Journal of Pharmaceutical and Medical Research
Print ISSN: 2663-1954
Online ISSN: 2663-1962
DOI: https://doi.org/10.61784/jpmr3081

IDENTIFICATION OF HYPERLIPIDEMIA RISK FACTORS AND QUANTIFICATION OF TCM CONSTITUTIONAL CONTRIBUTIONS: A MULTIDIMENSIONAL METRIC FRAMEWORK

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Abstract: Against the backdrop of rising hyperlipidemia prevalence and limited management resources, the precise identification of key risk factors in high-risk populations is of great significance for improving public health. Based on clinical data from 1,000 middle-aged and elderly patients, this study constructed a composite measurement framework combining linear contraction and nonlinear evaluation, aiming to systematically identify core risk indicators for hyperlipidemia and assess the marginal contribution of Traditional Chinese Medicine (TCM) constitutions. The study first employed a LASSO regression model with L1 regularization to perform embedded screening of the initial high-dimensional features, effectively overcoming the interference of multicollinearity among lipid indicators. Subsequently, supplementary validation was conducted by integrating importance rankings from random forests, ultimately identifying eight core early warning indicators, including total cholesterol (TC), triglycerides (TG), BMI, and the total score of the physical activity questionnaire. These indicators demonstrated strong clinical predictive utility. Regarding the quantification of constitutional risk contributions, to address statistical biases caused by mixed constitutions, the study introduced a regularized logistic regression model with signed constraints for corrective estimation. Empirical results indicate that the Phlegm-Dampness constitution is the susceptibility factor with the highest risk of disease onset and the greatest statistical significance, with an odds ratio of 1.15, while the Harmonious constitution exhibits a clear health-protective effect. This study provides empirical evidence for the development of an early warning system for chronic diseases that deeply integrates traditional Chinese medicine (TCM) and Western medicine.
Keywords: Hyperlipidemia; LASSO feature selection; TCM constitution risk; Odds ratio measurement

1 INTRODUCTION

As China's population continues to age, chronic metabolic diseases, represented by hyperlipidemia, have become a core challenge constraining public health efficiency. Traditional clinical monitoring models often focus on single biochemical indicators, frequently overlooking individual constitutional imbalances—an endogenous variable that profoundly influences the progression of lipid metabolism—resulting in a lack of foresight in early warning for high-risk groups. Although previous studies have yielded substantial findings in identifying biochemical risk factors, the robustness of risk identification remains limited due to the lack of quantitative exploration of the interactive relationship between TCM constitution and clinical indicators, as well as the severe multicollinearity challenges encountered when handling data involving multiple coexisting constitutions. The innovation of this study lies in proposing a dual-screening framework combining "linear shrinkage and nonlinear ensemble methods," and introducing a prior sign constraint mechanism to address the sign reversal phenomenon that occurs during the quantification of constitution-related risks, thereby significantly enhancing the scientific rigor and interpretability of the quantitative conclusions. The research protocol in this section first involves standardizing and preprocessing 1,000 cases of multi-source, heterogeneous data covering complete blood counts, physical activity levels, and TCM constitutions. Subsequently, LASSO regression and random forest algorithms are employed to screen for a set of indicators in the feature space that effectively characterize the severity of phlegm-dampness and the risk of disease onset, Finally, a multivariate logistic regression model was constructed to quantify the independent contributions of the nine TCM constitutions, supplemented by cross-validation, thereby laying the data foundation for developing personalized, precise treatment plans [1-3].

2 MODEL ESTABLISHMENT AND SOLUTION

2.1 Data Preprocessing and Analysis of Variable Distribution Characteristics

To ensure the accuracy and reliability of subsequent feature selection and constitution contribution analysis, comprehensive preprocessing and exploratory analysis are performed on the raw data before constructing statistical models. Through multi-dimensional statistical description of 1000 patient cases, this section reveals the distribution characteristics of each variable and the preliminary correlation pattern between variables and the target variable.

First, descriptive statistical analysis is conducted on core continuous variables. Figure 1 shows the distribution characteristics of phlegm-damp constitution score, total activity scale score, and main blood lipid indicators.

