

Predictive Model of Functional Exercise Compliance of Patients with Breast Cancer Based on Decision Tree

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Objective: Regular functional exercise can help recover the functions of upper limb for patients with breast cancer. By finding the influencing factors of functional exercise compliance and constructing a predictive model, patients with a poor functional exercise compliance can be better identified. This study aims to find out the factors influencing the functional exercise compliance of patients with breast cancer and build a predictive model based on decision tree.

Methods: Convenience sampling was used at two tertiary hospitals in Shantou from August 2020 to March 2021. Data of patients with breast cancer patient was obtained from questionnaires and based on demographics, Constant-Murley Score, Functional Exercise Compliance Scale for Postoperative Breast Cancer Patients, Champion Health Belief Model Scale, Social Support Rating Scale, Disease Perception Questionnaire and Family Care Index Questionnaire. Possible influencing factors of functional exercise compliance were analyzed using correlation analysis as well as univariate and binary logistic regression analysis through SPSS v25, and a CHAID decision tree was used to construct a predictive model on training, validation and test sets via SPSS Modeler v18 at a ratio of 6:2:2. Prediction accuracy, sensitivity, specificity and AUC were used to analyze the efficacy of the predictive model.

Results: A total of 227 valid samples were collected, of which 145 were assessed with a poor compliance (63.9%). According to a logistic regression analysis, perceived benefits, time after surgery and self-efficacy were influencing factors. The prediction accuracy, sensitivity, specificity and AUC of the predictive model, based on a CHAID decision tree analysis, were 70.73%, 57.1%, 77.8% and 0.81 respectively.

Conclusion: The predictive model, based on a CHAID decision tree analysis, had a moderate predictive efficacy, which could be used as a clinical auxiliary tool for clinical nurses to predict patients' functional exercise compliance.

Keywords: breast cancer, functional exercise, predictive model, decision tree

Introduction

According to the latest global cancer statistics in 2020, breast cancer incidence ranked first among all cancer types, accounting for 284,200 new cases.¹ Surgery is the most important treatment for breast cancer, but some patients will inevitably undergo complications after surgery, especially involving shoulder joint dysfunction following mastectomy and axillary lymph node dissection (ALND).² Therefore, it is important to promote functional exercise rehabilitation for patients with breast cancer who have undergone surgery, especially mastectomy and ALND. Studies also show that it is necessary for patients with breast cancer to do upper limb functional exercise within 6 months after surgery, so as to promote upper limb functional rehabilitation.^{3,4} Besides, according to the study of Zhou et al, a better upper limb

function recovery through functional exercise might be helpful for health-related quality of life improvement and reduce the chance for post-surgery breast cancer patient populations to experience pain-induced negative psychological states, fatigue, sleep disturbance, as well as upper limb function disabilities during the rehabilitation process.² However, Zhang et al,⁴ pointed out that the level of compliance with doing upper limb functional exercise was only moderate. According to the study of Chang et al, functional exercise has been shown effective and beneficial for improving the physical and physiological health outcomes of patients with breast cancer after surgery. If patients lack functional exercise, their risk of upper limb flap adhesion, limb edema, joint stiffness and muscle atrophy may increase; their confidence in physical recovery may be reduced; their discomfort symptoms may increase; and their quality of life will be damaged.⁵

It has been found through studies that numerous factors may be associated with functional exercise compliance of patients with breast cancer, including demographic, social psychic and disease-related factors, and so on.^{6,7} According to Lan et al, functional exercise compliance is related to disease perception and coping ability.⁸ Tao et al pointed out that social support and self-efficacy could directly affect functional exercise compliance, of which family support had the greatest effect.⁹ In addition, Tang et al suggested that functional exercise compliance of patients with breast cancer could be positively predicted based on health beliefs, who pointed out that patients with high levels of health beliefs had a better understanding of the functions of medical staff and a strong desire to speed up their rehabilitation, so that they had a higher functional exercise compliance.¹⁰ Because of the numerous possible factors, differences in the selection of variables and different predictive models could result. On the one hand, it is essential to explore the main factors influencing functional exercise compliance of patients with breast cancer within 6 months after surgery. On the other hand, risk factors can be combined with predictive models to make more accurate estimations.¹¹ So, it can help clinical nurses to better predict the compliance of functional exercise and do targeted intervention in a timely fashion by constructing a predictive model. Therefore, the aims of our study were to find out the main influencing factors and build a predictive model for functional exercise compliance of patients with breast cancer.

