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ARTICLE

Establishment of a Predictive Model for the Efficacy of Vestibular Rehabilitation Therapy in Patients With Vestibular Peripheral Vertigo

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Abstract

Aims/Background Vestibular peripheral vertigo, a common condition, is usually managed through vestibular rehabilitation therapy. However, while the current treatment approaches are effective, their efficacy varies among patients. Therefore, establishing a prediction model, evaluating rehabilitation outcomes, and optimizing treatment plans are crucial for patient rehabilitation. Hence, this study aims to explore the factors affecting the clinical efficacy of vestibular rehabilitation in peripheral vestibular vertigo and establish a prediction model based on these factors.
Methods This retrospective study analyzed clinical data from 212 patients with peripheral vestibular vertigo treated at Sichuan Mental Health Center, The Third Hospital of Mianyang, China, between January 2022 and December 2023. Patients were divided into a modeling group (n = 159) and a validation group (n = 53) in a 3:1 ratio. Patients in the modeling group were further divided into two subgroups based on efficacy: a group with good efficacy (n = 108) and a group with poor efficacy (n = 51). Baseline characteristics from the patients were compared between the modeling and validation groups. Furthermore, univariate and multivariate analyses were conducted to identify factors influencing the clinical efficacy of vestibular rehabilitation in peripheral vestibular vertigo.
Results There were statistically significant differences in anxiety, vertigo, concurrent headache, ear symptoms, and lack of sleep in the modeling group ($p < 0.05$). Multivariate logistic regression analysis identified anxiety, severity of dizziness, accompanying headaches, ear symptoms, and inadequate sleep as the independent factors affecting the clinical efficacy of vestibular rehabilitation in treating peripheral vertigo ($p < 0.05$). Furthermore, a model was established as follows: [Logit (P) = $-2.836 + (1.673X_1) + (2.220X_2) + (0.960X_3) + (1.150X_4) + (1.202X_5)$]. The calibration curves of the model in both the training and validation groups were a straight line close to 1, indicating that the predicted efficacy of the model was in agreement with the actual risk. The receiver operating characteristic (ROC) curve analysis revealed that the predicted area under the curve of the model for the clinical efficacy of vestibular rehabilitation in treating vestibular peripheral vertigo was 0.943 (95% confidence interval [CI]: 0.885–0.946, $p < 0.001$) in the modeling group and 0.881 (95% CI: 0.796–0.906, $p < 0.001$) in the validation group. Decision curve analysis (DCA) evaluated the clinical utility of the model in predicting efficacy, indicating the model's obvious positive net benefits.
Conclusion Anxiety, high vertigo severity, concomitant headache, ear symptoms, and inadequate sleep adversely impact the clinical efficacy of vestibular rehabilitation in peripheral vestibular vertigo. Establishing a prediction model based on these factors can help clinicians in early clinical intervention, thereby improving patient clinical efficacy.

Key words: vestibular; vertigo; clinical efficacy; prediction methods; machine

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Introduction

Peripheral vestibular vertigo is a common condition characterized by lesions in the vestibular receptors and the extratemporal segment of the vestibular nerve. It presents diverse clinical manifestations, including sudden rotational vertigo, spontaneous nystagmus, fluctuating tinnitus, and hearing loss, all of which significantly impact the patient's quality of life (Djaali et al, 2023). Research indicates that dizziness, including vertigo, has been a common symptom over the past decade, affecting about 15% to over 20% of adults annually (Neuhauser, 2016). Vestibular vertigo accounts for approximately a quarter of these cases, with a 12-month prevalence rate of 5% and an annual incidence rate of 1.4%. The prevalence rate increases with age, posing significant health concerns. Although medication and surgical interventions can help relieve symptoms, many patients still face challenges related to persistent vestibular dysfunction and functional impairments, leading to anxiety, depression, and other emotional disorders (Djaali et al, 2023; Vaishali et al, 2024). Hence, exploring effective rehabilitation approaches to enhance clinical outcomes and improve quality of life holds significant clinical and societal value (Wang et al, 2024a).

Vestibular rehabilitation, a non-invasive therapeutic approach, has gained increasing attention in recent years for the treatment of vertigo disorders. Primarily, it aims to promote the recovery and compensation of vestibular function through targeted rehabilitation exercises, thereby enhancing patients' balance and quality of life (Hall et al, 2022). However, the efficacy of vestibular rehabilitation is influenced by various factors, including the patient's age, duration of illness, underlying health issues, and psychological state (Demirtaş et al, 2024). Therefore, conducting in-depth research into these influencing factors and establishing an effective predictive model to assess the clinical efficacy of vestibular rehabilitation in peripheral vestibular vertigo is needed. This strategy would help guide clinical practice and optimize treatment approaches.

This study aims to collect and analyze clinical data from patients with peripheral vestibular vertigo to identify factors influencing the efficacy of vestibular rehabilitation therapy. Utilizing logistic regression analysis, a predictive model would be constructed to evaluate the clinical outcomes of vestibular rehabilitation in these patients. This model would serve as a scientific and objective tool to assist clinicians in formulating personalized rehabilitation treatment plans customized to individual patient needs.

Methods

Research Participants

This retrospective study incorporated 14 variables. Based on the usual sample size requirement, which is 5 to 20 times the number of variables, and accounting for a 20% sample loss rate, the computed sample size ranged from 84 to 336. Initially, data were collected from 316 patients. After a thorough screening, 212 patients were finally included in the analysis. These patients underwent vestibular rehabilitation therapy at the Sichuan Mental Health Center, The Third Hospital of

Mianyang between January 2022 and December 2023. Furthermore, patients were divided into a modeling group (n = 159) and a validation group (n = 53) in a 3:1 ratio. A flow chart of patient grouping is shown in Fig. 1. The general data for these two groups were screened, and any outliers were eliminated.