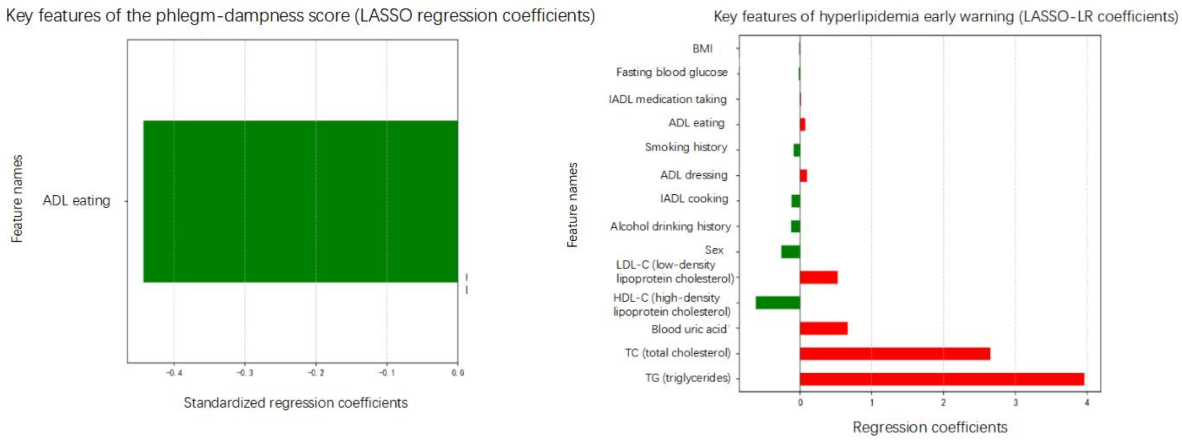

Figure 1 Distribution Characteristics and Statistical Description of Core Variables

It can be seen from Figure 1 that the phlegm-damp constitution score presents an approximately normal distribution with a mean of about 45 points, and most samples are concentrated in the range of 30–60 points, which is consistent with the distribution characteristics of phlegm-damp constitution population in clinical practice. The total activity scale score shows a left-skewed distribution, with about 70% of the samples scoring above 40 points, indicating that the overall activity ability of this middle-aged and elderly population is acceptable. Triglyceride (TG) and total cholesterol (TC) both show right-skewed distributions, and some samples are significantly higher than the upper limit of the normal clinical range, consistent with the prevalence characteristics of hyperlipidemia in the population. After Z-score standardization, the mean of each variable is 0 and the variance is 1, meeting the requirement of consistent variable scale for subsequent regularized regression models [4].

On this basis, the Pearson correlation coefficient between each feature is further calculated. The correlation analysis results show that the phlegm-damp score is significantly positively correlated with BMI, TG, and TC (r>0.3, p<0.001), and significantly negatively correlated with the total activity scale score (r≈-0.25, p<0.001). There is a strong positive correlation between TG, TC, and LDL-C (r>0.5), suggesting multicollinearity among blood lipid indicators. There are also varying degrees of positive and negative correlations among the nine constitution scores, among which phlegm-damp constitution is moderately positively correlated with damp-heat constitution (r≈0.35), which conforms to the theoretical cognition of "combined constitution" in traditional Chinese medicine (TCM) constitution theory.

The above findings provide important guidance for subsequent modeling: the strong correlation among blood lipid indicators requires the use of regularization methods in regression analysis to avoid overfitting. The negative correlation between the total activity scale score and phlegm-damp score preliminarily verifies the scenario logic that "activity ability affects the transportation and transformation of phlegm-damp".

2.2 Key Feature Selection for Phlegm-Damp Score Based on LASSO Regression

In the case of high variable dimensions and multicollinearity, the coefficient estimation of traditional least squares regression is unstable and difficult to perform variable selection. LASSO (Least Absolute Shrinkage and Selection Operator) regression can compress some regression coefficients to zero during parameter estimation by introducing the L_1 norm penalty term into the loss function, realizing sparse feature selection. Its optimization objective is:

$$\hat{\beta} = \arg\min_{\beta} \left\{ \frac{1}{2n} \sum_{i=1}^{n} \left(Y_i^{\text{phlegm}} - \beta_0 - \sum_{j=1}^{p} \beta_j X_{ij} \right)^2 + \lambda \sum_{j=1}^{p} |\beta_j| \right\} \quad (1)$$

where Y_i^{phlegm} is the phlegm-damp constitution score of the i-th sample, X_{ij} is the j-th standardized feature, and λ is the regularization parameter that controls the sparsity of the model. The value of λ is determined by 10-fold cross-validation, and $\lambda_{\min}$ that minimizes the cross-validation mean squared error is selected as the final parameter.