The decision tree is a data mining technology that has been widely applied in medicine and public health. Decision tree analysis consists of decision rules based on optimal feature cut-off values that make independent variables recursively split into different groups, so as to predict an outcome hierarchically.¹¹ On the one hand, a decision tree can provide a visual representation of predictive rules so that the predictive process can be more easily understood by clinical staff, which helps them make clinical decisions.¹² On the other hand, through a decision tree analysis, data can be powerfully classified, predicted, interpreted and processed as well as efficiently managed, including missing values and heavily-skewed data.¹³ The most commonly-used decision tree algorithms include classification and regression trees (CARTs), Chi-square automatic interaction detectors (CHAIDs) and C5.0.¹⁴ A CHAID allows one to resolve whole variables and partition consecutive data effectively, and the forward stopping or pruning rules are used to construct decision trees.¹⁵ In this study, we used a CHAID to create a decision tree predictive model, so as to predict the level of functional exercise compliance of patients with breast cancer after surgery.

Conceptual Framework

The behavioral model of health service use, also called the Anderson model, is an acknowledged model to analyze the influencing factors of individual health behavior.¹⁶ Its improved version has shown that individual health behavior is influenced by situational characteristics, personal characteristics and health outcomes.¹⁶ Situational characteristics include health policies and health care environment. Personal characteristics include demographic data, health beliefs and the perception of illness. Health outcomes include health status and patient satisfaction. We included 37 variables, from situational characteristics, personal characteristics and health outcomes, to the Anderson model, so as to predict the compliance of patients with breast cancer following surgery.

Methods

Subjects

Inclusion criteria were women ≥ 18 years of age with (1) breast cancer and had undergone breast surgery within 6 months; (2) Stage I, II or III breast cancer; (3) surgical drain tubes removed; (4) no cognitive impairment; and (5) agreed

to participate. Exclusion criteria were (1) locoregional recurrence or distant metastases; (2) having some complications or illnesses that affected exercise, such as flap necrosis, axilla effusion, and fractures; and (3) incomplete clinical information.

Procedure

An ethical approval was obtained from the Ethics Committee of the Cancer Hospital of Shantou University Medical College (No. 2021057). From August 2020 to March 2021, a cross-sectional questionnaire study was conducted in two tertiary hospitals in Shantou through convenience sampling. Patients were recruited by the first author, by whom all face-to-face investigations were conducted. According to the criterion of Kendall, the sample size should be 5–10 times the number of variables, and a sampling error of 10% should be assumed, therefore, 209–418 samples were required for our study. A total of 248 participants were initially recruited, but 21 were excluded because of their incomplete clinical information, resulting in 227 valid participants left.

Measurement

Based on the Anderson model, the outcome variables were the functional exercise compliance. We included 38 variables in the Anderson model from 3 dimensions (Table 1).

Measures

Functional Exercise Compliance Scale for Postoperative Breast Cancer Patients (FECSPBCP)

We used the FECSPBCP to estimate the functional exercise compliance of patients with breast cancer¹⁷, which consists of 18 items covering 3 dimensions: physical exercise, postoperative attention and actively seeking advice compliance. Each item is ranked on a 4-point scale from 1 (cannot do at all) to 4 (can do at all). The total score ranges from 18 to 72, with a higher score indicating more positive functional exercise. Compliance index = total actual dose/total required dose * 100%. According to the Seo et al, a good compliance is defined as a compliance index of higher than 75%.¹⁸ So, a compliance index >75% was defined as a good compliance, while that ≤75% was defined as a poor compliance. The Cronbach's alpha of the total scale in this study was 0.935.

Constant Murley Score (CMS)

We used an adjusted CMS to evaluate the shoulder functions of patients with breast cancer¹⁹ consisting of 9 items covering 3 dimensions: pain, activities of daily life and the range of active activities. A different scoring method was used for each item. The total score ranged from 4 to 75, with a higher score indicating greater shoulder functions. According to the CMS score, the shoulder functions were divided into five levels, namely very poor (<45), general (45–54), good (55–64), very good (65–69) and completely normal (>69).

Table 1 Variables Based on the Anderson Model

Dimensions		Variable
Situational characteristics		Resident address
Personal characteristics	Predisposing characteristics	Age, marital status, education level, family history, type of medical insurance, surgical method, radiotherapy history, BMI, time after surgery, clinical stage, health belief
	Enabling characteristics	Monthly income, number of children, social support, family care
	Need characteristics	Shoulder function, disease perception
Health outcomes		Comorbidities, PICC/CVC/Port, walking habits, attended lectures

Champion Health Belief Model Scale (CHBMS)

We used a revised CHBMS proposed by Lu to estimate the health belief in functional exercise¹⁷ consisting of 29 items covering 6 dimensions: susceptibility, perceived seriousness, perceived benefit, perceived barriers, health motivation, and self-efficacy. Each item was ranked on a 5-point scale from 1 (strongly disagree) to 5 (strongly agree). The total score ranged from 29 to 145, with a higher score indicating a more positive health belief in functional exercise. The Cronbach's alpha of the total scale in this study was 0.897.

