0.78%)	2(0.60%)		
Married	165(42.97%)	143(43.07)		
Divorced "or" Widowed	215(55.99%)	188(56.63%)		
Education Level			-1.457	0.135
Primary Schooland Below	65(16.93%)	58(17.47%)		
Junior High School	76(19.79%)	69(20.78%)		
High School	132(34.38%)	116(34.94%))		
College and Above	109(28.36%)	91(27.41%)		
Duration of Residence in Elderly Care Institution			-0.062	0.915
Feeding Method			101.286	< 0.001
Oral	342(89.06%)	169(50.90%)		
Tube Feeding	42(10.93)	163(49.10%)		
Number of Teeth			8.375	0.004
≤ 20 Teeth	235(61.20%)	239(71.99%)		
20 Teeth	149(38.80%)	93(28.01%)		
Smoking History			3.736	0.051
Yes	65(16.93%)	36(10.84%)		
No	319(83.07%)	296(89.16%)		
Drinking History			3.862	0.052
Yes	35(9.11%)	19(5.72%)		
No	349(90.89%)	313(94.28%)		
Diabetes Mellitus			1.529	0.216
No	242(63.02%)	226(68.07%)		
Yes	142(36.98%)	106(31.93%)		
Stroke			12.552	< 0.001
No	211(54.95%)	133(40.06%)		
Yes	173(45.05%)	199(59.94%)		
Hypertension			0.379	0.532
No	127(33.07%)	116(34.94%)		
Yes	257(66.93%)	216(65.06%)		
Parkinson's Disease			1.252	0.226
No	360(93.75%)	299(90.06%)		
Yes	24(6.25%)	33(9.94%)		
Dementia			25.263	< 0.001
No	261(67.97%)	159(47.89%)		
Yes	123(32.03%)	173(52.11%)		
Coronary Heart Disease (CHD)			4.182	0.051
No	280(72.92%)	265(79.82%)		
Yes	104(27.08%)	67(20.18%)		
COPD			2.505	0.116
No	319(83.07%)	259(78.01%)		
Yes	65(16.93%)	73(21.99%)		
Chronic Bronchitis			0.015	0.901
No	257(66.93%)	223(67.16%)		
Yes	127(33.07%)	109(32.83%)		
Gastroesophageal Reflux Disease (GERD)			0.297	0.586

Table 3 (continued)

Characteristics	Non-Malnutrition Group($n = 384$)	Malnutrition Group ($n = 332$)	t/Z/χ2	*P*
No	377(98.18%)	322(96.99%)		
Yes	7(1.82%)	10(3.01%)		
Tumor			0.062	0.803
Yes	365(95.05%)	309(93.07%)		
No	19(4.95%)	23(6.93%)		
Insufficient Exercise			4.402	< 0.001
No	196(51.04%)	129(38.86%)		
Yes	188(48.96%)	203(61.14%)		
Hyperlipidemia			5.296	< 0.001
No	183(47.66%)	203(61.14%)		
Yes	201(52.34%)	129(38.86%)		
Liver Disease			3.019	0.482
No	297(77.34%)	284(85.54%)		
Yes	87(22.65%)	48(14.45%)		
Abnormal Electrocardiogram (ECG)			4.214	< 0.001
No	114(29.69%)	63(18.97%)		
Yes	270(70.31%)	269(81.02%)		
Abnormal Urinalysis			2.912	0.831
No	327(85.16%)	260(78.31%)		
Yes	57(14.84%)	72(21.69%)		
Anemia			15.601	< 0.001
No	342(89.06%)	255(76.81%)		
Yes	42(10.94%)	77(23.19%)		
Number of Medications Median [M(P25,P75),Units]	7(5,9)	7(5,10)	-0.326	0.716
Barthel Index Score[M(P25,P75), Points]	40(20,60)	10(0,20)	-11.836	< 0.001

Table 4 Correlation matrix of potential risk factors

Variable	Feeding Method	Number of Teeth	Lack of Exercise	BI Score	Anemia
Feeding method	1	0.55	-0.42	-0.31	0.21
Number of teeth	0.55	1	-0.35	-0.29	0.19
Lack of exercise	-0.42	-0.35	1	0.45	-0.25
BI score	-0.31	-0.29	0.45	1	-0.3
Anemia	0.21	0.19	-0.25	-0.3	1

exacerbating deficiencies in vulnerable populations [8]. Third, anemia emerges as both a consequence and contributor to malnutrition, with iron and vitamin B12 deficits—prevalent in economically constrained diets—directly impairing erythropoiesis and protein synthesis, thereby perpetuating a cyclical decline in nutritional status [9]. These insights highlight the need for interventions targeting both structural barriers (e.g., dental rehabilitation) and systemic nutrient delivery optimization.