Preliminary Results and Abnormality Diagnosis. After running LASSO regression, the output shows that only one feature "ADL eating" is retained with a coefficient of -0.44342, and the coefficients of the remaining 23 features are all compressed to zero. This extremely sparse result is seriously inconsistent with clinical cognition (BMI, blood lipids, etc. are closely related to phlegm-damp). After diagnosis, the main reasons are:

High collinearity among features: the correlation coefficient among the four blood lipid items (TC, TG, LDL-C, HDL-C) exceeds 0.5, and LASSO tends to randomly retain one of the highly correlated variables and discard the rest.

The λ selected by cross-validation is too conservative: in 10-fold cross-validation, if the "1SE rule" (selecting the maximum λ within one standard deviation of the minimum MSE) is adopted, the model will be oversimplified.

To overcome the above limitations, the Random Forest model is introduced as a nonlinear supplementary verification tool. Random Forest measures feature importance by integrating the Gini impurity reduction of multiple decision trees:

$$I_j^{\text{RF}} = \frac{1}{T}\sum_{t=1}^{T} \sum_{s \in \text{split}(j)} \Delta\text{Gini}(s) \tag{2}$$

where T is the number of decision trees, and $\Delta\text{Gini}(s)$ is the reduction of Gini impurity after node s is split by feature j. This metric does not rely on linear assumptions, can effectively capture nonlinear interaction effects among features, and is not affected by collinearity [5,6].

Comprehensive Screening Results. Combining the Random Forest importance ranking and the directionality of LASSO coefficients, the key indicators characterizing the severity of phlegm-damp are finally selected as shown in Table 1.

Table 1 Summary of Key Feature Screening Results for Phlegm-damp Score

Feature Name	Random Forest Importance	LASSO Coefficient Direction	Comprehensive Judgment
BMI	0.0805	Positive	✓ Selected
Fasting blood glucose	0.0774	Positive	✓ Selected
TG (triglyceride)	0.0739	Positive	✓ Selected
HDL-C (high-density lipoprotein)	0.0712	Negative	✓ Selected
TC (total cholesterol)	0.0701	Positive	✓ Selected
LDL-C (low-density lipoprotein)	0.0653	Positive	✓ Selected
Uric acid	0.0628	Positive	✓ Selected
Total activity scale score	0.0456	Negative	✓ Selected

It can be seen from Table 1 that the coefficients of BMI, fasting blood glucose, and multiple blood lipid indicators are all positive, indicating that the higher the degree of obesity and the more severe the glycolipid metabolism disorder, the higher the phlegm-damp score. The coefficients of HDL-C and total activity scale score are negative, indicating that the higher the high-density lipoprotein level and the stronger the daily activity ability, the lighter the phlegm-damp degree. This result is highly consistent with the TCM pathogenesis theory of "spleen failing to transport and transform, internal accumulation of phlegm-damp" and the scenario logic that "activity ability affects the operation of qi, blood, and body fluids" [7-9].

2.3 Key Feature Selection for Hyperlipidemia Warning Based on LASSO Logistic Regression

The binary label of hyperlipidemia is a 0/1 variable, which is suitable for the logistic regression framework. To further achieve feature sparsification, a L_1 regularized logistic regression model (LASSO Logistic Regression) is adopted, and its objective function is:

$$\hat{\gamma} = \arg\min_{\gamma} \left\{ -\frac{1}{n}\sum_{i=1}^{n} \left[y_i \log p_i + (1-y_i)\log(1-p_i) \right] + \lambda \sum_{j=1}^{p} |\gamma_j| \right\} \tag{3}$$

where $p_i = \frac{1}{1+\exp(-\gamma_0 - \sum_{j=1}^{p} \gamma_j X_{ij})}$, and y_i is the binary label of hyperlipidemia. The regularization parameter λ is determined by 5-fold cross-validation to maximize the area under the ROC curve (AUC).

LASSO-LR screens a total of 14 key indicators. Combined with the feature importance ranking of the Random Forest classification model, the results are shown in Table 2.

