Original Article

Predicting the Functional Status of Post-Cardiac Surgery Patients at Six Months After Discharge from Hospital : Utilizing the 6-Minute Walk Test Distance (6-MWT) and Clinical Characteristics at Hatyai Hospital

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ABSTRACT

Objectives: To evaluate the use of the 6-minute walk test (6-MWT) in predicting the functional status of post-cardiac surgery patients six months after discharge

Study design: Prognostic prediction research and retrospective observational cohort design

Setting: Hatyai Hospital, Thailand

Subjects: Post-cardiac surgery pateints at six months after discharge from Hatyai Hospital

Methods: The study retrospectively reviewed pre- and post-cardiac surgery data records. Patients' functional status at six months was assessed using the New York Heart Association (NYHA) Classification. Multivariable logistic regression analysis was employed to identify variables to predict the patients' functional status. The predictive scores were assigned based on coefficient values derived from the regression equation.

Results: A total of 272 post-cardiac surgery patients were followed up six months after discharge, of whom 181 patients (66.5%) exhibited good functional status (NYHA Classification 1). Six variables were predictive of NYHA Classification 1: pre-surgery ejection fraction (EF), length of hospital stay (LOS), metabolic equivalences (METs) pre-discharge, duration of daily exercise at two weeks, duration of daily exercise at six weeks, and the six-minute walk test (6-MWT) at three months. The constructed prediction scores ranged from 0 to 23. The prediction score performed well in predicting the functional status at six months with an area under the receiver operating characteristic curve (AUROC) 0.89, 95%CI: 0.85-0.93. The clinical risk scores were categorized into two groups: low-good functional status scores (< 14) with a positive predictive value (PPV) of 37.5 (95%CI: 20-40, $p < 0.001$) and high-good functional status scores (≥ 14) with a PPV of 95.6 (95%CI: 0.91-0.98, $p < 0.001$).

Conclusions: The combination of pre-surgery EF, METs pre-discharge, LOS, duration of daily exercise at two weeks and six weeks, and the 6-MWT distance at three months can serve as a predictor of the good functional status of post-cardiac surgery patients at six months after discharge.

Keywords: prognostic prediction, 6-minute walk test, cardiac rehabilitation, post-cardiac surgery

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Introduction

The primary goal of cardiac rehabilitation is to restore heart function to a level where patients can engage in their daily activities and pursue a career that aligns with their physical condition, ultimately preventing recurrence. Cardiac rehabilitation programs offered in various settings (center-based, home-based, or through telerehabilitation) can improve functional capacity, physical activity, and health-related quality of life after coronary revascularization.[1] Utilizing the 6-minute walk test (6-MWT) distance has been identified as a simple, cost-effective, and highly efficient method that does not require additional equipment.[2] Moreover, this method is easily employed in clinical practice, serving as a crucial indicator for planning cardiac rehabilitation and appropriately adjusting exercise patterns.[3] The 6-MWT is used to assess the patient's ability to perform activities of daily living.[4]

Following open-heart surgery, patients were normally followed up for an average period of 6.8 months (range 2 to 15 months). Most of the post-operative patients were classified as New York Heart Association (NYHA) Classification 1.[5] Functional capacity was evaluated according to the NYHA Classification before and 18 months after surgery. The functional status improved clinically significantly after coronary artery bypass grafting (CABG) surgery, particularly in physical functioning.[6] At 12 weeks after CABG surgery, patients were advised to engage in daily activities such as self-help and exercise. However, it was found that the patient's ability to perform their duties had decreased compared to prior to surgery. There was also a decline in functional capacity between the 8th and 12th week after surgery, with patients

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performing fewer activities than before. Such limitations may persist for up to three months. Functional capacity represents an individual's maximum potential for carrying out everyday life activities, meeting basic needs, and tolerating various activities as required, constituting an essential aspect of overall functional status.[7] In addition, post-cardiac surgery patients who had responsibilities as either a working professional or as a family leader frequently experienced anxiety when returning to work and daily routines.

A study examining factors predicting functional status in CABG patients found that multiple variables collectively predicted function recovery at the second post-surgery appointment by a statistically significant 17.7%. Specific variables that predicted the levels of functional recovery at the second appointment were ejection fraction (EF) and fatigue.[8] This finding suggests that lower EF and higher fatigue levels are associated with poorer functional recovery outcomes following CABG. The NYHA Classification is used to appraise the status of patients with heart disease and to evaluate treatment outcomes in clinical and research settings. There is an inverse correlation between NYHA Classification 2 and 4 and the 6-MWT in heart failure patients. Significant heterogeneity exists across studies in 6-MWT scores within each NYHA classification, with overlap in 6-MWT performance between NYHA Classification 1 and 2. The NYHA Classification is particularly effective in assessing more symptomatic patients (NYHA Classification 3 or 4) more than less asymptomatic or mildly symptomatic patients (NYHA Classification 1 or 2).

Nonetheless, the NYHA Classification is a practical and widely used tool in routine clinical practice.[9] For that reason, the NYHA Classification was utilized in this study as an assessment tool to effectively reflect the functional status of these patient groups. Patients were divided into 2 groups based on the NYHA Classification: NYHA Classification 1 and NYHA Classifications 2, 3, and 4.

Hatyai Hospital recognizes the importance of comprehensive cardiac rehabilitation services and has established a dedicated clinic to address the needs of pre- and post-cardiac surgery patients. However, despite these efforts, there remains a gap in predicting the outcomes of such rehabilitation interventions.