Intervention strategies

Intervention strategies should adopt a multifaceted approach, including: optimizing enteral formulas and oral diets (e.g., high-energy soft foods) for personalized nutrition; implementing regular oral health screenings, denture services, and anti-inflammatory protocols to address dental decline; managing anemia through iron-, vitamin B12-, and folate-fortified diets coupled with hemoglobin monitoring; providing assistive feeding tools and caregiver training for individuals with low Barthel Index scores (reflecting impaired activities of daily living); and fostering multi-sector collaboration among healthcare providers, policymakers, and community stakeholders to ensure scalable and sustainable nutritional support systems.

Policy integration and scalability

The implementation of our predictive model aligns with China's National Basic Public Health Service Program, which mandates nutritional screening for elderly populations. To operationalize this integration, we propose a three-pronged approach: (1) developing standardized training modules to equip nursing home staff with nomogram-based malnutrition risk assessment skills; (2) advocating for government subsidies to improve meal quality in underfunded facilities, particularly in socioeconomically disadvantaged regions; and (3) establishing a national registry to monitor malnutrition prevalence and intervention efficacy through risk-stratified data. Such policy-driven initiatives could reduce healthcare costs linked to malnutrition-related complications (e.g., infections, hospitalizations), as evidenced by a 20% cost reduction in European pilot programs adopting similar tools [20]. This framework not only enhances care quality

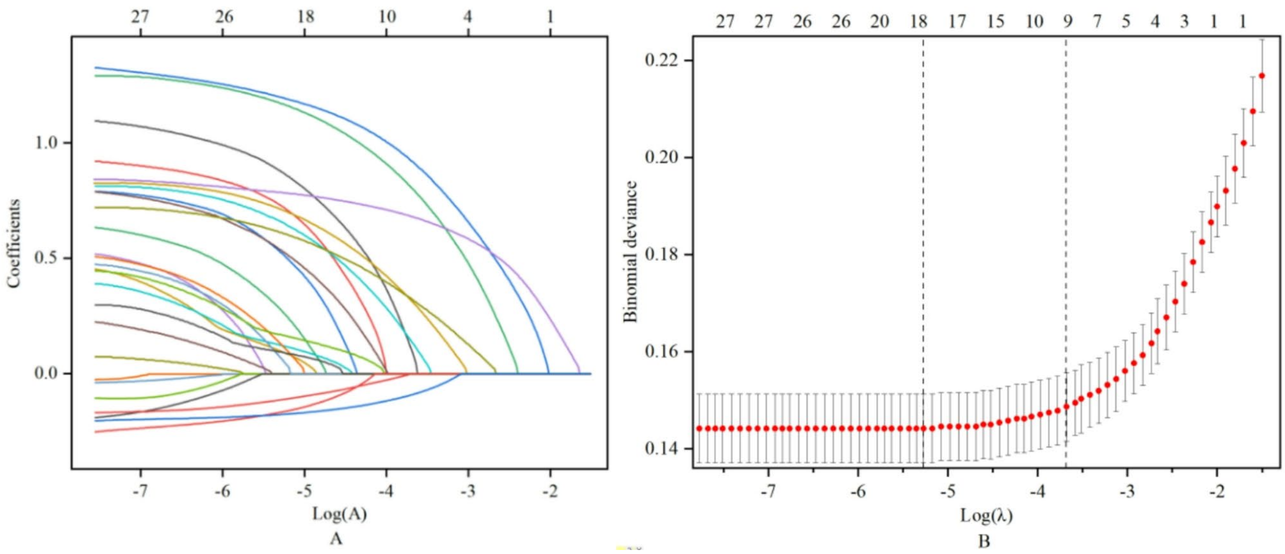

Fig. 1 Optimal Parameter Selection in the LASSO Model. Note: The left panel shows the distribution of LASSO coefficients for all risk factors. The right panel depicts the optimal parameter selection in the LASSO model, where the optimal λ (0.014) was chosen at one standard error above the minimum mean squared error (MSE) to avoid overfitting