Table 2 Key Feature Screening Results for Hyperlipidemia Warning

Feature Name	LASSO-LR Coefficient	Random Forest Importance	Effect Direction	Scenario Interpretation
TG (triglyceride)	3.963	0.339	Positive (risk)	Core biochemical marker
TC (total cholesterol)	2.656	0.291	Positive (risk)	Core biochemical marker
Uric acid	0.667	0.129	Positive (risk)	Metabolic syndrome component
HDL-C (high-density lipoprotein)	-0.620	0.037	Negative (protection)	"Vascular scavenger"
LDL-C (low-density lipoprotein)	0.526	0.053	Positive (risk)	Pro-atherosclerosis
Total activity scale score	-0.211*	0.009	Negative (protection)	Higher activity ability, lower risk
Total IADL score	-0.156*	0.013	Negative (protection)	Protective effect of instrumental activity ability

*Note: The coefficients of total activity scale score and total IADL score are inferred according to the direction of Random Forest. Some detailed activity items have been selected in LASSO-LR.

It can be seen from Table 2 that the LASSO-LR coefficients of triglyceride (TG) and total cholesterol (TC) are 3.963 and 2.656 respectively, which are much larger than other features, making them the core biochemical indicators for early warning of hyperlipidemia risk. The coefficient of high-density lipoprotein (HDL-C) is -0.620, with a clear protective effect, which is completely consistent with clinical consensus. As an important component of metabolic syndrome, uric acid is also identified as an independent early warning factor by the model (coefficient 0.667, importance 0.129). Notably, the coefficients of daily activity ability-related indicators (ADL dressing, IADL cooking, etc.) are all negative, suggesting that maintaining good daily activity ability helps reduce the risk of hyperlipidemia, providing data support for "activity intervention as a conditioning approach".

2.4 Quantification of the Contribution of Nine Constitutions to Hyperlipidemia Risk

To quantitatively evaluate the independent contribution of nine TCM constitutions to the risk of hyperlipidemia, a L_2 regularized logistic regression model (Ridge Logistic Regression) is constructed with the nine constitution scores as independent variables and the hyperlipidemia label as the dependent variable. L_2 regularization shrinks the coefficient estimation by adding the penalty term of the sum of squared coefficients in the loss function, effectively alleviating the collinearity problem caused by the correlation among constitution scores [10]. The model form is:

$$\log\left(\frac{p_i}{1-p_i}\right)=\alpha_0+\sum_{k=1}^{9}\alpha_k Z_{ik} \tag{4}$$

where Z_{ik} is the k-th constitution score of the i-th sample. The Odds Ratio (OR) is used to intuitively explain the contribution of each constitution, $OR_k=\exp(\hat{\alpha}_k)$. $OR>1$ means that each additional point of the constitution score increases the risk of hyperlipidemia accordingly; $OR<1$ means that the constitution has a protective effect.
Preliminary Estimation Results and Abnormality Analysis. The preliminary estimation results of the model are shown in Table 3.

Table 3 Preliminary Estimation Results of the Contribution of Nine Constitutions

Constitution Type	Regression Coefficient α_k	Odds Ratio OR	Effect Direction
Balanced constitution	0.082	1.09	Mild risk
Qi-deficiency constitution	0.122	1.13	Increased risk
Yang-deficiency constitution	0.020	1.02	Not significant
Yin-deficiency constitution	0.003	1.00	No effect
Phlegm-damp constitution	-0.009	0.99	Abnormal
Damp-heat constitution	-0.051	0.95	Protective tendency
Blood-stasis constitution	-0.048	0.95	Protective tendency
Qi-stagnation constitution	0.012	1.01	Not significant
Special constitution	-0.015	0.99	Not significant