Social Support Rating Scale (SSRS)

We used the SSRS to estimate the level of social support²⁰ consisting of 10 items covering 3 dimensions: objective support, subjective support, and the utilization of support. Item 1–5 and Item 8–10 were ranked on a 4-point scale from 1 to 4. Items 6 and 7 were multiple-choice items. The total score ranged from 12 to 66, with a higher score indicating more positive social support. The Cronbach's alpha of the total scale in this study was 0.890.

Disease Perception Questionnaire (DPQ)

We used the DPQ to estimate the disease perception of breast cancer consisting of 9 items covering 3 dimensions: cognitive ability, emotions and comprehension.²¹ In total, 8 items are ranked on an 11-point scale from 0 to 10. Item 9 was an open question to estimate the cause of the disease. The total score ranges from 0 to 80, with a higher score indicating more positive disease perception of breast cancer. The Cronbach's alpha of the total scale in this study was 0.752.

Family Care Index Questionnaire (FCIQ)

We used the FCIQ to estimate the level of family care consisting of 5 items covering 5 dimension: intimacy, emotion, adaptability, cooperation and growth.²² Each item was ranked on a 3-point scale from 0 (strongly disagree) to 3 (strongly agree). The total score ranged from 0 to 10, with a higher score indicating more positive family care. The Cronbach's alpha of the total scale in this study was 0.924.

Demographic and Clinical Characteristics of Patients

We used an electronic medical record system and face-to-face surveys to acquire demographic and clinical characteristics of patients, including age, education level, marital status, monthly income, type of medical insurance, resident address, attended lectures, breast surgery, axillary lymph node dissection, radiotherapy history, BMI, time after surgery, clinical stage, number of children, comorbidities, PICC/CVC/Port, family history, and walking habits.

Data Analysis

Data were analyzed using SPSS 25.0. Descriptive statistics were used to summarize patients' characteristics and variables, and the non-normally-distributed variables were represented by quartiles. The CMS, as well as demographic and clinical characteristics of patients, was analyzed through a Chi-square test. Because of the non-normally-distributed scores of the scales, the correlations among CHBMS, SSRS, DPQ, FCIQ and FECSPBCP were analyzed through Spearman correlation analysis. Binary logistic regression analysis was used to select the main influencing factors of functional exercise compliance. Differences of less than 0.05 ($P < 0.05$) were considered statistically significant. A predictive model was constructed through SPSS Modeler 18, in which a CHAID decision tree was used to construct the predictive model. A CHAID analysis was used to detect statistical interactions and describe the relations between the independent variables and dependent variables. In classification problems, balanced datasets with equal counts of all classes are optimal for training.²³ However, data often has an imbalanced class distribution. Because of the unbalanced dependent variables, the over-sampling approach was used to solve data imbalance. The data were randomly divided to three subsets: a training set, a validation set and a test set at a ratio of 6:2:2. The CHAID decision tree model was graphed in a tree structure to provide a straightforward visualization regarding the relationship between independent and dependent variables. The analysis would be stopped when $P > 0.05$, or there were < 2 observations on parent nodes, or

there were <1 observations on child nodes. We used prediction accuracy, sensitivity, specificity and the area under the receiver operation characteristic curve (AUC) to analyze the efficacy of the predictive model.

Results

Demographics, Clinical Characteristics and CMS

Of the 227 patients, 36.1% were defined to be in a good compliance, and 77.1% were more than 44 years old. The majority (96%) of patients were married 70% whom had not attended lectures. Total normal shoulder functions were observed among 56.4% of the patients. Chi-square tests on the demographics, clinical characteristics, CMS and functional exercise compliance are presented in Table 2. Attended lectures ($P=0.002$), time after surgery (month) ($P=0.006$), walking habits ($P=0.034$) and the difference among groups have statistical significance according to Chi-square tests.

Table 2 Demographics, Clinical Characteristics, and CMS (N=227)

Variables	Grade	Poor Compliance	Good Compliance	χ^2	P
		n=145 (63.9%)	n=82 (36.1%)		
Age	18~44	33	19	3.450	0.178
	45~59	74	50		
	≥60	38	13		
Education level	Primary school and below	69	34	0.838	0.840
	Junior high school	35	22		
	High school/ Technical secondary school	21	14		
	Junior college and above	20	12		
Marital status	Never married	3	3	0.522	0.770
	Married	140	78		
	Widowed/ Divorced	2	1		
Monthly income	<3000	25	9	5.020	0.081
	3000~6000	83	41		
	>6000	37	32		
Type of medical insurance	Residents	109	66	0.912	0.634
	Employees	28	13		
	Self-paying	8	3		
Resident address	Village	59	23	4.279	0.118
	Town	38	30		
	City	48	29		
Attended lectures	No	112	47	9.910	0.002*
	Yes	33	35		
Breast surgery	Breast conserving surgery	43	22	0.247	0.884
	Total mastectomy	51	29		
	Modified radical mastectomy	51	31		
Axillary lymph node dissection	No	96	52	0.180	0.671
	Yes	49	30		

(Continued)

Table 2 (Continued).