In light of this, the present study aimed to fill this research gap by focusing on using the distance covered in the 6-MWT as a predictive measure of functional status in post-cardiac surgery patients and to integrate the 6-MWT distance with clinically relevant characteristics such as age, gender, pre-surgery BMI (body mass index), pre-surgery EF, surgical method, post-surgery complications, re-admission occurrences, comorbidities, pre-surgery congestive heart failure (CHF), smoking habits, LOS (length of stay), pre-surgery NYHA Classification, METs (metabolic equivalents) pre-discharge, as well as duration and frequency of daily exercise. Combining these relevant clinical characteristics was used to seek a comprehensive understanding of their collective impact on predicting functional status at six months of post-cardiac surgery patient cohorts.

Methods

Study design

Using Hatyai Hospital's medical record data, a retrospective observational cohort design and prognostic prediction research effort was developed. The study protocol received approval from the Institutional Ethics Committee (Hatyai Hospital Certificate No. HYH EC 071-65-01) and the research was conducted in accordance with the Declaration of Helsinki.

Participants

This study included pre- and post-cardiac surgery patients from the cardiac rehabilitation clinic at Hatyai Hospital from October 2018 to September 2022.

The inclusion criteria were:

1. Entering the cardiac rehabilitation program during both pre- and post-cardiac surgery (Phase I) and continuing participation in the program after discharge from Hatyai Hospital (phases II and III)
2. Continuing the cardiac rehabilitation training program at home following the standard cardiac rehabilitation protocol

The exclusion criteria were:

1. Patients with neurological disease and/or musculoskeletal injuries
2. Patients with incomplete medical records
3. Juveniles with congenital heart disease (CHD)
4. Death

Data collection

Potential clinical predictors included various clinical characteristics, such as age, gender, pre-surgery BMI, pre-surgery EF, surgical method, post-surgery complications pre-discharge (e.g., lung atelectasis, pneumonia, CHF, pleural effusion and pneumothorax), re-admission, comorbidities (e.g., hypertension, diabetes mellitus, hyperlipidemia, and chronic kidney disease (CKD), pre-surgery CHF, smoking, LOS, pre-surgery NYHA Classification, METs pre-discharge, 6-MWT at three different time points (at two weeks, six weeks and three months), frequency and duration of exercise at three different time points (at two weeks, six weeks and three months).

Sample size calculation

The prediction analysis was conducted at six months for post-cardiac surgery patients. The current study incorporated the distance covered in the 6-MWT and relevant clinical characteristics of 20 randomly selected patients assumed to have a pre-surgery EF in the 40% to 49% range. The estimated sample size analysis in this study was classified according to the standard of NYHA Classification, whereby participants classified as NYHA classification 1 were considered to have a 0% risk. Those who were classified as NYHA Classification

2, 3, and 4 were considered to have a 10% risk. For statistical analysis, a two-sided method with a significance level of 0.05 and a power of 0.9, assuming a ratio of 2:1 between NYHA Classification 1 and NYHA Classification 2, 3, and 4 was used. This study anticipated having 162 patients in NYHA Classification 1 and 81 patients in NYHA Classification 2, 3, and 4. Therefore, a total of 243 patients was the minimum number to be recruited into this study.

Outcome measurements

The primary purpose of this study was to evaluate utilizing the 6-MWT at two weeks, six weeks, and three months combined with relevant clinical characteristics to predict good function status (NYHA Classification 1) among post-cardiac surgery patients at six months after discharge from Hatyai Hospital. The NYHA classification was divided into four classifications: Classification 1 (no limitation of physical activity), Classification 2 (slight limitation of physical activity), Classification 3 (marked limitation of physical activity), and Classification 4 (inability to perform any physical activity).[10]

Statistic methods

Statistical analysis

Continuous data are presented as means (M) and standard deviations (SD), while categorical data are presented as frequencies and percentages. The comparison of categorical data was performed using the Chi-square test or Fisher's exact probability test, and unpaired t-tests were used for the analysis of continuous data. Variables that showed significance in the univariate logistic regression were subsequently incorporated into the multivariable logistic regression analyses using STATA version 18 (Stata Corp LLC, College Station, TX, USA, under license of Medical Education Center at Hatyai Hospital). Statistical significance was defined as $p < 0.05$.

Model development

Among the 36 candidate predictors, elimination of predictors was based on various factors, including odds ratio, statistical significance (*p*-value), AUROC, and clinical relevance. Logistic regression analysis was employed to identify predictors of functional status. Initially, univariate analysis was conducted on the clinical characteristics data to avoid bias. The resulting reduced multivariable model was evaluated for its predictive performance in terms of discrimination and calibration. The measure of discrimination is reported as AUROC. The measure of calibration is reported as the Hosmer-Lemeshow goodness-of-fit test, where a nonsignificant χ^2 value indicates a good fit of the model.

The final predictors were assigned logistic regression coefficients. Each predictor's logistic coefficient was divided by this reference, and the results were rounded to the nearest non-decimal integer for practicality. The scores were used to classify individuals into lower or higher-risk categories. The positive predictive value (PPV) was calculated for each score group, providing insight into the average post-cardiac surgery patient predictor associated with each score. Measures of calibration and discrimination were also conducted using regression with the functional status on the score. A calibration plot comparing the score-predicted risk with the observed risk indicated the model's predictive performance. Internal validation was performed through nonparametric receiver operating characteristic (ROC) regression with 1,000 bootstrapped replicates. Statistical significance was established at $p < 0.05$.

Scores were classified into two groups for clinical utility: low and high. In the low-good functional status group, lower cut-off points were chosen to minimize the magnitude of the PPV. In contrast, higher cut-off points were selected in the high-good functional status group to maximize the PPV's magnitude. The model's discriminative ability was assessed using a 95%CI to avoid overlapping with the specific PPV. The potential clinical utility of the model was determined through decision curve analysis. This analysis calculated the net benefit (NB) of applying the model to classify patients across a range of clinically relevant threshold probabilities, comparing the two groups of outcomes (good and poor functional status) in post-cardiac surgery patients at six months after discharge from Hatyai Hospital.