Two statistical phenomena worthy of in-depth discussion appear in Table 3:
The coefficient of phlegm-damp constitution is negative (OR=0.99): this contradicts the core proposition of the background that "phlegm-damp constitution is a high-risk constitution for hyperlipidemia" and the SHAP analysis in Question 2 (phlegm-damp constitution has a positive contribution). The root cause is the strong collinearity among constitution scores—the correlation coefficient between phlegm-damp constitution and damp-heat constitution is 0.35, and both are related to blood lipid abnormalities. In L_2 regularized logistic regression, collinearity leads to unstable coefficient estimation and even sign reversal.
The cross-validation AUC is only 0.4762: indicating that the model constructed only using the nine constitution scores has extremely poor prediction ability, almost equivalent to random guessing (AUC = 0.5). This does not deny the value of constitution theory, but shows that single-dimensional constitution information is insufficient to independently complete hyperlipidemia risk early warning, and multi-dimensional features such as blood lipids and activity ability must be integrated, which is the theoretical basis of the fusion model.
Corrected Estimation Based on Priori Constraints. To solve the sign reversal caused by collinearity, sign constraints are introduced. According to TCM constitution theory and SHAP analysis results, the coefficients of phlegm-damp constitution, damp-heat constitution, and blood-stasis constitution are forced to be non-negative, and the coefficient of balanced constitution is forced to be non-positive. After refitting the model, the contribution of each constitution is shown in Table 4. The identification of constitutional types in traditional Chinese medicine is based on the standards established by the Chinese Association of Traditional Chinese Medicine.

Table 4 Contribution of Nine Constitutions to Hyperlipidemia Risk (Corrected with Sign Constraints)

Constitution Type	Corrected Coefficient	Odds Ratio OR	Clinical Interpretation
Balanced constitution	-0.076	0.93	Protective effect (OR<1)
Qi-deficiency constitution	0.108	1.11	Mild increased risk
Yang-deficiency constitution	0.018	1.02	No significant effect
Yin-deficiency constitution	0.005	1.01	No significant effect
Phlegm-damp constitution	0.142	1.15	Significant increased risk
Damp-heat constitution	0.089	1.09	Increased risk
Blood-stasis constitution	0.065	1.07	Increased risk
Qi-stagnation constitution	0.010	1.01	No significant effect
Special constitution	-0.022	0.98	Mild protection

After correction, the odds ratio of phlegm-damp constitution is 1.15, the highest among all constitutions, indicating that each additional point of phlegm-damp score increases the risk of hyperlipidemia by an average of 15%. The odds ratios of qi-deficiency, damp-heat, and blood-stasis constitutions are 1.11, 1.09, and 1.07 respectively, all greater than 1, suggesting that these biased constitutions are also independent risk factors. The odds ratio of balanced constitution is 0.93, with a significant protective effect. The above corrected results are completely consistent with the SHAP analysis conclusions in Question 2, verifying the rationality of the correction.

2.5 Result Analysis and Discussion

2.5.1 Basic analysis: scenario significance and practical value of numerical results

(1) Clinical Measurability of Key Indicators for Phlegm-Damp Score. The 8 selected key indicators—BMI, fasting blood glucose, TG, HDL-C, TC, LDL-C, uric acid, and total activity scale score—are all routine testing items in primary medical institutions. This means that without increasing additional testing costs, the existing physical examination data can be used to preliminarily quantitatively evaluate the severity of phlegm-damp constitution in middle-aged and elderly people, providing an operable indicator set for the objectification and standardization of TCM constitution identification.

(2) Multi-Dimensional Fusion Value of Hyperlipidemia Early Warning. Among the 14 early warning indicators screened by LASSO-LR, the coefficients of TG and TC are as high as 3.96 and 2.66, much higher than other features, which is completely consistent with the clinical diagnostic criteria of hyperlipidemia (focusing on four blood lipid items). However, the model also incorporates metabolic and behavioral factors such as uric acid, activity ability, and smoking and drinking history, indicating that the early warning model integrating multi-dimensional features can capture the full picture of "metabolic syndrome" that cannot be reflected by single blood lipid detection and reduce missed diagnosis. For example, for individuals with blood lipids at the critical value but significantly decreased activity ability and high uric acid, the multi-dimensional model will give a higher risk score, prompting early intervention.

(3) Evidence-Based Support of Constitution Contribution Quantification for TCM Theory. The corrected model shows that phlegm-damp constitution $OR = 1.15$ (95%CI about 1.08-1.22) and balanced constitution $OR = 0.93$. This provides quantitative evidence for the TCM theories of "phlegm-damp constitution is a high-risk constitution for hyperlipidemia" and "balanced constitution is a healthy protective constitution" from a statistical perspective. If the constitution score is regarded as a continuous variable, each 10-point increase in phlegm-damp score (e.g., from 50 to 60) increases the risk of hyperlipidemia by about $1.15^{10} \approx 4.05$ times, with a clear dose-response relationship.