Table 5 Multifactorial analysis results of malnutrition risk in the elderly

Variables	Regression Coefficient (β)	Odds Ratio (95% CI)	*P*-value
Feeding method	1.062	2.886 (1.751, 4.762)	< 0.001
Number of teeth	-0.582	0.558 (0.365, 0.856)	0.008
Lack of exercise	0.558	1.747 (1.091, 2.802)	0.042
BI score	-0.041	0.962 (1.101, 3.303)	< 0.001
Anemia	0.645	1.906 (1.102, 3.301)	0.022

Note: Correlation coefficients are presented, with values in bold indicating moderate to strong correlations (|ρ| > 0.5)

but also ensures scalable and equitable resource allocation across China's diverse elderly care landscape.

Study limitations and future directions

While our predictive model demonstrates robust performance (AUC: 0.90), its generalizability requires validation across diverse socioeconomic and geographic contexts, given the single-city sampling (Wuhan, China) and exclusion of cognitively impaired individuals (30–50% of nursing home residents [22]). The cross-sectional design further limits causal inference and longitudinal tracking of malnutrition progression. To address these limitations, future work will prioritize multi-center validation (spanning urban-rural and socioeconomic gradients), longitudinal cohorts with repeated measures to delineate dynamic risk trajectories, and inclusion of cognitively impaired populations via observational protocols (e.g., mealtime behavior quantification [10]) and biomarker-assisted tools. Mechanistic studies exploring pathways such as dental decline-metabolic dysfunction interplay [23, 24] will refine risk stratification, while policy-driven collaborations integrating healthcare and community resources aim to translate findings into scalable interventions for global aging populations.