Results

The study grouped medical records according to the NYHA Classification: there were 181 patients in NYHA Classification 1 and 91 patients in NYHA Classification 2, 3, and 4. Therefore, this study's minimum number of participants was 272 patients (Fig. 1). Patient Baseline clinical characteristics are detailed in Tables 1 and 2. Prognostic factors with high predictive performance were chosen, characterized by a statistically significant $p < 0.05$, AUROC of > 0.51 , and clinically meaningful correlation. In the univariable logistic regression analysis, variables, including pre-surgery EF, METs pre-discharge, LOS, daily exercise duration at two weeks, six weeks, and the 6-MWT distance at three months, were identified as critical clinical predictors.

A multivariable logistic regression analysis was conducted to examine six potential clinical predictors, as presented in Table 3. The functional status score was calculated by summing the scores assigned to each variable. Consequently, the constructed prediction score had a range of 0 to 23 scores.

In the multivariate binary logistic regression analysis of the data, clinical features were statistically significant at $p < 0.05$. Although pre-surgery EF were non-statistically significant, they held clinical importance (Table 3). This study transformed the score predictors (β) regression coefficients into a simple score. Subsequently, the researcher developed a simplified model that integrated the distance of the 6-MWT with relevant clinical characteristics, facilitating easy application in clinical practice. Interestingly, the simple score demonstrated excellent discriminative ability (AUROC: 0.89, 95%CI: 0.85-0.93) (Fig. 2), while the Hosmer-Lemeshow good-

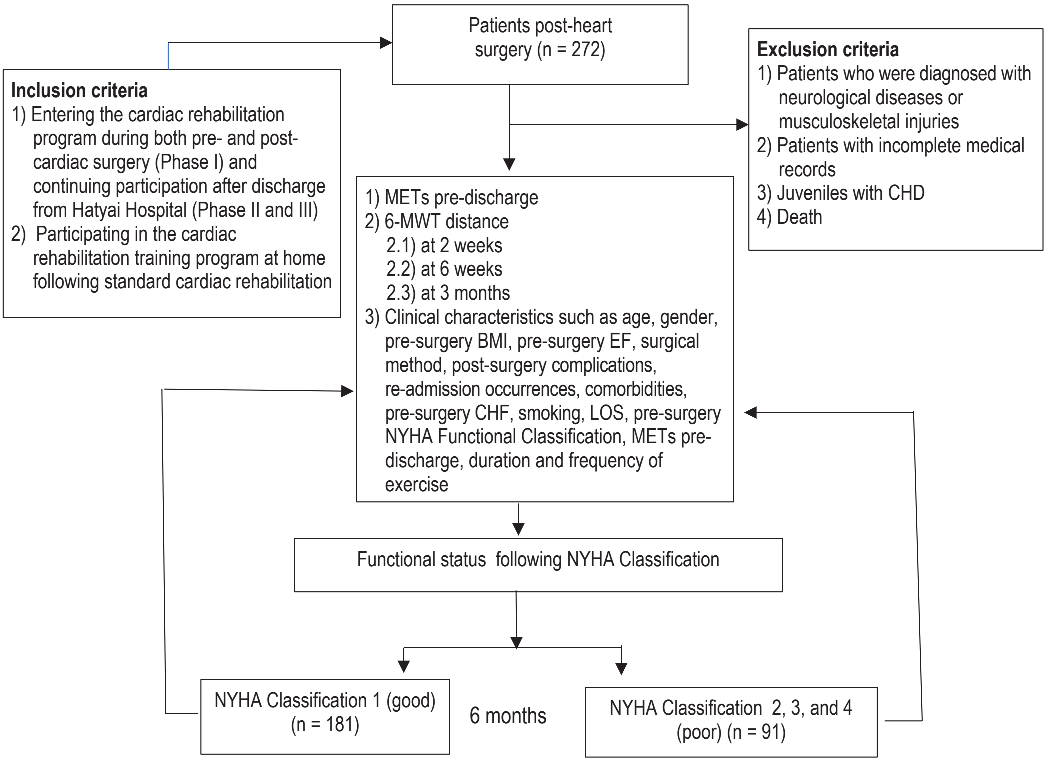

Figure 1. Study flow of the selection of eligible patients for development of a prediction tool for functional status

ness-of-fit test revealed a non-significant *p*-value of 0.64.

Measures of calibration showed strong performance in the developed model. The calibration plot showed that the scores predicted functional status and observed functional status increased concomitantly (CITL = 0.000, slope = 1.000, respectively) (Fig. 3). Internal validation of the model using nonparametric ROC with 1,000 bootstrap sampling replicates demonstrated robust performance (bootstrap shrinkage of 0.990) and an AUROC of 0.889 (95%CI: 0.853-0.927).

The clinical predictions were classified into two groups. The PPVs in the low-good functional status at six months (< 14) and high-good functional status at six months (≥ 14) groups were 37.5 (95%CI: 20-40, $p < 0.001$) and 95.6 (95% CI: 91-98, $p < 0.001$), respectively (Table 4, Fig. 4).

The model's performance regarding clinical usefulness and curve analysis elucidated the net benefit (NB) in predicting. With Functional status at a cut-off probability threshold of 0.665 (the prevalence point), the prediction model demonstrated an NB 4.5 times greater than that without the predictive model (Fig. 5).