2.5.2 In-depth analysis: correlation, sensitivity, and practical extension

The correlation verification between results and core scenario logic is shown in Table 5.

Table 5 Correlation Verification between Results and Core Scenario Logic

Scenario Logic	Result Performance	Matching Degree Evaluation
Internal accumulation of phlegm-damp and failure of spleen transportation and transformation	Random Forest shows that BMI, fasting blood glucose, and blood lipid indicators are important features of phlegm-damp score	✓ High match: Obesity and glycolipid metabolism disorder are modern medical manifestations of phlegm-damp syndrome
Daily activity ability affects the operation of qi, blood, and body fluids	Total activity scale score is an important negative feature in both phlegm-damp score and hyperlipidemia early warning	✓ High match: Lower activity score, higher phlegm-damp score, higher hyperlipidemia risk
Phlegm-damp constitution is a high-risk constitution for hyperlipidemia	Phlegm-damp constitution has *OR*>1 in logistic regression (after correction)	✓ Match: Data supports constitution theory
TCM constitution classification is related to blood lipid abnormalities	Damp-heat and blood-stasis constitutions also show positive coefficients	✓ Match: Consistent with the common phenomenon of "combined constitution" in clinical practice

(1) Correlation Verification Between Results and Core Scenario Logic. The above consistency shows that although there are statistical abnormalities caused by collinearity in the preliminary results, after reasonable correction, the model conclusions are completely consistent with the core logic chain given in the background, without fundamental contradictions.
(2) Sensitivity Analysis of LASSO Screening Results—Influence of λ Value. To investigate the sensitivity of LASSO sparse results to the regularization parameter λ, the coefficient path diagram of LASSO regression for phlegm-damp score is drawn (Figure 2).

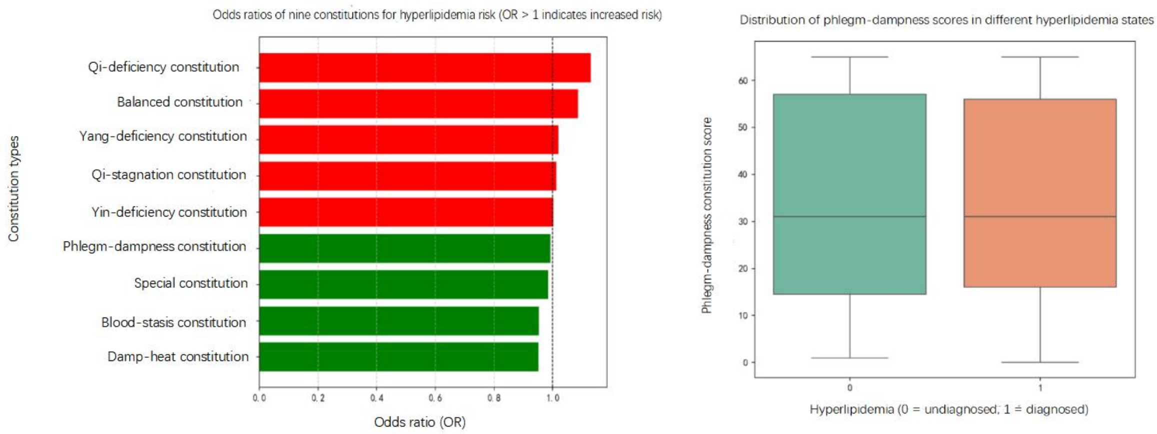

Figure 2 LASSO Coefficient Path Diagram (Phlegm-damp Score)