Variables	Grade	Poor Compliance	Good Compliance	χ^2	P
		n=145 (63.9%)	n=82 (36.1%)		
Radiotherapy history	No	51	29	0.001	0.977
	Yes	94	53		
BMI	<18.5	2	6	5.787	0.055
	18.5~24.9	93	52		
	≥25	47	22		
Time after surgery (month)	0~1	13	16	16.505	0.006*
	>1~2	29	27		
	>2~3	25	16		
	>3~4	24	9		
	>4~5	22	6		
	>5~6	32	8		
	Clinical stage	0	17		
I		27	17		
II		80	50		
III		21	9		
Number of children	0	6	4	0.245	0.885
	1~2	96	56		
	≥3	43	22		
Comorbidities	0	60	42	2.439	0.295
	1~2	70	31		
	≥3	15	9		
PICC/CVC/Port	No	62	25	4.694	0.196
	PICC	7	8		
	CVC	8	4		
	Port	68	45		
Family history	No	129	73	<0.001	0.989
	Yes	16	9		
Walking habits	No	76	31	4.486	0.034*
	Yes	69	51		
CMS	Poor	2	1	3.593	0.464
	General	7	3		
	Good	14	15		
	Very good	38	19		
	Completely normal	84	44		

Notes: *Indicates that the variable between "Poor compliance" and "Good compliance" was statistically significant, $P < 0.05$.

FECSPBCP, CHBMS, SSRS, DPQ, and FCIQ

The score of FECSPBCP, CHBMS, SSRS, DPQ, and FCIQ was 49 (38,58), 90 (81,102) points, 35 (30,40) points, 34 (25,41) points and 8 (5,10) points, respectively. The correlation between self-efficacy and functional exercise compliance was the strongest, with a correlation coefficient of 0.784. The correlations among CHBMS, SSRS, DPQ, FCIQ and FECSPBCP are presented in Table 3. Through a Spearman correlation analysis, FECSPBCP showed statistically significant correlations with perceived seriousness, perceived benefit, perceived barriers, health motivation, self-efficacy, objective support, subjective support, utilization of support, emotions, comprehension, intimacy, emotion, adaptability, cooperation and growth.

Binary Logistic Regression Analysis

The variables identified through Chi-square tests and correlation analyses as independent variables were entered into a binary logistic regression analysis. Functional exercise compliance was the dependent variable. There were 3 variables (time after surgery, perceived benefit and self-efficacy) with statistical significance. The categorical variable assignment is presented in Table 4. The result of binary logistic regression analysis is presented in Table 5. The adjusted $R^2=0.654$. The significant factors were time after surgery ($P=0.03$), perceived benefit ($P<0.001$) and self-efficacy ($P=0.017$) through a binary logistics regression analysis.

Construction and Evaluation of the Predictive Model

We used a CHAID decision tree for constructing the predictive model. Time after surgery, perceived benefit and self-efficacy were independent variables and the functional exercise compliance was the dependent variable. The CHAID

Table 3 Correlation Between CHBMS, SSRS, DPQ, FCIQ and FECSPBCP

Variables	Number of Item	Score Range	M (P25, P75)	r
FECSPBCP	18	18~72	49 (38,58)	1.000*
Physical exercise compliance	8	8~32	22 (16, 30)	0.945*
Postoperative attention compliance	5	5~20	15 (13,16)	0.622*
Actively seeking advice compliance	5	5~20	11 (8, 15)	0.841*
CHBMS	29	29~145	90 (81,102)	0.549*
Susceptibility	4	4~20	8 (5,14)	0.103
Perceived seriousness	6	6~30	20 (14,23)	0.188*
Perceived benefit	3	3~15	12 (9,12)	0.781*
Perceived barriers	5	5~20	13 (10,15)	-0.212*
Health motivation	7	7~35	25 (21,28)	0.707*
Self-efficacy	4	4~32	15 (12,16)	0.784*
SSRS	10	12~66	35 (30,40)	0.312*
Objective support	3	1~22	9 (8,10)	0.253*
Subjective support	4	8~32	20 (17,24)	0.266*
Utilization of support	3	3~12	5 (3,7)	0.266*
DPQ	8	0~80	34 (25,41)	0.119
Cognitive ability	5	0~50	18 (13,24)	0.066
Emotions	2	0~20	10 (9,11)	0.166*
Comprehension	1	0~10	5 (3,7)	0.159*
FCIQ	5	0~10	8 (5,10)	0.265*
Intimacy	1	0~2	2 (1,2)	0.186*
Emotion	1	0~2	2 (1,2)	0.230*
Adaptability	1	0~2	2 (1,2)	0.284*
Cooperation	1	0~2	2 (1,2)	0.270*
Growth	1	0~2	2 (1,2)	0.278*