Discussion

The present study aimed to evaluate utilizing the 6-minute walk test distance (6-MWT) with relevant clinical characteristics to predict the functional status among post-cardiac surgery patients six months after discharge from Hatyai Hospital, Thailand. Six variables can predict the functional status, including 1) pre-surgery EF, 2) LOS, 3) METs before discharge, 4) duration of exercise at two weeks, 5) duration of exercise at six weeks, and 6) 6-MWT at three months. The scores generated from these variables ranged from 0 to 23 points, indicating a statistically significant difference between patients with a good functional status (NHYA Classification 1) and those with poor functional status (NYHA Classification 2, 3, and 4) at six months (15.6±4.8 and 7.6±3.7, $p < 0.001$). The clinical score demonstrated a capability for predicting good functional status (NYHA Classification 1) at six months, as evidenced by an AUROC value of 0.89 (95%CI: 0.85-0.93, $p < 0.001$). The clinical score was divided into two groups: 1) low-good functional status (score < 14) exhibited a PPV of 37.5 (95%CI: 20-40, $p < 0.001$), while the high-good functional status (score ≥ 14) demonstrated a PPV of 95.6 (95%CI: 91-98, $p < 0.001$) indicating that the developed score has potential for practical clinical use. Rungtiwa et al.[11] reported the mean work ability of the body within two weeks after discharge from the hospital with an average value of 4.5±0.3 METs. This value aligns with the METs associated with moderate-intensity physical activity which typically range from 3 to 5 METs. That study also found that the METs values before discharge from the hospital were significantly different between 2 groups: those with good functional status (3.6±1.3) and those with poor functional status (2.9±1.4), ($p < 0.001$). That is, patients with good functional status before discharge from the hospital demonstrated the ability to perform physical activities at a moderate intensity.

The 6-MWT and clinical characteristics can be collectively utilized to construct clinical prediction scores, effectively predicting functional status according to the NYHA Classification after six months post-cardiac surgery. Patients were also

Table 1. Baseline characteristics of post-cardiac surgery patients with good functional status (New York Heart Association Classification, NYHA 1) and poor functional (New York Heart Association, NYHA 2-4) at 6 months: Univariable analysis

Clinical characteristics	Functional status at 6 months		*p*-value	AUROC (95%CI)
	NYHA Class 1 (n = 181)	NYHA Class 2, 3, and 4 (n = 91)		
Age (years)	54.8 (11.4)	61.4 (8.9)	<0.001	0.66 (0.26, 0.40)
Gender, n (%)				
Female	60 (33.2)	47 (51.7)	0.003	0.59 (0.53, 0.66)
Male	121 (66.9)	44 (48.4)		
Pre-surgery BMI	23.7 (4.0)	23.5 (3.9)	0.697	0.52 (0.45, 0.59)
Pre-surgery EF	55.9 (15.5)	56.2 (16.5)	0.871	0.51 (041, 0.56)
Methods of surgery, n (%)				
CABG	109 (60.2)	54 (59.3)	0.866	0.51 (0.43, 0.56)
Valve surgery	67 (37.0)	33 (36.3)		
Re-valve surgery	2 (1.1)	1 (1.1)		
CABG + valve surgery	3 (1.7)	3 (3.3)		
Post-surgery complication, n (%)				
Atelectasis (Yes)	10 (5.5)	10 (11.5)	0.086	0.53 (0.44, 0.51)
Pneumonia (Yes)	2 (1.1)	11 (12.1)	<0.001	0.55 (0.41, 0.48)
CHF (Yes)	10 (5.5)	10 (11.0)	0.086	0.53 (0.44, 0.51)
Pleural effusion (Yes)	25 (13.8)	16 (17.6)	0.258	0.52 (0.44, 0.53)
Pneumothorax (Yes)	1 (0.6)	1 (1.1)	0.558	0.50 (0.49, 0.51)
Re-admitted, n (%)				
CHF (Yes)	7 (3.9)	8 (8.8)	0.084	0.52 (0.44, 0.51)
Pleura effusion (Yes)	5 (2.8)	2 (2.2)	0.568	0.50 (0.44, 0.51)
Co-morbidities, n (%)				
Hypertension (Yes)	111 (61.4)	64 (70.4)	0.090	0.55 (0.40, 0.51)
Diabetes mellitus (Yes)	42 (23.2)	23 (25.3)	0.0407	0.51 (0.44, 0.55)
Hyperlipidemia (Yes)	98 (54.2)	53 (58.3)	0.305	0.52 (0.42, 0.54)
CKD (Yes)	7 (3.9)	7 (7.7)	0.146	0.52 (0.45, 0.51)
CHF pre-surgery (Yes), n (%)	48 (26.6)	33 (36.3)	0.065	0.55 (0.39, 0.51)
Smoking (yes), n (%)	98 (54.2)	35 (38.5)	0.010	0.58 (0.52, 0.64)
LOS (day)	10.1 (3.7)	13.7 (12.9)	<0.001	0.55 (0.38, 0.53)
METs pre-discharge	3.6 (1.3)	2.9 (1.4)	<0.001	0.63 (0.56, 0.70)
Duration of daily exercise (minutes)				
2 weeks	12.8 (8.3)	8.3 (5.6)	<0.001	0.68 (0.62, 0.75)
6 weeks	22.7 (9.8)	16.5 (9.4)	<0.001	0.70 (0.64, 0.77)
3 months	33.1 (13.2)	22.2 (9.6)	<0.001	0.75 (0.69, 0.81)
Frequency of exercise (day/weeks)				
2 weeks	6.9 (0.4)	7.0 (0.0)	0.266	0.50 (0.48, 0.50)
6 weeks	6.7 (0.9)	6.9 (0.5)	0.120	0.53 (0.44, 0.51)
3 months	6.4 (1.1)	6.6 (0.9)	0.084	0.55 (0.40, 0.50)