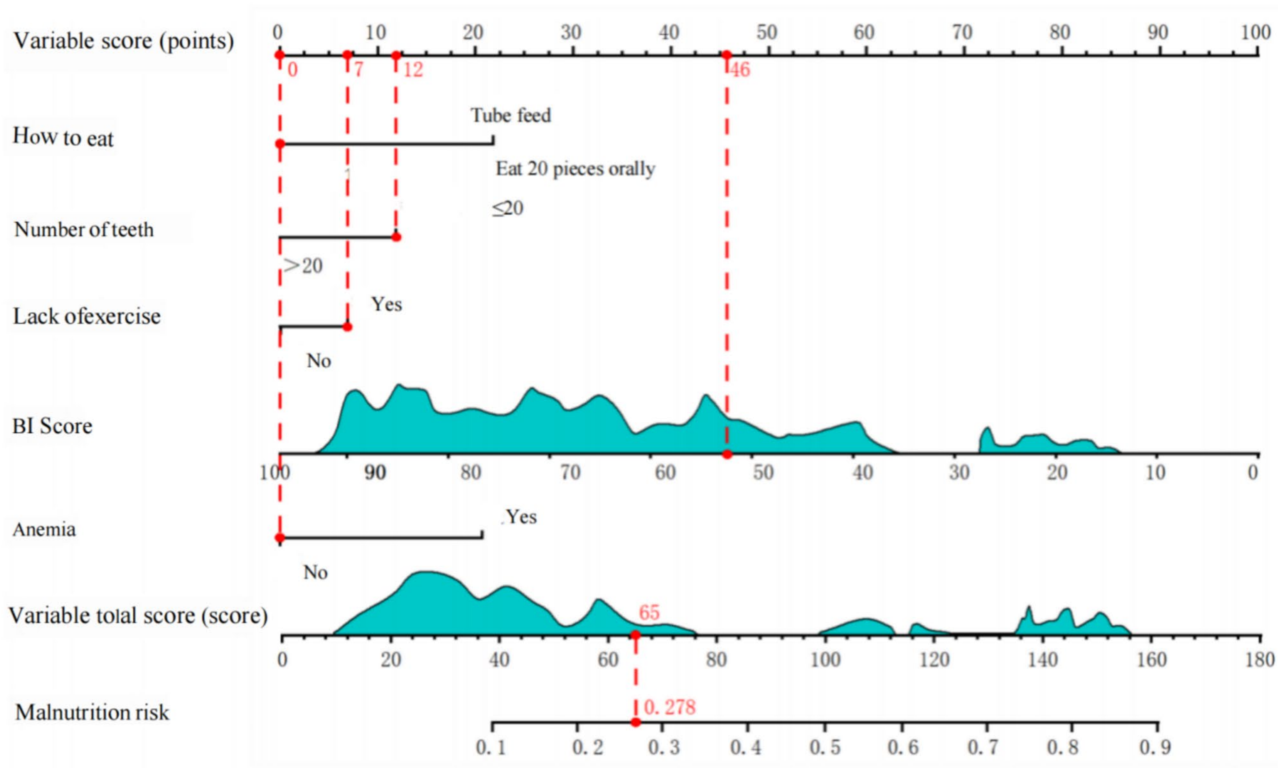

Fig. 2 Individualized nomogram predictive model for malnutrition risk in nursing home elderly