Notes: *Indicates that the correlation between variable and functional exercise compliance was statistically significant, $P<0.05$.

Table 4 Assignment of Categorical Variables

Variable	Assignment
Time after surgery (month)	0~1=0, >1~2=1, >2~3=2, >3~4=3, >4~5=4, >5~6=5
Attended lectures	Not=0, Yes=1
Walking habits	Not=0, Yes=1
Functional exercise compliance	Poor compliance=0, Good compliance=1

Table 5 Logistic Regression Analysis for the Influencing Factors of Functional Exercise Compliance

Variable	B	SE	Wald χ^2	P	Exp (B)	Exp (B)95% CI	
						Low	High
Time after surgery (month)			12.373	0.03			
Time after surgery =1	-0.853	0.678	1.586	0.208	0.426	0.113	1.608
Time after surgery =2	-0.471	0.743	0.401	0.527	0.625	0.146	2.68
Time after surgery =3	-2.006	0.882	5.179	0.023	0.134	0.024	0.757
Time after surgery =4	-2.607	0.906	8.27	0.004	0.074	0.012	0.436
Time after surgery =5	-1.875	0.859	4.765	0.029	0.153	0.028	0.826
Perceived benefit	0.523	0.148	12.451	<0.001	1.686	1.262	2.254
Self-efficacy	0.386	0.162	5.655	0.017	1.471	1.07	2.021
Constant	-15.164	3.121	23.606	<0.001	0		

decision tree model is presented in Figure 1 (The CHAID decision tree of functional exercise compliance). There were 12 nodes in total, 9 of which were terminal nodes. Perceived benefit was the most predictive for functional exercise compliance with a variable importance of 0.52. Time after surgery was the second most predictive with a variable importance of 0.25, and the least predictive variable was self-efficacy, with a variable importance of 0.23.

Results show that perceived benefit is associated with functional exercise compliance ($P<0.001$). When the perceived benefit was ≤ 8 (Node 1), the probability of a poor functional exercise compliance was greater (100%) than that of a good functional exercise compliance. When perceived benefit was from 8 to 11 (Node 2), the probability of a poor functional exercise compliance was also greater (79.5%) than a good one. When perceived benefit was from 11 to 13 (Node 3), the probability of a good functional exercise compliance was greater (69.4%) than of a poor one. When perceived benefit was >13 (Node 4), the probability of a good functional exercise compliance was also greater (91.4%) than that of a poor one.

Node 2 was split into two child nodes (Nodes 5–6). When self-efficacy was ≤ 12 (Node 5), the probability of a poor functional exercise compliance was greater (100%) than that of a good one. When self-efficacy was >12 (Node 6), the probability of a poor functional exercise compliance was greater (68%) than that of a good one.

Node 3 was split into three child nodes (Nodes 7–9). When time after surgery was 0–1 month, or >1 –2 months (Node 7), the probability of a good functional exercise compliance was greater (87.5%) than that of a poor one. When time after surgery was >2 –3 months, or >3 –4 months (Node 8), the probability of a good functional exercise compliance was greater (63.6%) than that of a poor one. When time after surgery was >4 –5 months, or >5 –6 months (Node 9), the probability of a poor functional exercise compliance was greater (87.5%) than that of a good one.

Node 7 was split into two nodes (Nodes 10–12). When self-efficacy was ≤ 14 (Node 10), the probability of a poor functional exercise compliance was greater (60%) than that of a good one. When self-efficacy was from 14 to 16 (Node 11), the probability of a good functional exercise compliance was greater (100%) than that of a poor one. When self-efficacy was >16 (Node 12), the probability of a good functional exercise compliance was greater (66.7%) than that of a poor one.