Data are presented as mean (SD); $p < 0.05$ indicates statistical significance; AUROC, area under the receiver operating characteristic curve; CI, confidence interval; BMI, body mass index; EF, ejection fraction; CABG, coronary artery bypass grafting; CHF, congestive heart failure; CKD, chronic kidney disease; LOS, length of stay; METs, metabolic equivalents

Table 2. Baseline characteristics of post-cardiac surgery patients with good functional status (New York Heart Association Classification, NYHA 1) and poor functional (New York Heart Association, NYHA 2-4) at 6 months (univariable analysis)

Clinical characteristics	Functional status at 6 months		*p*-value	AUROC (95%CI)
	NYHA class 1 (n = 181)	NYHA class 2, 3, and 4 (n = 91)		
NYHA Class pre-surgery, n (%)				
NYHA Class 1	47 (25.9)	19 (10.9)	0.002	0.62 (0.32, 0.45)
NYHA Class 2	79 (43.7)	40 (43.9)		
NYHA Class 3	51 (28.2)	32 (35.2)		
NYHA Class 4	4 (2.2)	9 (9.9)		
6-MWT distance (meters)				
2 weeks	328.1 (76.9)	238.5 (76.6)	<0.001	0.80 (0.74, 0.85)
6 weeks	397.7 (70.7)	286.4 (77.4)	<0.001	0.86 (0.82, 0.91)
3 months	428.6 (62.5)	315.4 (60.9)	<0.001	0.92 (0.88, 0.95)

Data are presented as mean (SD); $p < 0.05$ indicates statistical significance; AUROC, area under the receiver operating characteristic curve; CI, confidence interval; 6-MWT, 6-minute walk test

Table 3. Best multivariable clinical predictors, odds ratios (OR), 95% confident intervals (CI), logistic regression beta coefficients (β), and assigned item scores

Predictors	OR	95%CI	*p*-value	βeta	Score
EF % (pre-surgery)					
< 40	1.00	Reference	-	-	0
40-49	0.62	0.16, 2.36	0.487	-0.47	1
≥ 50	0.59	0.25, 1.42	0.239	0.52	1.5
METs pre-discharge					
≤ 3	1.00	Reference	-	-	0
> 3	1.59	0.78, 3.26	0.200	0.47	1
LOS (day)					
< 10	1.00	Reference	-	-	0
≥ 10	1.49	0.57, 3.94	0.419	0.40	1
Duration of daily exercise (minutes) at 2 weeks					
< 10	1.00	Reference	-	-	0
10-15	1.61	0.75, 3.47	0.221	0.48	1
> 15	5.73	1.52, 21.59	0.010	1.75	4.5
Duration of daily exercise (minutes) at 6 weeks					
< 15	1.00	Reference	-	-	0
15-30	1.68	0.70, 4.02	0.242	0.52	1.5
> 30	0.44	0.09, 2.25	0.326	-0.82	2
6-MWT (meters) at 3 months					
< 320	1.00	Reference	-	-	0
320-400	5.28	2.02, 13.79	0.001	1.66	4
> 400	134.46	35.59, 494.17	0.000	4.90	12

P < 0.05 indicates statistical significance

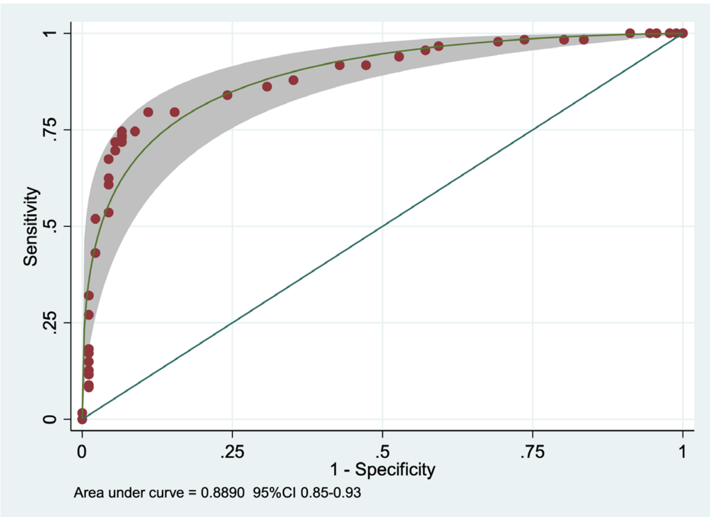

Figure 2. Area under received operating characteristic curve (AUROC) of clinical prediction scores of functional status at 6 months

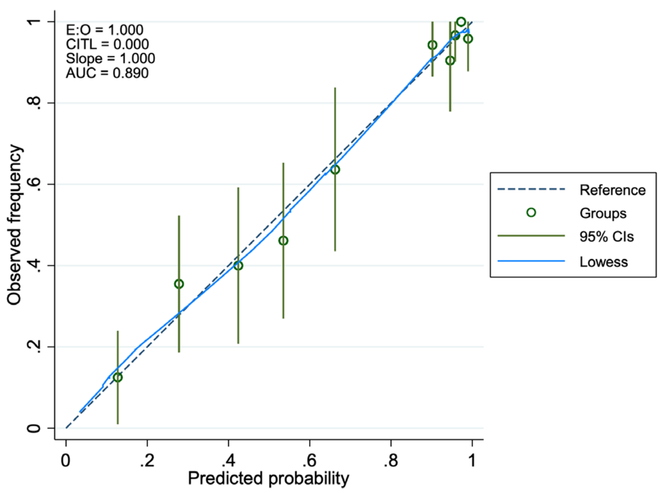

Figure 3. Calibration plot of score-predicted probability of functional status at 6 months and observed functional status at 6 months