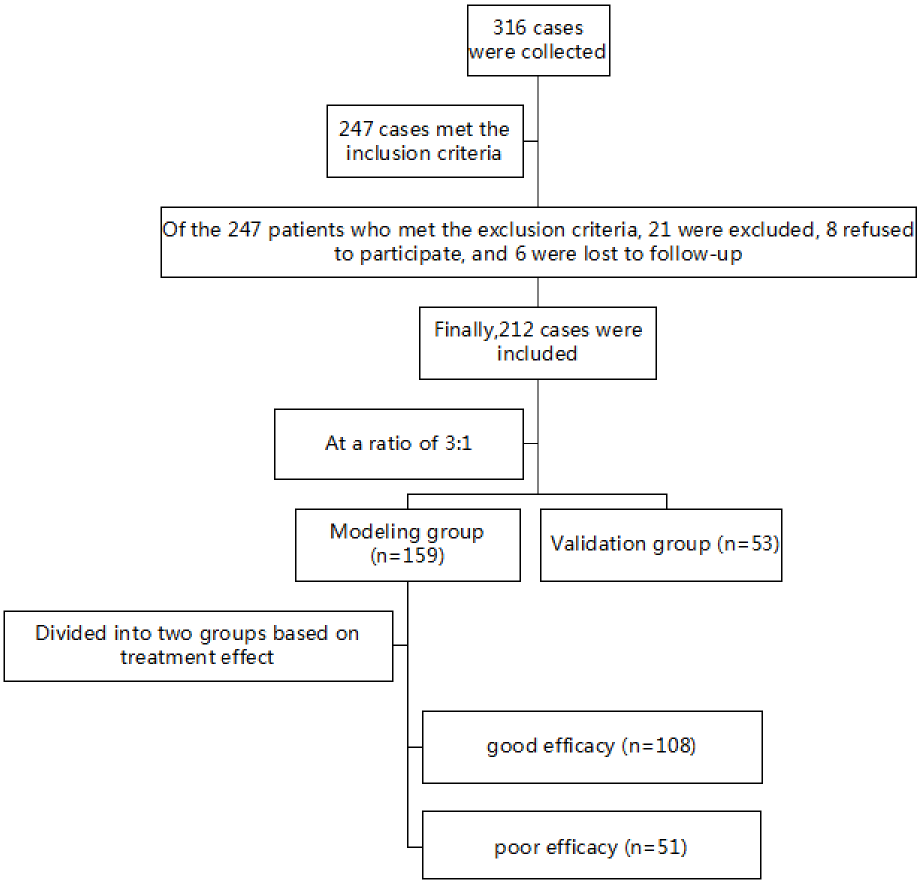

Fig. 1. A flowchart of patient recruitment and their grouping.

Inclusion criteria were as follows: (1) patients meeting the clinical diagnosis of peripheral vestibular vertigo and the indications for clinical vestibular rehabilitation therapy (Umibe et al, 2021); (2) patients with no cognitive impairments; (3) patients aged >18 years and with complete clinical data; and (4) patients receiving their first diagnosis and treatment at the Sichuan Mental Health Center, The Third Hospital of Mianyang. However, patients with malignant tumours, unstable vital signs, or frail physical conditions, and those with contraindications to the treatment methods used in this research were excluded from the study cohort.

The study design adhered to the Declaration of Helsinki and obtained approval from the Medical Ethics Committee of the Third Hospital of Mianyang (approval number: 2022-8). Informed consent was obtained for each patient or their families after thoroughly explaining the study protocol.

Patients Grouping

The patients in the modeling group were divided into two subgroups based on treatment outcomes: a group with good efficacy (n = 108) and a group with poor efficacy (n = 51). Treatment efficacy was assessed by predetermined criteria, with a group with good efficacy consisting of patients who achieved or surpassed a defined standard, typically characterized by significant symptom improvement and a substantial enhancement in quality of life.

The group with good efficacy comprised the following categories (Bhattacharyya et al, 2017):

(1) Recovery: Patients who, following treatment, experienced a complete disappearance of vertigo and related symptoms, resumed normal daily and work activities, and no longer required further medication or rehabilitation interventions.

(2) Marked improvement: Patients who achieved significant relief of symptoms, though not complete resolution, substantially enhanced quality of life and reduced reliance on frequent medication to manage symptoms.

Moreover, the group with poorer efficacy comprised patients who did not meet the predetermined efficacy criteria, exhibiting minimal symptom improvement or worsening conditions.

All rehabilitation treatments and drugs were implemented by the same medical team of professionals, ensuring consistency and continuity of treatment. The team closely monitored each patient's progress and adjusted treatment plans as required to obtain the best possible treatment outcomes.

Data Collection

Patient data were collected in a questionnaire as follows:

(1) General patient data were collected using the electronic medical record system and patient interviews, including age, body mass index (BMI), gender, chief complaint, pathological type, duration of disease, presence of headache, ear symptoms, trigger factors, hypertension, and diabetes.

(2) The severity of dizziness in patients was assessed using the Dizziness Handicap Inventory (DHI) scale (Jacobson and Newman, 1990), consisting of 25 questions. Each question has three response options: "Yes" (scored 4 points), "Sometimes" (scored 2 points), and "No" (scored 0 points). The total score ranged from 0 to 100, providing the overall severity of dizziness symptoms. Scores between 0–30 indicate mild impairment, 31–60 indicate moderate impairment and scores exceeding 60 represent severe impairment, possibly associated with an elevated risk of falls. The scale showed higher reliability, with a Cronbach's alpha coefficient of 0.918.