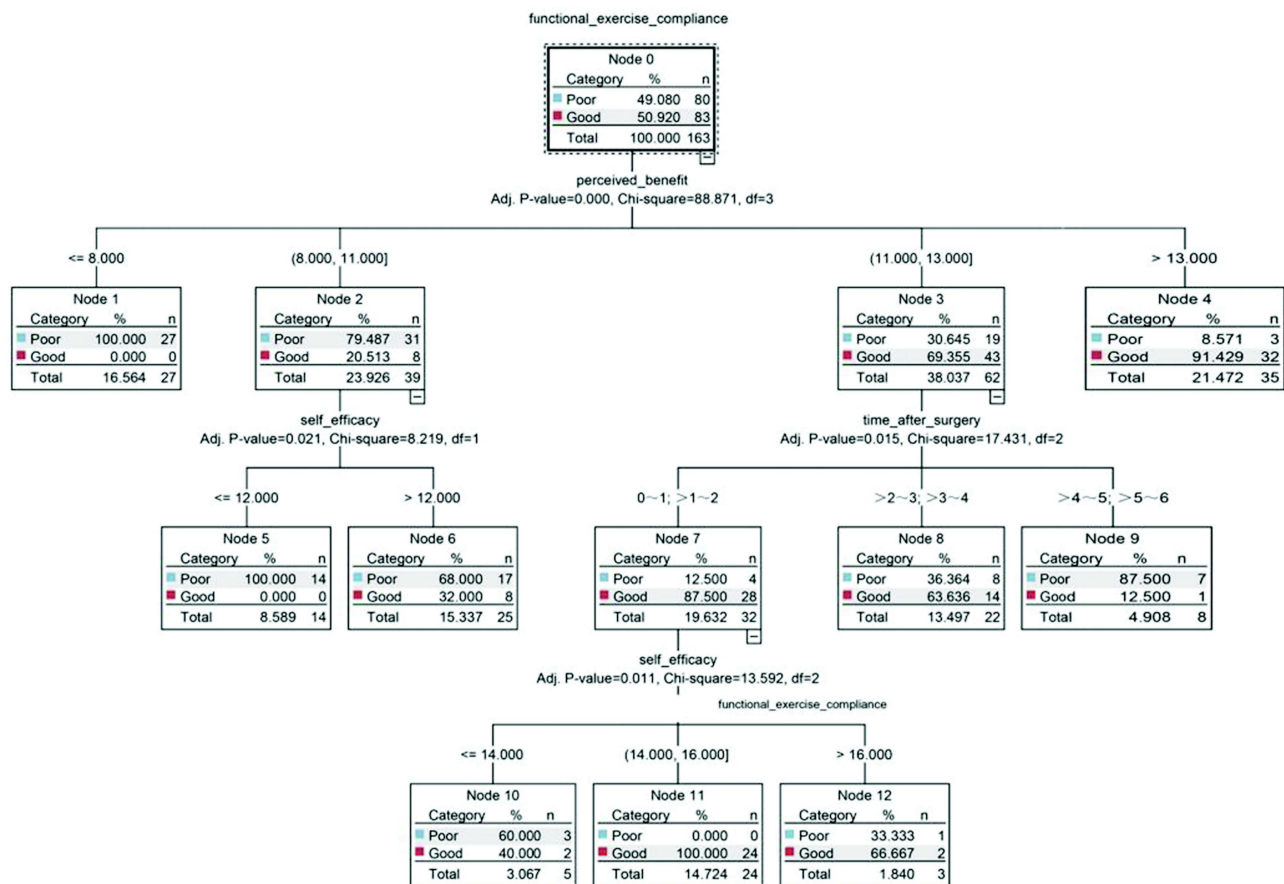


Figure 1 The CHAID decision tree of functional exercise compliance.

The confusion matrix of the test set was used to assess the performance of the predictive model. Prediction accuracy, sensitivity, specificity and AUC were 70.73%, 57.1%, 77.8% and 0.81 respectively. The confusion matrix of test set is presented in Table 6. The AUC of the training set, test set and validation set was 0.924, 0.81 and 0.85, respectively. The ROC of the training set, test set and validation set is presented in Figure 2 (ROC curves for the training set, test set and validation set).

Discussion

The aims of our study were to identify the main influencing factors and build a predictive model that could be used to predict the functional exercise compliance of patients with breast cancer. This is the first study to construct a predictive model of functional exercise compliance for patients with breast cancer. Regular functional exercise has been shown to