Table 4. Distribution of good functional status (New York Heart Association Classification, NYHA 1) and poor functional (New York Heart Association, NYHA 2-4) at 6 months into low and high probability categories

Probability categories	Score	Functional status at 6 months				PPV (%)	95%CI	*p*-value
		NYHA Class 1 (n = 181)		NYHA Class 2, 3, and 4 (n = 91)				
		n	%	n	%			
Low	<14	51	37.50	85	62.50	37.5	0.2, 0.4	<0.001
High	≥14	130	95.59	6	4.41	95.6	0.91, 0.98	<0.001
Mean (SD)		15.6	(4.0)	7.6	(3.7)			<0.001

Data are presented as mean (SD); CI, confidence interval; PPV, positive predictive value; $p < 0.05$ indicates statistical significance

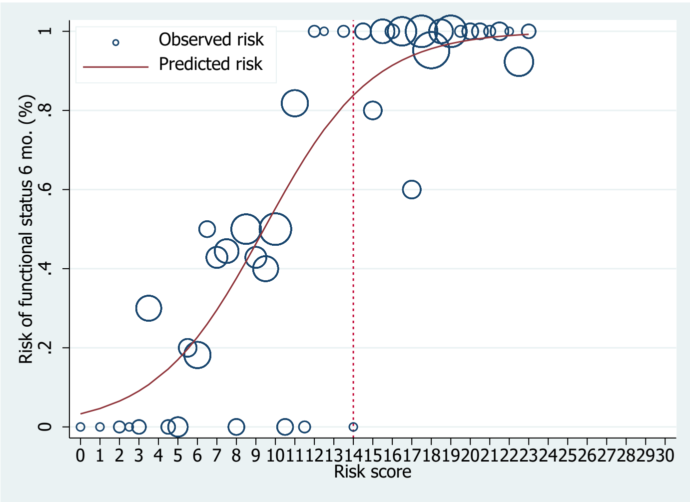

Figure 4. The Risk curve analysis: observed risk of functional status at 6 months (functional status 6 mo) (hollow circles) and predicted risk of functional status at 6 months by scores (solod line), size of circles represents relative number of patients in each score

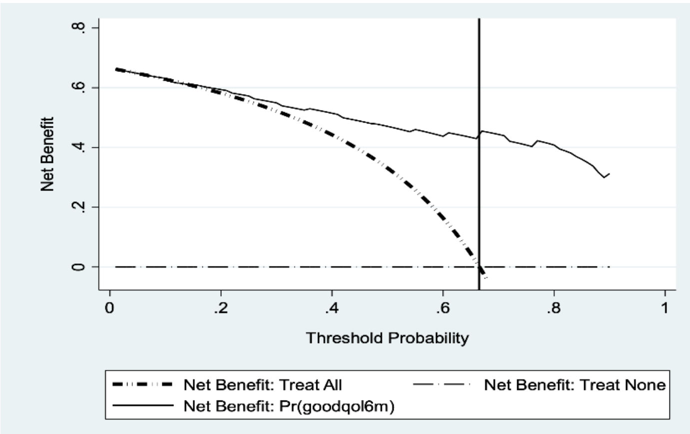

Figure 5. Decision curve analysis of the clinical score

categorized into two groups: those with a good functional status (NYHA Classification 1) and those with a poor functional status (NYHA Classification 2, 3, and 4). After dividing the patients into risk categories according to these levels, the assessment revealed good discriminative performance and good calibration for predicting functional status six months after surgery (Bumrungkittikul, J. et al.[12])The study reported independent predictors and developed an equation for the 6-MWT in post-cardiac surgery patients. The study identified that the 6-MWT at discharge, regular exercise, age, gender, and NYHA classification were the critical factors used to generate an equation to predict the 6-MWT performance at 4-6 weeks after hospital discharge. Surprisingly, existing studies have yet to illustrate the prediction of functional status using NYHA classification. The NYHA classification in the current study can be used to predict functional status in post-cardiac surgery patient cohorts.

The relevant clinical characteristics considered in this study were age, gender, pneumonia, diabetes mellitus, smoking, pre-surgery EF, LOS, NYHA classification pre-surgery, METs pre-discharge from the hospital, and duration of exercise at three different time points (at two weeks, six weeks and three months). These clinical characteristics were used in combination with the distance covered in the 6-MWT to predict the functional status. Previous research has similarly reported that age and gender are common predictors of 6-MWT distance.[3,10] The present study, however, did not assess the distance covered in the 6-MWT before discharge due to limitations associated with inpatient testing locations. Furthermore, a study conducted by Paorod et al.[13] illustrated that the NYHA Classification and pre-surgery EF have a statistically significant influence on the 6-MWT distance (p = 0.003, 0.008, respectively). Duongkamon et al.[8] also found that age, gender, and heart compression values are related to the level of functional ability after CABG surgery. In that study during the second follow-up examination, statistical significance was observed (r = 0.207, r =0.203, and r = -0.201; $p < 0.05$), which is contrary to the current study, in that it did not find pre-surgery EF to be clinically associated with 6-MWT in predicting functional status. Thus, investigation into the complex interplay of pre-surgical factors and post-surgery outcomes requires further investigation.