(3) Anxiety levels were assessed employing the Hamilton Anxiety Scale (HAMA) (Thompson, 2015), which comprises 14 items, each scored on a scale from 0 to 4. Higher scores indicate higher levels of anxiety. Each item is rated as follows: 0 = no symptoms, 1 point = mild, 2 points = moderate, 3 points = severe, 4 points = very severe. A total score exceeding 29 points may indicate severe anxiety, over 21 points indicate definite anxiety, over 14 points indicate some level of anxiety, over 7 points suggest possible anxiety, and scores below 7 points indicate an absence of anxiety symptoms. The scale shows a Cronbach's alpha coefficient of about 0.8, indicating good reliability.

(4) Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI) developed by Buysse et al (1989). The index comprises 7 items, each rated from 0–3 points, with a total score ranging from 0 to 21 points. A score of $\geq$7 points suggests the presence of sleep disorders. The scale has a Cronbach's alpha coefficient of about 0.8, indicating good reliability.

The questionnaires were filled out by patients and scored by professionally trained medical staff. These raters require professional knowledge and evaluation capabilities to ensure the reliability and effectiveness of the outcomes. Furthermore, the medical staff collected and analyzed scoring data to draw scientifically valid conclusions.

Statistical Analysis

The experimental data was statistically analyzed using SPSS 27.0 (International Business Machines Corporation, Armonk, NY, USA). The Shapiro-Wilk test was used for normality testing. Normally distributed metric data were expressed as $\bar{x} \pm$ S, with group comparison performed using independent sample t-tests. However, count data were presented as frequencies or percentages and analyzed using the χ^2 test. Factors influencing the clinical efficacy of vestibular rehabilitation therapy for peripheral vestibular vertigo were evaluated by employing univariate and multivariate logistic regression analysis (with significant variables from multivariate analysis incorporated in the multivariate model). The model was established using SPSS 27.0, and its performance was evaluated with the receiver operating characteristic (ROC), calibration curve, and decision curve analysis (DCA). A p-value of $<$0.05 was considered statistically significant for all differences.

Results

Comparison of Baseline Data Between the Two Groups

A comparison of baseline data between the modeling and validation groups revealed no statistically significant differences ($p > 0.05$, Table 1).

Univariate Analysis Between the Good Efficacy and Poor Efficacy Subgroups

A comparison of age, BMI, gender, chief complaint, pathological type, duration of disease, trigger factors, hypertension, and diabetes between two subgroups in the modeling group showed no statistically significant differences ($p > 0.05$). However, there were significant differences in anxiety levels, severity of dizziness, presence of accompanying headache, ear symptoms, and inadequate sleep ($p < 0.05$, Table 2).

Multivariate Logistic Regression Analysis

A logistic regression analysis was conducted using anxiety level, severity of dizziness, presence of accompanying headache, ear symptoms, and inadequate sleep as independent variables (Table 3), and the clinical efficacy of vestibular rehabilitation therapy for peripheral vertigo as the dependent variable (poor = 1, good = 0). The findings of the multivariate logistic regression analysis showed that anxiety,

Table 1. Comparison of baseline data between the modeling and validation groups.

Baseline data	Modeling group (n = 159)	Validation group (n = 53)	t/χ^2 value	p-value
Age (years)	46.79 ± 2.44	47.57 ± 2.98	1.903	0.058
BMI (kg/m^2)	21.26 ± 1.68	21.16 ± 1.75	0.371	0.711
Gender			0.006	0.936
Male	91 (57.23)	30 (56.60)		
Female	68 (42.77)	23 (43.40)		
Chief complaint				
Circular rotation	82 (51.57)	31 (58.49)	0.764	0.382
Dizziness and sinking sensation	61 (38.36)	20 (37.74)	0.007	0.935
Unsteady walking	40 (25.16)	13 (24.53)	0008	0.927
Floating sensation	25 (15.72)	8 (15.09)	0.012	0.913
Inarticulation	22 (13.84)	7 (13.21)	0.013	0.908
Pathological type			0.357	0.949
Benign paroxysmal positional vertigo	70 (44.03)	23 (43.40)		
Meniere's disease	50 (31.45)	15 (28.30)		
Vestibular migraine	34 (21.38)	13 (24.53)		
Vestibular neuritis	5 (3.14)	2 (3.77)		
Disease duration (years)	5.16 ± 1.66	5.41 ± 1.43	0.981	0.328
Anxiety			0.327	0.988
None	75 (47.17)	24 (45.28)		
Possible	31 (19.50)	10 (18.87)		
Definite	22 (13.84)	9 (16.98)		
Obvious	18 (11.32)	6 (11.32)		
Severe	13 (8.18)	4 (7.55)		
Severity of dizziness			0.321	0.852
Light	85 (53.46)	27 (50.94)		
Moderate	52 (32.70)	17 (32.08)		
Severe	22 (13.84)	9 (16.98)		
Headache			0.006	0.937
Yes	76 (47.80)	25 (47.17)		
No	83 (52.20)	28 (52.83)		
Ear symptoms			0.546	0.909
Tinnitus	19 (11.95)	7 (13.21)		
Hearing loss	24 (15.09)	10 (18.87)		
Tinnitus and hearing loss	39 (24.53)	12 (22.64)		
None	77 (48.43)	24 (45.28)		
Trigger factors			0.572	0.450
Yes	108 (67.92)	33 (62.26)		
No	51 (32.08)	20 (37.74)		
Hypertension			0.144	0.705
Yes	35 (22.01)	13 (24.53)		
No	124 (77.99)	40 (75.47)		
Diabetes			0.164	0.685
Yes	29 (18.24)	11 (20.75)		
No	130 (81.76)	42 (79.25)		
Inadequate sleep			0.026	0.873
Yes	68 (42.77)	22 (41.51)		
No	91 (57.23)	31 (58.49)		

Note: BMI, body mass index.

Table 2. Univariate analysis of the good efficacy and poor efficacy subgroups.