Table 6 Confusion Matrix of the Test Set

		Predicted	
		Poor	Good
Observed	Poor	21	6
	Good	6	8

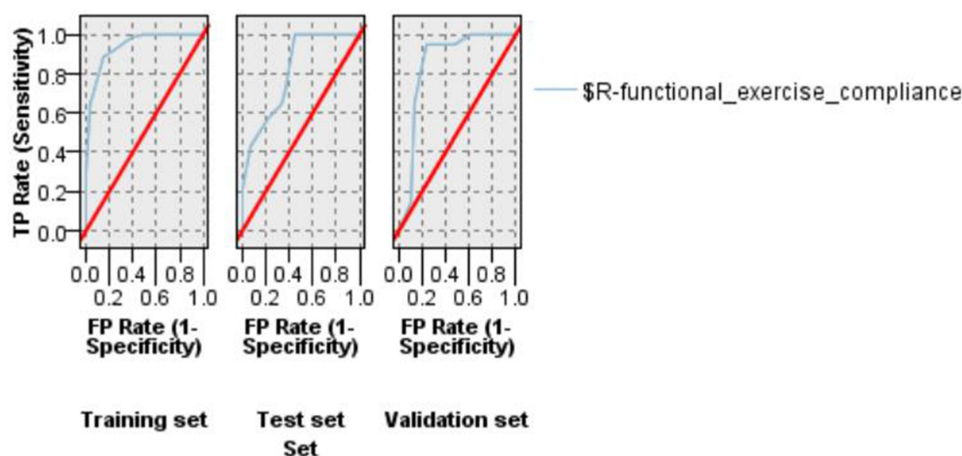


Figure 2 ROC curves for the training set, test set and validation set.

benefit the recovery of upper limbs if patients with breast cancer initiate within 6 months after breast surgery, which can promote lymph and blood return, reduce swelling and decrease the risk of lymphedema as well as motor dysfunction of upper limbs.³ According to the study of Shen et al, functional exercise compliance was a factor influencing shoulder joint dysfunction, which were characterized by joint stiffness and the motion limitations of the affected upper limb.²⁴ So, shoulder joint dysfunction may greatly affect the quality of life of patients with breast cancer.

Through literature review, functional exercise has been shown effective and beneficial for improving the physical and physiological health outcomes of patients with breast cancer after surgery. According to our study, the result showed that the main factors affecting functional exercise compliance were time after surgery, perceived benefit and self-efficacy. Clinical nurses can put the results of time after surgery, perceived benefit and self-efficacy into the prediction model, and then predict the level of functional exercise compliance of patients with breast cancer, so as to decide the degree of interventions for them. Besides, we used a CHAID decision tree for constructing the predictive model, which could provide a visual representation of predictive rules so that the predictive process could be more easily understood by clinical nurses while helping them make decisions.

In our study, the score of FECSPBCP was 49 (38, 58), and there were only 36.1% of patients were defined as displaying a good compliance. These findings were consistent with the study of Ze et al²⁵ who also found that the score of FECSPBCP was 49 (46,53). Therefore, the functional exercise compliance alone, for patients with breast cancer, was not sufficient. Early interventions are also necessary which require the identification of patients predicted to have a poor functional exercise compliance.

The results of binary logistic regression analysis indicated that perceived belief, time after surgery and self-efficacy were the main factors contributing to functional exercise compliance whose importance index was 0.52, 0.25 and 0.23, respectively. Thus, under the guidance of the Anderson model, we can select main influencing factors more effective.

Perceived benefit and self-efficacy are important predictive variables for functional exercise compliance. These findings are partially similar to the research of Abdelhalim et al, who pointed out that all predictors come from health belief model were predictive variables for the compliance with anti-hypertensive therapies, including perceived severity, perceived susceptibility, perceived benefits, perceived barriers and cues to actions.²⁶ Perceived benefit and self-efficacy are important dimensions of the CHBMS. In our study, the CHBMS we used was revised by Lu to estimate the health belief of patients with breast cancer in functional exercise.¹⁷ A health belief model is a prominent theoretical framework to understand how illness perception, patients' context and the environment affect their health behavior.²⁷ In the Anderson model, health belief is an important variable for analyzing the health behavior of individuals.¹⁶ However, in the health belief model, only perceived benefits and self-efficacy emerged as significant predictors of functional exercise compliance in our study. In the study of Shitu et al perceived barriers and self-efficacy were suggested as significant predictors of students' compliance with COVID-19 preventive behavior.²⁸ Perceived barrier refer to one's belief in the

tangible and psychological costs of the advised behavior.²⁹ As the authors acknowledged, the biggest barrier for functional exercise was the lack of time. In our study, 96% of the patients were married, most of whom (54.6%) were 45 to 59 years old, so they had to carry additional burdens such as taking care of their families, limiting the time for them to do functional exercise. However, perceived barrier was not a significant predictor in our study, which might be because functional exercise is simple, low-cost, easy to perform and has no side effects.