The present study found significant differences in exercise duration at two weeks, six weeks, and three months between the groups with good and poor functional status. Similarly, a study by Paorod et al.[14] reported a significant within-group difference in the 6-MWT distance after completing a home-based cardiac rehabilitation program compared to the distance before hospital discharge and at the first follow-up (4-8 weeks). This finding suggests that the 8-12-week home-based cardiac rehabilitation program significantly increases exercise capacity in open heart surgery patients. Zanini et al.[15] reported that the 6MWT was significantly higher on day six and on day 30 post-discharge in groups that included exercise training post-surgery. The 6-MWT of the individualized exercise group was significantly higher than the basic exercise group post-surgery at day ten and day 60. The present study found significant differences in exercise duration between groups with good and poor functional status at two weeks, six weeks, and three months post-surgery. This factor can be used to predict functional status at six months. Thus, continuous exercise appears to positively influence function status at six months. Paorod et al.[14] demonstrated that patients undergoing open-heart surgery benefited from a home exercise program, as evidenced by a notable increase in the 6-MWT value from 209.0 (SD = 62.0) meters before discharge and during the first follow-up appointment (4-8 weeks; 306.0 (SD = 88.0) meters) to 337 (SD =69.0) meters at the end of the study (8-12 weeks) with a statistically significant improvement ($p < 0.05$). Hence, a home exercise program spanning 8-12 weeks can effectively enhance exercise capacity among patients undergoing open-heart surgery. Similarly, Zanini et al.[15] observed higher 6-MWT values in the individual exercise group compared to the conventional exercise group, both post-surgery and on days six and 30 after discharge, as well as on day ten and day 60. Herdy et al.[16] also highlighted the efficacy of individualized exercise, which can enhance cardiac function and expedite recovery post-surgery. These findings underscore the pivotal role of exercise, particularly home exercise, in improving functional status. Additionally, Suwanakitch et al.[17] emphasized the importance of multidisciplinary care planning for open-heart surgery patients, including pre-, peri-, and postoperative self-care education to promote good functional status. Thus, intensive exercise and frequent patient follow-ups are warranted for those with poor functional status at six months, while regular and continuous exercise should be maintained for patients with good functional status.

The strength of this study is that it is the first study exploring the use of the 6-MWT distance in combination with relevant clinical characteristics to predict functional status in post-cardiac surgery patients six months after discharge from Hatyai Hospital. Additionally, the NYHA Classification was first employed in this study, as this tool is practical and easily accessible for evaluating functional status. Statistical calculations for predicting a good functional status included Bootstrap score (AUROC 0.889, 95%CI: 0.853-0.927), Bootstrap shrinkage 0.99), calibration plot (CITL=0.000 and Slope=1.000), and decision curve analysis (the prevalence point was 0.665 and the predicted score showed a net benefit of 4.5 times). The results of this study suggest that this clinical model holds promising potential for practical clinical use, enabling the prediction of good functional status and offering valuable insights for patient evaluation, guidance, exercise planning, and treatment design for individuals recovering from post-cardiac surgery.

Limitations of this study include the absence of results from the 6-MWT distance conducted before hospital discharge. This absence was due to limitations for testing at the inpatient building due to its location. Prior studies have suggested that the ideal distance for such tests should be 30 meters.[3,18] In another study, distances ranging from 15-50 meters were considered adequate, although those studies focused on groups not exceeding 20 years of age.[19] The present study's reliance on data from a single hospital setting may restrict the generalizability of findings to broader patient populations. Future research should address these limitations by incorporating multi-center studies and comprehensive pre- and post-surgery assessments. Moreover, future research should be considered to further refine and validate the clinical prediction scores and explore additional predictors of QoL (e.g., psychosocial factors, socioeconomic status, and comorbidities) to enhance the score's predictive accuracy and clinical utility.

Conclusions

Pre-surgery EF, METs pre-discharge, LOS, duration of exercise at two weeks and six weeks, as well as the 6-MWT distance at three months, are associated with accurate prediction of functional status (NYHA Classification 1) among post-cardiac surgery patients at six months after discharge from Hatyai Hospital. This comprehensive set of clinical characteristics can be used for evaluating, providing guidance, and designing exercise and treatment plans for patients recovering from post-cardiac surgery. Importantly, the clinical characteristics identified in this study can help researchers to enhance assessment and management during the post-surgery period, which can contribute to improving patient outcomes and overall functional status.