Baseline data	Group with good efficacy (n = 108)	Group with poor efficacy (n = 51)	t/χ^2 value	p-value
Age (years)	46.96 ± 2.31	46.41 ± 2.68	1.330	0.185
BMI (kg/m^2)	21.01 ± 1.70	21.49 ± 1.80	1.631	0.105
Gender			0.078	0.781
Male	61 (56.48)	30 (58.82)		
Female	47 (43.52)	21 (41.18)		
Chief complaint				
Circular rotation	56 (51.85)	26 (50.98)	0.011	0.918
Dizziness and sinking sensation	37 (34.26)	24 (47.06)	2.400	0.121
Unsteady walking	30 (27.78)	10 (19.61)	1.228	0.268
Floating sensation	19 (17.59)	6 (11.76)	0.888	0.346
Inarticulation	15 (13.89)	7 (13.73)	0.001	0.978
Pathological type			0.264	0.967
Benign paroxysmal positional vertigo	47 (43.52)	23 (45.40)		
Meniere's disease	35 (32.41)	15 (29.41)		
Vestibular migraine	23 (21.30)	11 (21.57)		
Vestibular neuritis	3 (2.78)	2 (3.92)		
Disease duration (years)	5.19 ± 1.71	5.11 ± 1.56	0.283	0.778
Anxiety			25.27	<0.001
None	64 (59.26)	11 (21.57)		
Possible	21 (19.44)	10 (19.61)		
Definite	10 (9.26)	12 (23.53)		
Obvious	8 (7.41)	10 (19.61)		
Severe	5 (4.63)	8 (15.69)		
Severity of dizziness			20.71	<0.001
Light	71 (65.74)	14 (27.45)		
Moderate	27 (25.00)	25 (49.02)		
Severe	10 (9.26)	12 (23.53)		
Headache			5.074	0.024
Yes	45 (41.67)	31 (60.78)		
No	63 (58.33)	20 (39.22)		
Ear symptoms			25.06	<0.001
Tinnitus	9 (8.33)	10 (19.61)		
Hearing loss	12 (11.11)	12 (23.53)		
Tinnitus and hearing loss	20 (18.52)	19 (37.25)		
None	67 (62.04)	10 (19.61)		
Trigger factors			0.357	0.550
Yes	75 (69.44)	33 (64.71)		
No	33 (30.56)	18 (35.29)		
Hypertension			0.101	0.751
Yes	23 (21.30)	12 (23.53)		
No	85 (78.70)	39 (76.47)		
Diabetes			0.094	0.759
Yes	19 (17.59)	10 (19.61)		
No	89 (82.41)	41 (80.39)		
Inadequate sleep			12.24	<0.001
Yes	36 (33.33)	32 (62.75)		
No	72 (66.67)	19 (37.25)		

Table 3. Assigning values to independent variables.

Variables	Value assignment
Anxiety	None = 0, Possible = 1, Definite = 2, Obvious = 3, Severe = 4,
Severity of dizziness	Light = 0, Moderate = 1, Severe = 2
Accompanying headache	No = 0, Yes = 1
Ear symptoms	None = 0, Tinnitus = 1, Hearing loss = 2, Tinnitus and hearing loss = 3
Inadequate sleep	No = 0, Yes = 1

Table 4. Results of multivariate logistic regression analysis.

Variable	β	Standard error	Wald	p-value	Exp (B)	95% CI	
						Lower limit	Upper limit
Anxiety	-	-	15.775	0.003	-	-	-
[Anxiety = 1]	–0.505	0.931	0.294	0.587	0.603	0.097	3.743
[Anxiety = 2]	–0.285	0.939	0.092	0.761	0.752	0.119	4.733
[Anxiety = 3]	0.371	0.861	0.185	0.667	1.449	0.268	7.836
[Anxiety = 4]	1.673	0.828	4.088	0.043	5.330	1.053	26.993
Severity of dizziness	-	-	16.993	$<$0.001	-	-	-
[Severity of dizziness = 1]	0.494	0.637	0.602	0.438	1.639	0.471	5.708
[Severity of dizziness = 2]	2.220	0.647	11.764	0.001	9.211	2.590	32.763
[Accompanying headache = 1]	0.960	0.443	4.698	0.030	2.612	1.096	6.225
Ear symptoms	-	-	6.324	0.097	-	-	-
[Ear symptoms = 1]	0.533	0.749	0.506	0.477	1.704	0.392	7.403
[Ear symptoms = 2]	–0.199	0.783	0.065	0.799	0.820	0.177	3.801
[Ear symptoms = 3]	1.150	0.539	4.560	0.033	3.160	1.099	9.083
[Inadequate sleep = 1]	1.202	0.440	7.465	0.006	3.325	1.404	7.874
Intercept	–2.836	1.054	7.235	0.007	0.059	-	-

Note: CI, confidence interval.

the severity of dizziness, accompanying headache, ear symptoms, and inadequate sleep were independent factors affecting the clinical efficacy of vestibular rehabilitation in treating peripheral vertigo ($p < 0.05$, Table 4).

Establishment of a Predictive Model

Based on the findings of logistic regression analysis, anxiety, the severity of dizziness, accompanying headache, ear symptoms, and inadequate sleep (expressed as X_1, X_2, X_3, X_4, and X_5, respectively) were included in the predictive model. The joint detection factor model was represented as: Logit (P) = –2.836 + ($1.673X_1$) + ($2.220X_2$) + ($0.960X_3$) + ($1.150X_4$) + ($1.202X_5$).

The calibration curves for the modeling group closely aligned to the slope of 1, indicating good consistency between the predicted treatment efficacy risks and actual outcomes (Fig. 2). The ROC analysis revealed that the area under the curve (AUC) for predicting the clinical efficacy of vestibular rehabilitation treatment in the model group was 0.943 (95% confidence interval [CI]: 0.885–0.946, $p < 0.001$).