In this study, the score of perceived benefits was relatively high at 12 (9,12), with an importance of 0.52. The diagram of the CHAID decision tree shows that when the perceived benefit is ≤ 8 , the probability of a poor functional exercise compliance is 100%. Perceived benefit refers to an individual's concept of benefits, the efficacy of a treatment or behavioral changes in combating risks.³⁰ For patients with breast cancer who undergo surgery, should they determine that they are at risk of upper limb dysfunction or breast-cancer-related lymphoedema, they must evaluate whether functional exercise is likely to mitigate their chances of developing diseases. In order to improve functional exercise compliance, clinical nurses should increase advocacy for the benefits of functional exercise.

Self-efficacy can determine an individual's efforts to perform a certain task and his or her ability to "bounce back" when encountering difficulties.³⁰ The results of self-efficacy in our study are consistent with those of prior studies of Tao et al, Hu et al suggested that the selection and maintenance of an individual's behavior were largely affected by self-efficacy, which was closely related to functional exercise compliance.^{6,31} Self-efficacy plays an important role in exercise and medication compliance.^{32,33}

Time after surgery is the second most predictive factor, with a variable importance of 0.25. The CHAID decision tree diagram shows that when the score of perceived belief is 11–13 and the time after surgery is more than 4 months, the probability of a poor functional exercise compliance is 87.5%. Previous researches are consistent with our outcomes about time after surgery.^{4,34,35} On the one hand, we have shown that with the progression of time and the recovery of upper limb functions, the functional exercise compliance of patients can gradually drop. On the other hand, we have pointed out that at 3 months after surgery, the functional exercise compliance of patients has started to decrease. The results of our binary logistic regression analysis indicate that compared to the first postoperative month, functional exercise compliance decreased 3 to 6 months after surgery. As is noted in the study of *Petito et al*, the shorter the postoperative time is, the higher the level of health belief will be, and the better the functional exercise compliance will be.³⁶ Additionally, when patients are discharged from hospital, the guidance intensity of functional exercise by clinical nurses will decrease and patients may lack functional exercise. Thus, as the time after surgery goes on, the functional exercise compliance changes accordingly. So, clinical nurses should carry out targeted interventions according to different periods after surgery, such as strengthening guidance when the postoperative time has exceeded 3 months.

At present, the most commonly used tool for evaluating the level of functional exercise compliance of patients with breast cancer is FECSPBCP whose clinical usefulness and reliability have been fully validated. However, with the development of artificial intelligence, FECSPBCP may no longer be suitable for assessing compliance. For example, *Ye et al* developed an electronic rehabilitation system based on human-action-detection technology, where a patient could perform functional exercise following the videos and the system could identify and correct exercise errors.³⁷ Thus, one of the items of FECSPBCP, you can remember the specific methods and techniques of functional exercise, was not suitable. Because it would no be necessary for a patient to remember the specific methods or techniques of functional exercise with the help of videos. In our study, we just needed to evaluate the patients' perceived benefit (3 items), self-efficacy (4 items) and time after surgery (1 item) and, in turn, predict the probability of functional exercise compliance. Compared with FECSPBCP, our predictive model may be more suitable for assessing the level of functional exercise compliance today. The predictive model constructed based on CHAID decision tree analysis in this study provides a visual solution, which helps to improve our understanding of the predictive process.

Limitations

Although the selection of main factors influencing functional exercise compliance was based on a theoretical Anderson model, the predictive accuracy, specificity and AUC of our model are at the moderate level. This study revealed the influencing factors of functional exercise compliance and pointed out the predictive role of each of them. In addition, the decision tree could provide a visual representation of predictive rules so that the predictive process could be more easily understood by clinical staff while helping them make clinical decisions. So, our study can still be a clinical auxiliary tool to aid nurses in clinical decision-making. However, the sensitivity of our model was low (57.1%). We need to expand the sample size and external validation in further research. Additionally, our study was conducted in two hospitals, where the two functional exercise programs were mostly concordant, and the functional exercise compliance of patients was assessed based on the program of their hospitals, but the sample size of different hospitals might have led to a certain degree of biases in the results.

Conclusion

The functional exercise compliance of patients with breast cancer is not sufficient, whose main influencing factors are perceived benefit, time after surgery and self-efficacy. The predictive power of the predictive model based on CHAID is moderate, but the decision tree can provide a visual representation of predictive rules, so it can still be a clinical auxiliary tool to aid nurses in clinical decision-making. A larger sample size and external validation are needed in further research.

Data Sharing Statement

We have a full control of all primary data and agree to allow the journal to review the data if requested.

Compliance with Ethical Standards

The study was approved by the Ethics Committee of Cancer Hospital of Shantou University Medical College (No. 2021057). The study complies with the Declaration of Helsinki, and all participants provided informed consent.

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Author Contributions

All authors made a significant contribution to the work reported, whether in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revision or critically reviewing the article; gave final approval of the version to be published; they have agreed on the journal to which the article had been submitted; and agreed to be accountable for all aspects of the work.

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