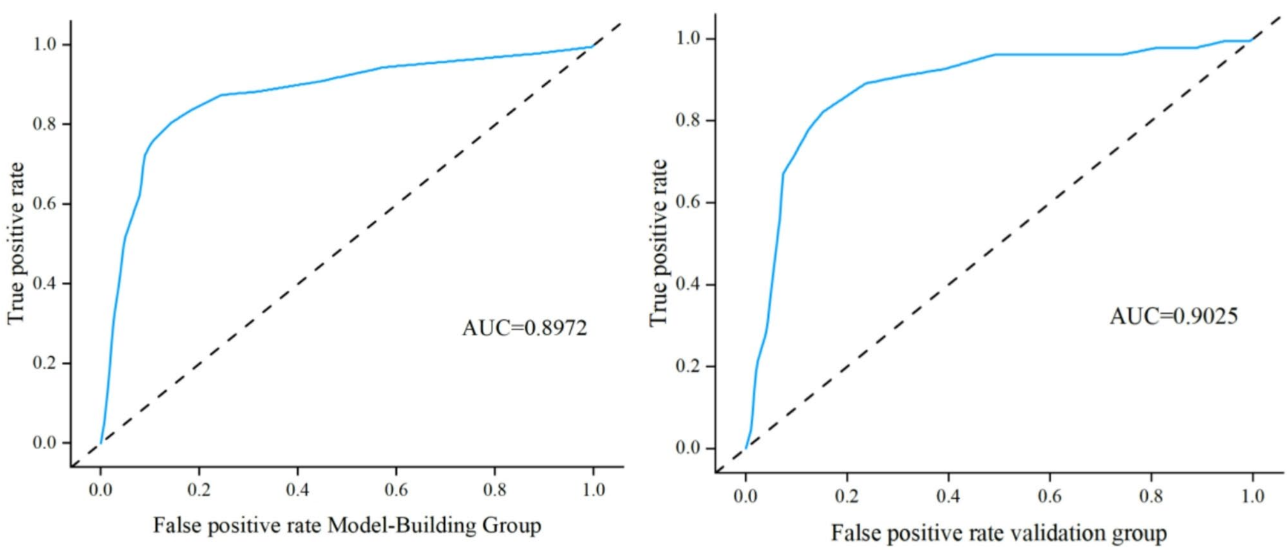

Fig. 3 ROC curves of the prediction model in the modeling and validation cohorts

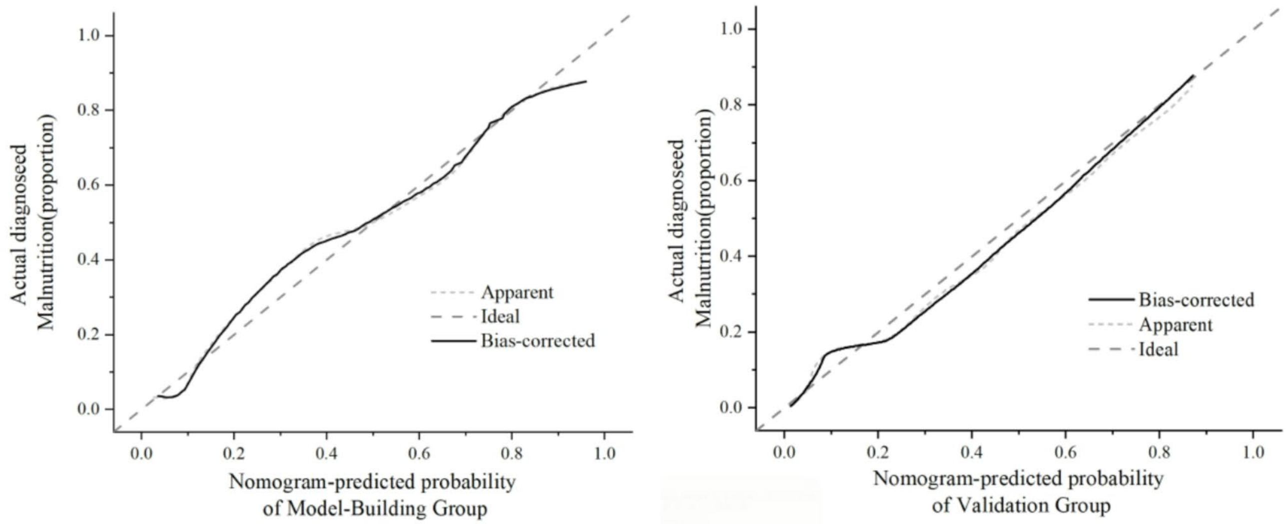

Fig. 4 Calibration curves of the prediction model in the modeling and validation cohorts

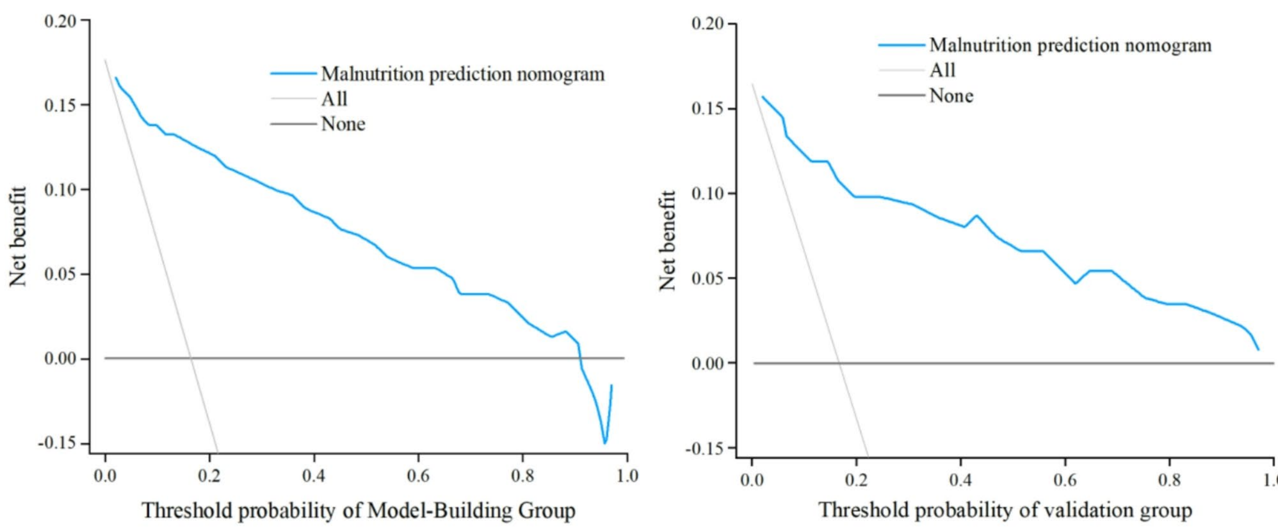

Fig. 5 Decision curves of the prediction model in the modeling and validation cohorts

Conclusion

This study provides a validated tool for malnutrition risk prediction in Chinese nursing homes. Targeted interventions addressing both institutional governance and individual risk profiles hold significant potential to enhance health outcomes among elderly nursing home residents.

Author contributions

Yan Wu: writing-original draft. Wei Tan: conceptualization and proof reading. Wenlong Yi: polishing the text of the manuscript. Yujuan Chen: writing-review & editing. All authors agreed on the final version.

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Not applicable.