The standard error was 0.012, with a Youden index of 0.89, sensitivity of 93.12%, and specificity of 95.63% (Fig. 3). Furthermore, the DCA curve showed the clinical utility of the model in predicting efficacy. The findings demonstrated a positive net benefit, indicating the model's excellent clinical utility (Fig. 4).

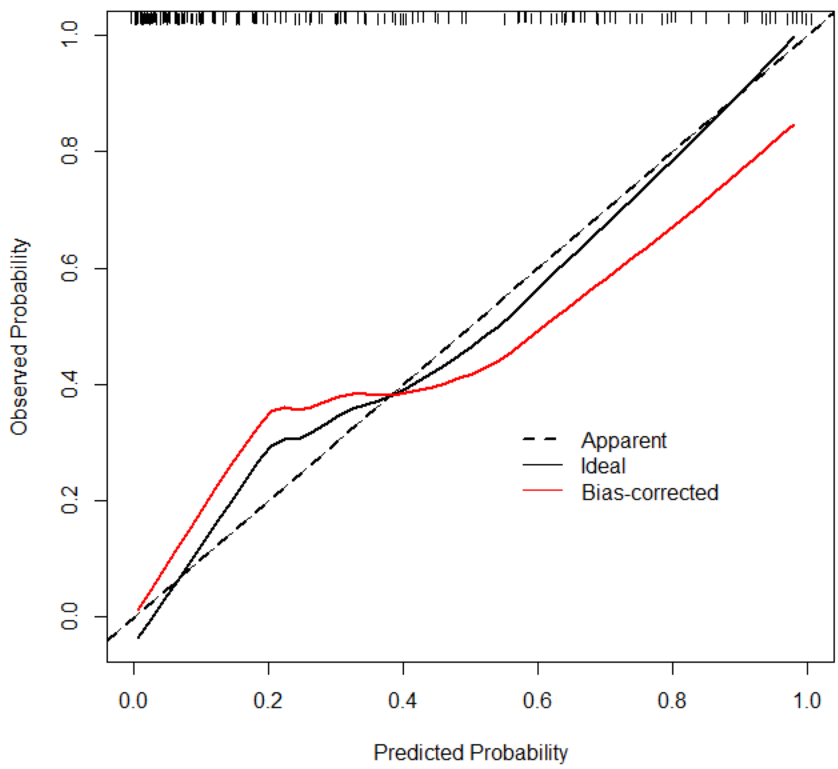

Fig. 2. Calibration curve of training group. The curve appears as a line close to 1, indicating that the model demonstrates good consistency between clinical treatment efficacy risks and actual outcomes.

Validation of the Predictive Model

The slopes of the calibration curves for the validation group were close to 1, indicating good consistency between the model's predicted treatment efficacy and actual risks in this group (Fig. 5). Furthermore, the ROC analysis showed that the AUC for predicting the clinical efficacy of vestibular rehabilitation treatment for peripheral vestibular vertigo in the validation group was 0.881 (95% CI: 0.796–0.906, $p < 0.001$). The standard error was 0.026, with a Youden index of 0.59, sensitivity of 77.64%, and specificity of 80.93% (Fig. 6). Additionally, DCA curves assessed the clinical utility of the model in predicting treatment efficacy in the validation group. The findings revealed a positive net benefit, indicating the model's excellent clinical practicality (Fig. 7).

Discussion

Identifying factors affecting the clinical efficacy of rehabilitation therapy for peripheral vestibular vertigo is crucial for optimizing treatment strategies and en-

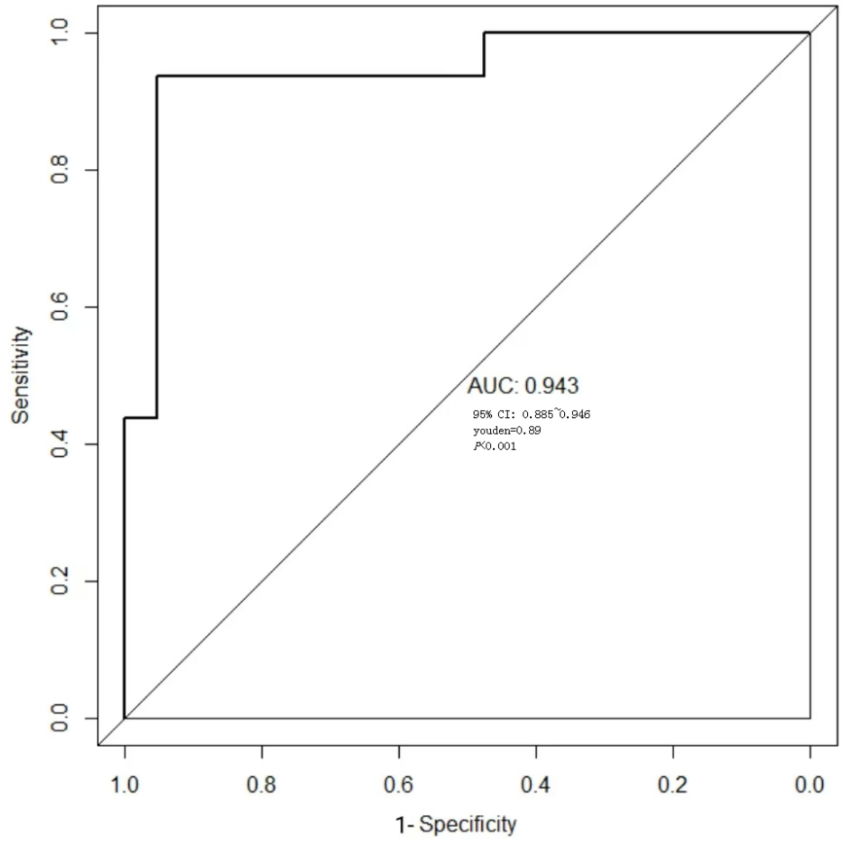

Fig. 3. Receiver operating characteristic (ROC) curve of training group. The area under the ROC curve is close to 1, indicating excellent diagnostic performance of the model in the training group. AUC, area under the curve.

hancing patients' quality of life (Ata et al, 2023). This study analyzed the clinical data of 212 patients with peripheral vestibular vertigo to assess the impact of various potential factors on the effectiveness of vestibular rehabilitation therapy. Furthermore, a predictive model was successfully established based on these findings.