Author contributions

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References

1. Prabhu NV, Maiya AG, Prabhu NS. Impact of cardiac rehabilitation on functional capacity and physical activity after coronary revascularization: a scientific review. Cardiol Res Pract [Internet]. 2020 Mar [cited 2022 Jul 13];2020:1-9. Available from:https://pubmed.ncbi.nlm.nih.gov/32274208. doi:10.1155/2020/1236968
2. Srisaeng A, Wungsang C.Cardiopulmonary assessment by six-minute walk test. Siriraj Med Bull [Internet]. 2018 Jan-Apr [cited 2022 Jul 13];11(1):57-64. Available from: https://he02.tci-thaijo.org/index.php/simedbull/article/view/127707/96255
3. Yasud M, Songsaengrit B, Kittipanya-ngam P. Factors affecting distance of 6-minute walk test in post cardiovascular surgery patients after discharge at queen sirikit heart center of the northeast. Srinagarind Med J [Internet]. 2020 Oct [cited 2022 Jul 13];35(6):687-93. Available from: https://li01.tci-thaijo.org/index.php/SRIMEDJ/article/view/247320
4. Fiorina C, Vizzardi E, Lorusso R, Maggio M, De Cicco G, Nodari S, et al. The 6-min walking test early after cardiac surgery. reference values and the effects of rehabilitation programme. Eur J Cardiothorac Surg [Internet]. 2007 Sep [cited 2024 Mar 17];32(5):724-9. Available from:https://pubmed.ncbi.nlm.nih.gov/17881241. doi:10.1016/j.ejcts.2007.08.013
5. Rergkliang C, Chetpaophan A, Chittitaworn V, Vasinanukorn P. Open heart surgery: initial experience in songklanagarind hospital. Songklanagarind Med J [Internet]. 2004 Jan [cited 2022 Jul 13];22(1):47-53. Available from http://smj.medicine.psu.ac.th/index.php/smj/article/view/821
6. Douki ZE, Vaezzadeh N, Zakizad M, Shahmohammadi S, Sadeghi R, Mohammadpour RA. Changes in functional status and functional capacity following coronary artery bypass surgery. Pak J Biol Sci [Internet]. 2010 Apr [cited 2024 Mar 17];13(7):330-4. Available from: https://he02.tci-thaijo.org/index.php/journalthaicvtnurse/article/view/116719
7. Onpetch P, Ua-Kit N. The effect of self-efficacy program on functional capacity among patients with post coronary artery bypass graft.Thai J.Cardio-Thorac Nurs [Internet]. 2021 Jul-Dec [cited 2024 Mar 17];32(2):89-104. Available from: https://he02.tci-thaijo.org/index.php/journalthaicvtnurse/article/view/244682
8. Duongkamon Waiwaree, Siriporn Sindhu, Ketsarin Utriyaprasit, Worawong Slisatkorn. Factors predicting functional status in patients coronary artery bypass graft. Thai J.Cardio-Thorac Nurs [Internet]. 2017 Jul-Dec [cited 2024 Mar 17];28(2):126-39. Available from: https://he02.tci-thaijo.org/index.php/journalthaicvtnurse/article/view/116719
9. Yap J, Lim FY, Gao F, Teo LL, Lam CSP, Yeo KK. Correlation of the new york heart association classification and the 6-minute walk distance: a systematic review. Clin Cardiol [Internet]. 2015 Oct [cited 2022 Jul 13];38(10):621-8. Available from: https://pubmed.ncbi.nlm.nih.gov/26442458/doi:10.1002/clc.22468
10. Miller-Davis C, Marden S, Leidy NK. The new york heart association classes and functional status: what are we really measuring?. Heart & Lung [Internet]. 2006 Jul [cited 2024 Mar17];35(4):217-24. Available from: https://www.sciencedirect.com/science/article/pii/S014795630600032X/ doi:10.1016/j.hrtlng.2006.01.003
11. Rungtiwa Suriya B.S, Wanachaporn Jomkan, Supab Konsawan, Paijittra Promwichai. Rating of perceived exertion and physical activity in patients with open heart surgery in chiangrai prachanukroh hospital. CMJ [Internet]. 2017 Jun [cited Mar 17];9(1):87-97. Available from: https://www.crhospital.org/CMJ/article/FULL_20170927154252.pdf
12. Bumrungkittikul J, Thirapatarapong W. Independent predictors and equation of six-minute walk test in post-cardiac surgery. Heart &Lung [Internet]. 2023 Mar [cited 2022 Jul 13];58:134-8. Available from:https://pubmed.ncbi.nlm.nih.gov/36508845/doi: 10.1016/j.hrtlng.2022.12.002
13. Paorod P, Chidnok W, Panomchaisawang P, Sayasathid J. The study of exercise capacity by 6 minute walk test in open heart surgery patients at naresuan university hospital before discharge. Songklanagarind Med J [Internet]. 2016 Nov-Dec [cited 2022 Jul 13];34(6):321-9. Available from: http://202.29.147.116/index.php/smj/article/view/612
14. Paorod P, Chidnok W, Sayasathid J. Effect of Home-Based Cardiac Rehabilitation Program on Exercise Capacity in Open Heart Surgery Patients at Naresuan University Hospital. Songklanagarind Med J [Internet]. 2017 Oct- Dec [cited 2022 Jul 13];35(4):285-91. Available from: http://smj.medicine.psu.ac.th/index.php/smj/article/view/744
15. Zanini M, Nery RM, de Lima JB, Buhler RP, da Silveira AD, Stein R. Effects of different rehabilitation protocols in inpatient cardiac rehabilitation after coronary artery bypass graft surgery: a randomized clinical trial. J Cardiopulm Rehabil Prev [Internet]. 2019 Nov [cited 2024 Mar];1739(6):9-25. Available from: https://journals.lww.com/jcrjournal/abstract/2019/11000/effects_of_different_rehabilitation_protocols_in.14.aspx,doi: 10.1097/HCR.0000000000000431
16. Herdy AH, Marcchi PLB, Vila A, Tavares C, Collaço J, Niebauer J, et al. Pre- and postoperative cardiopulmonary rehabilitation in hospitalized patients undergoing coronary artery bypass surgery: a randomized controlled trial. Am J Phys Med Rehabil [Internet]. 2008 Sep [cited 2024 Mar 17];87(9):714-9. Available from: https://pubmed.ncbi.nlm.nih.gov/18716482/ doi:10.1097/PHM.0b013e3181839152
17. Suwanakitch P, Suwanlumpha S, Krongphaiklang N, Samer W, Kaemahanin W, Sayasatit J. Patients' Quality of Life after open-heart surgery. Srinagarind Med J [Internet]. 2019 Mar-Apr [cited 2022 Jul 13];34(2):178-83. Available from: https://li01.tci-thaijo.org/index.php/SRIMEDJ/article/view/181355
18. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med [Internet]. 2002 [cited 2022 Jul 13];166(1):111-7. Available from: https://www.atsjournals.org/doi/10.1164/ajrccm.166.1.at1102, doi: 10.1164/ajrccm.166.1.at1102
19. Cacau L de AP, de Santana-Filho VJ, Maynard LG, Gomes Neto M, Fernandes M, Carvalho VO. Reference values for the six-minute walk test in healthy children and adolescents: a systematic review. Braz J Cardiovasc Surg [Internet] . 2016 [cited 2022 Jul 13];31(5):381-8. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5144571/ doi:10.5935/1678-9741.20160081