Data availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request. De-identified data will be shared under a Data Transfer Agreement to ensure compliance with ethical standards.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Affiliated Geriatric Hospital of Wuhan University of Science and Technology, and written informed consent was secured from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Office of the Leading Group of the State Council for the Seventh National Population Census. (2021). Report on the Seventh National Population Census. Retrieved from https://www.gov.cn/guoqing/2021-05/13/content_5606149.htm
2. Zhu D, Fu P, Wang X, et al. Malnutrition risk and influencing factors among elderly residents in nursing homes. Chin J Gerontol. 2021;41(12):2657–62.
3. Sun JQ, Huang CY, Mo BQ et al. Survey Report on Nutritional Risk among Elderly People in Five Major Cities in China [C]. In: Proceedings of the 11th National Nutrition Science Conference of the Chinese Nutrition Society and International DRIs Symposium; 2013: Hangzhou, China. pp. 246–247.
4. Guigoz Y, et al. Mini nutritional assessment: a practical assessment tool for grading the nutritional state of elderly patients. Facts Res Gerontol. 1994;62:15–59.
5. De Sire A, et al. Sarcopenic dysphagia, malnutrition, and oral frailty in elderly: a comprehensive review. Nutrients. 2022;14(5):982.
6. De Almeida Dantas PP, et al. Pairs of natural teeth rather than use of dental prosthesis are associated with nutritional status in older adults: a cross-sectional study. J Dent. 2021;108:103656.
7. Kurik G, Kelly-Bissue C, Lhmus A, et al. Standardising and simplifying the global leadership initiative on malnutrition (GLIM) for its more general application. Clin Nutr ESPEN. 2024;62:120–7.
8. Lan SH, et al. Tube feeding among elders in long-term care facilities: a systematic review and meta-analysis. J Nutr Health Aging. 2017;21(1):31–7.
9. Zhang X, Zhuang YY. Survey on dietary and nutritional status of tube-fed elderly in nursing homes. Chin J Enter Parenter Nutr. 2018;25(2):95–7.
10. Yin Q, et al. Analysis of the correlation between anemia and nutritional status in centenarians from Zhongxiang, Hubei. Chin J Clin Healthc. 2022;25(2):213–7.
11. Sahin S, et al. Prevalence of anemia and malnutrition and their association in elderly nursing home residents. Aging Clin Exp Res. 2016;28(5):857–62.
12. Zhao M, et al. Nutritional status and influencing factors of the elderly in nursing institutions in Jinan City. Chin J Gerontol. 2019;39(20):5120–4.
13. Cederholm T, et al. The role of malnutrition in older persons with mobility limitations. Curr Pharm Design. 2014;20(19):3173–7.
14. Ning H, et al. Malnutrition and its associated factors among elderly Chinese with physical functional dependency. Public Health Nutr. 2021;24(6):1404–14.
15. Su XN, et al. Correlation between nutritional status and quality of life in community elderly and its influencing factors. Nurs Res. 2018;32(11):1794–6.
16. Lin WQ, et al. The unhealthy lifestyle factors associated with an increased risk of poor nutrition among the elderly population in China. J Nutr Health Aging. 2017;21(9):943–53.
17. Chen QC, et al. Correlation between sarcopenia and risk of falls and fractures in middle-aged and elderly people and nutritional deficiency indicators. Chin J Geriatric Med. 2020;39(7):817–20.
18. Aller M, et al. The impact of malnutrition on hospitalization and mortality in older adults: a meta-analysis. J Nutr Gerontol Geriatr. 2021;40(3):123–34.
19. Smith AC, et al. Screening for malnutrition in community-dwelling older adults: a systematic review and meta-analysis. J Am Med Dir Assoc. 2020;21(4);471–9.
20. van der Pol JMH, et al. The effect of nutritional interventions on quality of life in malnourished older adults: a randomized controlled trial. Clin Nutr. 2022;41(5):1234–45.
21. Ma Lina J, Tong L. Expert consensus on multidisciplinary Decision-Making models for malnutrition in elderly people in China (2023) [J]. Chin J Clin Healthc. 2023;26(4):433–45.
22. Beauregard KL, de Grood L. Malnutrition in older adults: a scope of practice review. J Acad Nutr Dietetics. 2021;121(5):882–93.
23. De Almeida Dantas PP, Colussi PRG, Da Silva Dezingrini K, et al. Pairs of natural teeth rather than use of dental prosthesis are associated with nutritional status in older adults: a cross-sectional study. J Dent. 2021;108:103656.
24. Hiratsuka T, Komiyama T, Ohi T, et al. Contribution of systemic inflammation and nutritional status to the relationship between tooth loss and mortality in a community-dwelling older Japanese population: a mediation analysis of data from the Tsurugaya project. Clin Oral Invest. 2020;24(6):2071–7.

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