Previously, Wang et al (2024a) reported the efficacy of vestibular rehabilitation treatment for peripheral vertigo; however, no comprehensive analysis of influencing factors was performed. Our study indicates that anxiety is a significant factor affecting the effectiveness of vestibular rehabilitation treatment, aligning with previous findings. Anxiety not only exacerbates the patient's psychological burden on patients but may also impact vestibular function recovery through its effects on the neuroendocrine system (Kanyılmaz et al, 2022). Anxious patients often exhibit skepticism towards the treatment process, lack confidence in therapy, and show reduced compliance, ultimately affecting rehabilitation outcomes. Therefore, providing psychological counselling and targeted interventions in clinical practice is crucial to enhance the effectiveness of vestibular rehabilitation treatment for these patients. Additionally, the severity of vertigo is another critical influencing factor. Patients with severe vertigo often experience significant balance impairments and discomfort, which directly disrupt their daily activities and pose significant challenges to effective rehabilitation training (Shaphe et al, 2023).

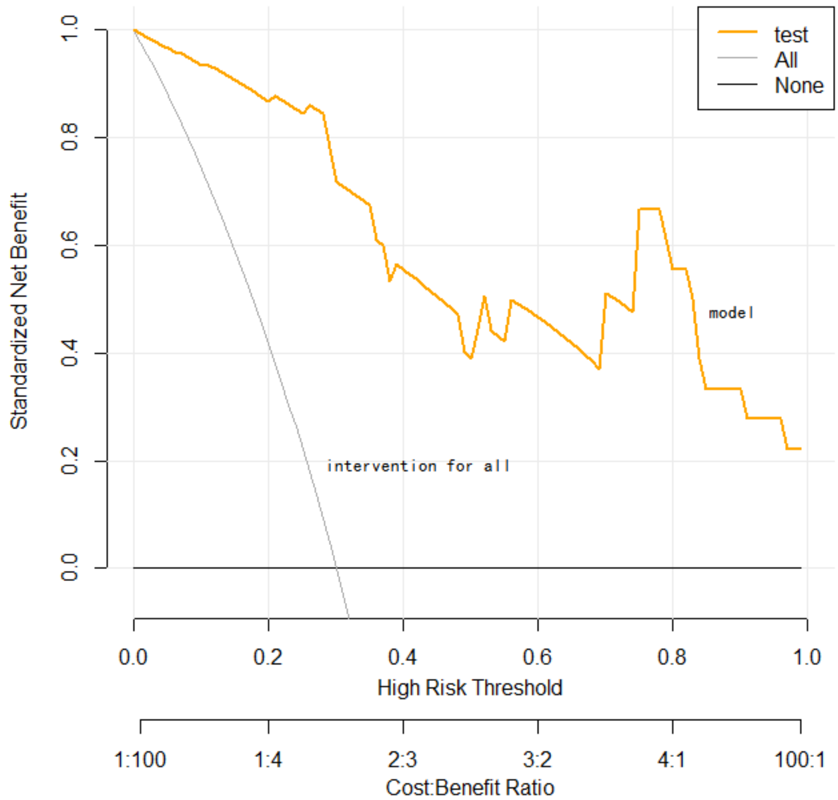

Fig. 4. Decision curve analysis (DCA) curve of training group.

This study observed that patients with higher levels of vertigo require more time for adaptation and recovery during rehabilitation, leading to comparatively poorer outcomes. These findings align with a previous study by Dornhoffer et al (2021), which showed that the Dizziness Disorder Scale (DHI) score substantially impacts the efficacy of vestibular rehabilitation for peripheral vertigo, further supporting the results of this study. For such patients, it is crucial to formulate personalized and targeted rehabilitation plans to expedite the recovery of vestibular function (Dunlap et al, 2019). Additionally, the presence of concurrent headaches emerged as another significant factor affecting the effectiveness of vestibular rehabilitation treatment. Headaches and vertigo are often interlinked, acting as both cause and effect. Headaches may exacerbate vertigo symptoms, elevating distress and anxiety in patients, while vertigo can trigger or worsen headaches. This vicious cycle increases patient suffering and complicates rehabilitation (Parfenov et al, 2020; Scholtz et al, 2019). Therefore, patients with concurrent headaches, attention should be given to treating their headache symptoms to break this cycle and improve the effectiveness of rehabilitation treatment.