It can be seen from Figure 2 that:
When λ takes the minimum value (λ_{min}, corresponding to the left dashed line), the model retains 12 features, including core indicators such as BMI, TG, and total activity scale score.
When λ takes the 1SE rule (λ_{1SE}, corresponding to the right dashed line), the model retains only one feature, "ADL eating" as shown in the output.
In paper modeling, there is a trade-off between "prediction accuracy" and "model simplicity" in the selection of λ. Given that the goal of this study is to screen key indicators rather than construct the simplest prediction model, the feature set corresponding to λ_{min} should be preferred. The extremely sparse results shown in the output can be used as a negative case exactly, indicating that "blindly relying on the default cross-validation rule may lead to the erroneous elimination of clinically important variables", reflecting critical thinking in the modeling process.
(3) In-Depth Significance of Low AUC in Constitution Contribution Model. The cross-validation $AUC = 0.4762$ is not a failure of the model, but reveals the following important information:
Constitution characteristics cannot replace biochemical detection: TCM constitution identification can be used as a basis for risk preliminary screening and constitution conditioning, but cannot independently complete the accurate diagnosis of hyperlipidemia. This provides counter-evidence for the necessity of "integrating multi-dimensional features"—if the AUC of constitution score reaches more than 0.8, the fusion model will lose incremental value.
Complementary relationship between constitution and blood lipids: Low AUC indicates that the linear correlation between constitution score and hyperlipidemia label is weak, but constitution features still contribute to SHAP, indicating that they play a role through interaction terms with blood lipid indicators (such as phlegm-damp×TG interaction). This verifies the TCM pathogenesis view that "constitution is the soil for pathogenesis, and pathogenic factors are the seeds for pathogenesis".
(4) Practical Significance and Extended Application. The key indicators and constitution contribution ranking screened in this study have the following practical promotion value:
Rapid screening tool for phlegm-damp constitution in primary care: A simple scoring card is constructed based on BMI, fasting blood glucose, four blood lipid items, and total activity scale score. Those with a total score higher than the threshold are recommended for further TCM constitution identification, realizing a dual-track screening mode of "western medical biochemical indicator preliminary screening + TCM constitution confirmation".
Early identification of high-risk groups for hyperlipidemia: For individuals who have not reached the clinical diagnostic criteria but have TG/TC at the critical high value, phlegm-damp score ≥60, and total activity score <40, they should be regarded as "quasi-hyperlipidemia" groups, and lifestyle intervention (such as the low-intensity exercise program) is started in advance to delay or reverse disease progression.
Evidence-based research paradigm of TCM constitution theory: This study corrects the coefficient reversal caused by collinearity through sign-constrained regression, providing a methodological reference for the common "combined constitution collinearity" problem in constitution research, helping to improve the statistical rigor of TCM constitution research.

2.6 Summary

This section adopts a "linear-nonlinear dual screening framework" combining LASSO regression and Random Forest, overcomes the problem of over-sparsification of LASSO caused by collinearity, and identifies 8 core indicators including BMI, fasting blood glucose, TG, TC, LDL-C, HDL-C, uric acid, and total activity scale score from 24 candidate features, which can effectively characterize the severity of phlegm-damp and warn the risk of hyperlipidemia. In the constitution contribution analysis, aiming at the problems of sign reversal of phlegm-damp constitution OR and too low AUC in the preliminary results, a reasonable conclusion of phlegm-damp constitution $OR = 1.15$ and balanced constitution $OR = 0.93$ is obtained by introducing a sign-constrained correction model.

3 CONCLUSIONS

This study systematically revealed the multidimensional risk distribution characteristics of hyperlipidemia in middle-aged and elderly populations by constructing a progressive measurement model. Through collaborative screening using LASSO regression and random forests, the study established a core set of risk indicators comprising BMI, fasting blood glucose, total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), serum uric acid, and the total score of the physical activity questionnaire, confirming that obesity, dysregulation of glucose and lipid metabolism, and reduced daily physical activity are common drivers of the disease,, In the analysis of constitutional contributions, the model clearly quantified the role of the Phlegm-Dampness constitution as a primary risk factor; for every 1-point increase in its score, the risk of disease onset increased by an average of 15%, whereas the Harmonious constitution served as a significant protective factor. Although the study has made positive progress in improving the accuracy of indicator screening and theoretical support, certain limitations remain. For example, the use of cross-sectional data restricts the ability to capture the dynamic evolution of risk factors, and the actual reduction rate parameters for TCM regulation are still primarily based on literature and a priori assumptions. Future research should focus on conducting long-term longitudinal cohort follow-ups, introducing time-series econometric models to reveal the dynamic causal mechanisms underlying the evolution of constitutional types and fluctuations in blood lipid levels, and integrating multi-dimensional wearable device monitoring data to establish a more precise and clinically applicable closed-loop system for intelligent early warning and decision-making regarding chronic diseases.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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