Furthermore, ear symptoms such as tinnitus and hearing loss, also play a crucial role in affecting the effectiveness of vestibular rehabilitation treatment. These symptoms are often closely associated with vestibular dysfunction and can be challenging to resolve (Scholtz et al, 2022). The presence of ear symptoms impacts auditory function and may disrupt vestibular recovery through interconnected neural pathways. Hence, patients with ear symptoms should receive adequate attention

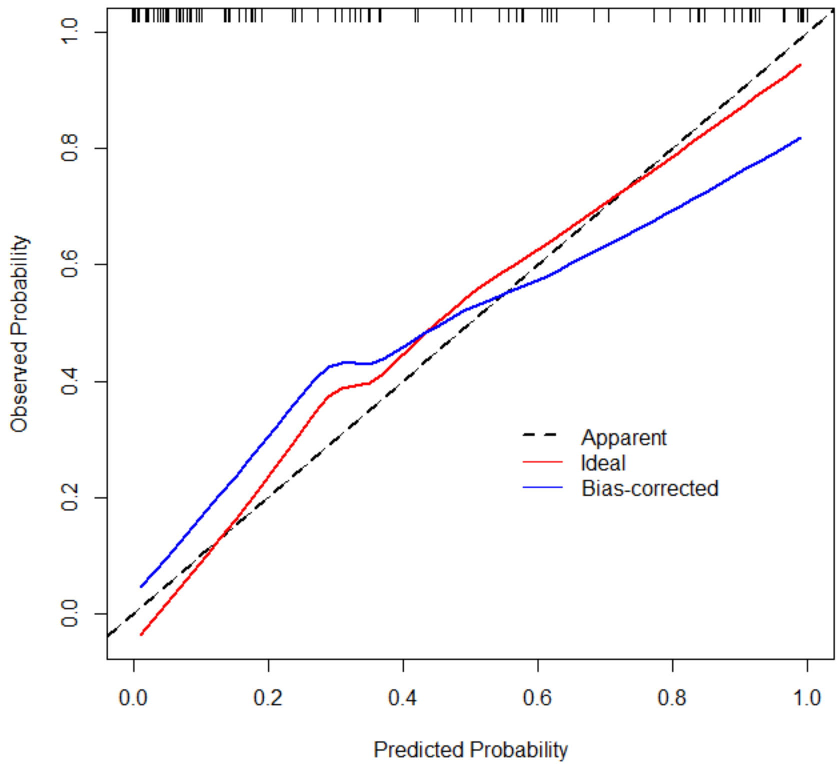

Fig. 5. Calibration curve of the validation group. The curve resembles a line close to 1, indicating that the model demonstrates relatively good consistency between the predicted clinical treatment efficacy risks and actual risks.

and comprehensive treatment measures to alleviate these symptoms and promote vestibular function recovery. Additionally, the negative impact of sleep deprivation on the effectiveness of vestibular rehabilitation treatment is equally significant and cannot be underestimated (Wang et al, 2024b). Sleep is vital for the body's recovery and repair processes, especially for restoring vestibular function. Sleep deprivation can lead to poor mental states, reduced concentration, and decreased effectiveness in rehabilitation training (Sana et al, 2023). Moreover, sleep deprivation may also affect neuroendocrine system regulation, further exacerbating vertigo symptoms. Therefore, clinical practices should prioritize the evaluation and enhancement of patients' sleep quality. Approaches like improving sleep environments, establishing consistent sleep routines, and using sleep-promoting interventions are crucial to ensuring sufficient sleep and optimizing rehabilitation outcomes (Swaminathan et al, 2023; Zhuang et al, 2024).

Based on the analysis of the key influencing factors, this study successfully constructed a predictive model for assessing the clinical efficacy of vestibular rehabilitation treatment for peripheral vestibular vertigo. This model comprehensively incorporates variables such as anxiety, severity of vertigo, concurrent headaches, ear symptoms, and sleep deprivation. Employing logistic regression analysis, the model determined the relative significance and interactions of these factors. Furthermore, the model was validated in both the modeling and validation groups, which demonstrated excellent predictive performance, with the calibration curve slope exhibiting slopes close to 1, indicating high consistency between predicted

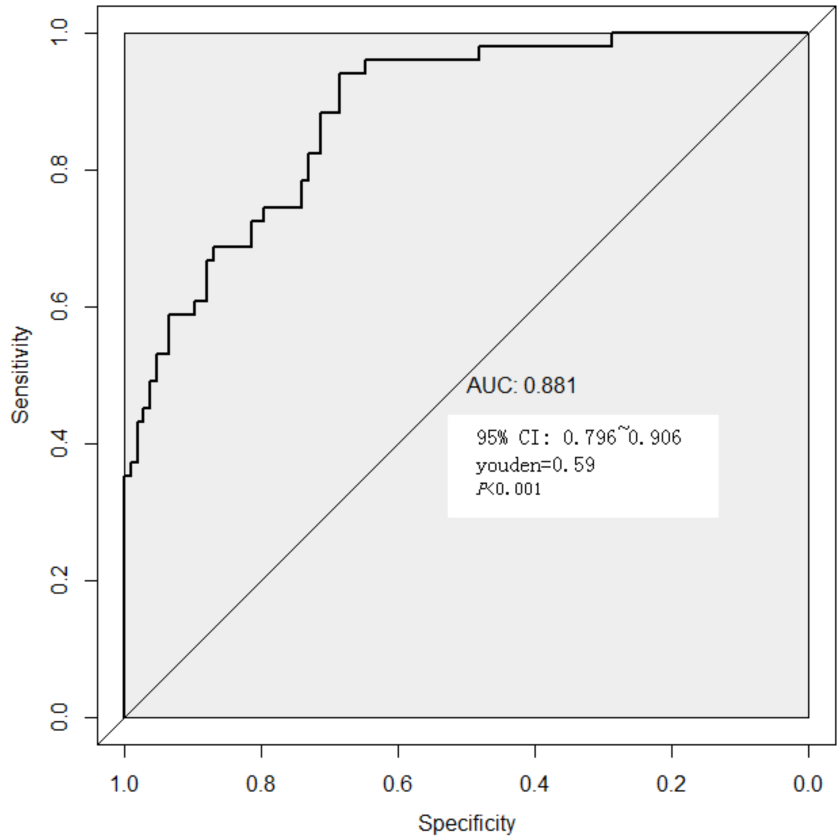

Fig. 6. ROC curve of the validation group. The ROC curve with an AUC of 0.7–0.9 indicates that the model exhibits good predictive value in the validation group.

and actual risks. ROC analysis further validated the model's predictive performance, revealing a high AUC and robust sensitivity and specificity. Additionally, DCA demonstrated significant net positive benefits, indicating good clinical efficacy of the model.

The predictive model established in this study holds potential clinical significance and broad application prospects. Firstly, this model provides clinicians with a scientific and objective predictive tool for assessing rehabilitation outcomes and prognosis, aiding in developing more personalized and targeted treatment plans. Secondly, applying this model can help optimize resource allocation and streamline process management in vestibular rehabilitation, enhancing treatment efficiency and patient satisfaction. Lastly, this research provides novel insights and approaches for future studies on the rehabilitation treatment of peripheral vestibular vertigo, contributing to the advancement and improvement of this field.

Despite several promising outcomes, this study has certain limitations. Firstly, as illustrated in Fig. 2, the ROC curve for the modeling group showed few inflection points, whereas the calibration curve and DCA findings were favourable. Such variation indicates a potential imbalance in the data. A possible reason is the relatively small sample size and reliance on single-center data, which may limit the representativeness and generalizability of the results. Future research should address this limitation by increasing the sample size and incorporating multicenter data to

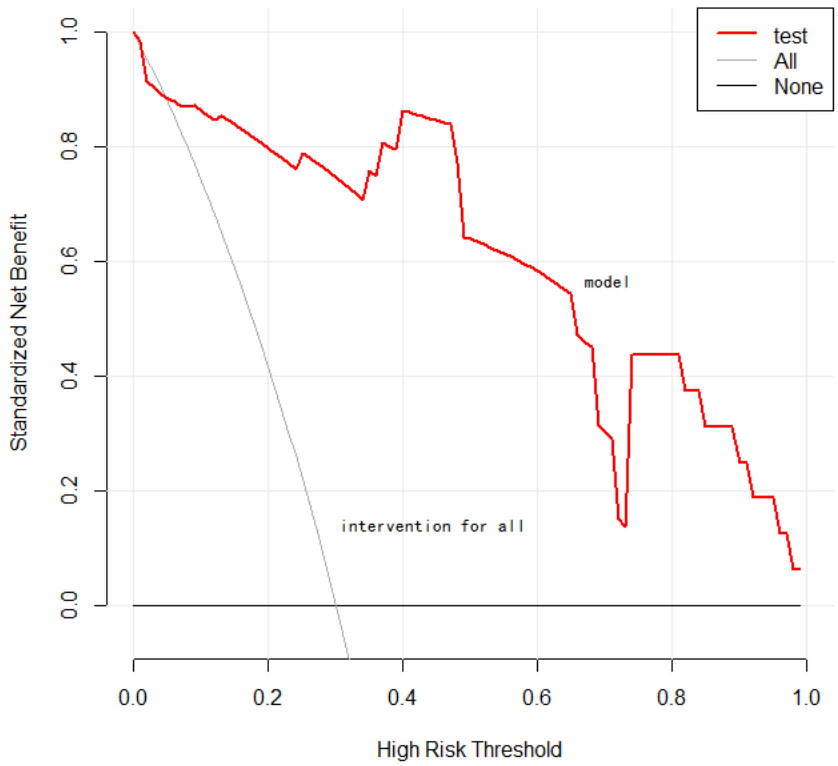

Fig. 7. DCA curve of the validation group. The curve closer to the upper right indicates the model's good clinical efficacy.

improve the reliability and generalizability of the results. Secondly, the observed problems with the ROC curve in the modeling group may also be due to the study's focus on the limited number of influencing factors to construct the predictive model. In reality, the effectiveness of vestibular rehabilitation treatment may be impacted by a diverse and more complex array of variables. Future research should explore other potential factors and include them in the model to enhance its predictive accuracy and comprehensiveness. Lastly, the retrospective study design may introduce information and selection biases, as data collected based on past events can be affected by incompleteness, inaccuracies, or recall bias. Additionally, sample size limitations may also affect the stability and reliability of the model. Moreover, the external applicability of the model needs further investigation, as the data was obtained from specific patient groups and medical institutions, which may not fully represent other populations or medical settings. Therefore, future research must expand the sample size and adopt a proactive study design to verify and optimize the predictive model, ensuring higher accuracy and generalizability.

Conclusion

In conclusion, this study successfully constructed a predictive model for evaluating the effectiveness of vestibular rehabilitation treatment by analyzing clinical data from patients with peripheral vestibular vertigo. The study explored the mechanisms of various influencing factors and provided important insights for clinicians. This model is a significant tool for optimizing treatment strategies and improving patient's quality of life. Future studies should focus on exploring additional potential factors and optimizing the predictive model to enhance its accuracy and clinical application.

Key Points

- This study aims to explore the factors influencing rehabilitation therapy for vestibular peripheral vertigo and establishes a predictive model to optimize treatment options and improve rehabilitation outcomes.
- This study analyzed the clinical data from 212 patients and divided them into the modeling and validation groups. Furthermore, independent factors affecting efficacy of the treatment were assessed.
- A prediction model was established based on identified independent factors, and the prediction performance of the model was validated using calibration curves and ROC analysis.
- The DCA curves evaluated the clinical utility of the model, revealing significant positive net benefits, which supported early clinical intervention and enhanced rehabilitation outcomes.

Availability of Data and Materials

All data included in this study are available from the corresponding author upon reasonable request.

Author Contributions

SW and JP designed the research study. DZ and FC performed the research. SW and XH analyzed the data. SW drafted the manuscript. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study is in accordance with the Declaration of Helsinki. The study was approved by the Medical Ethics Committee of the Third Hospital of Mianyang (2022-8). The principle of informed consent was followed throughout the experiment, and information about the study was provided to patients or their families, and consent was obtained.

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Conflict of Interest

The authors declare no conflict of interest.

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