

Validating the 6-minute walk test as an indicator of recovery in patients undergoing cardiac surgery

A prospective cohort study

Yueh-Chi Chen, MS^{a,b,c}, Kun-Chung Chen, PhD^{b,c}, Li-Hua Lu, MS^b, Yi-Liang Wu, MD^d, Te-Jen Lai, MD PhD^{a,e}, Chun-Hou Wang, BS^{b,c,*}

Abstract

The 6-minute walk test (6MWT) has been applied to assess postsurgical recovery in cardiac populations. This study mainly investigated whether the 6MWT could serve as an indicator for physical functioning in patients undergoing cardiac surgery.

Participants completed the 6MWT and the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36) at baseline, discharge, and 3 months postoperatively, in order to analyze the construct validity and responsiveness of the 6MWT. The participants in this study were 125 patients (92 males and 33 females) with an average age of 65.1 ± 11.1 years. The mean 6MWT was 308.9 ± 77.3 m in the preoperative phase, decreased to 277.3 ± 85.7 m at discharge, and returned to 378.1 ± 95.2 m at 3-month follow-up. The results showed that the 6-minute walk distances at baseline and at 3-month follow-up were moderately to highly correlated with the physical functioning subscale of the SF-36 ($r_s = .44$ and $.54$, respectively) and had weak correlation with the nonphysical functioning subscales. The recovery level of physical functioning is meaningfully associated with the 6MWT change from baseline to discharge and from baseline to 3-month follow-up. Patients with higher New York Heart Association (NYHA) Functional Classification levels had lower 6MWT. Additionally, the 6MWT was sensitive to change during the perioperative period (effect sizes from -0.51 to 1.72).

The supporting evidence includes the construct validity and responsiveness of the 6MWT. This study supports the feasibility of the 6MWT as an evaluation tool of physical functioning for assessment of postcardiac surgical recovery.

Abbreviations: 6MWT = 6-minute walk test, ADLs = activities of daily living, CABG = coronary artery bypass graft, CPET = cardiopulmonary exercise testing, LVEF = left-ventricular ejection fraction, MCID = minimum clinically important difference, MCS = mental component summary, NYHA = New York Heart Association, PCS = physical component summary, QoL = quality of life, SF-36 = Medical Outcomes Study 36-Item Short-Form Health Survey, STS score = the Society of Thoracic Surgeons score.

Keywords: cardiac surgery, physical functioning, 6-minute walk test, validity

1. Introduction

To date, no consistent indicators regarding postsurgical recovery have been established because recovery is a complex construct

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^a Institute of Medicine, ^b Department of Physical Therapy, Chung Shan Medical University, ^c Physical Therapy Room, ^d Division of Cardiovascular Surgery, ^e Department of Psychiatry, Chung Shan Medical University Hospital, Taichung, Taiwan.

* Correspondence: Chun-Hou Wang, Department of Physical Therapy, Chung Shan Medical University, and Physical Therapy Room, Chung Shan Medical University Hospital, No. 110, Sec. 1, Jianguo N. Road, South District, Taichung 40201, Taiwan (e-mail: chwang@csmu.edu.tw).

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that includes multiple domains and timeframes.^[1] Different measures of postcardiac surgical recovery have been used during different periods of time, examples being the physical functioning, functional capacity, quality of life (QoL) and mortality.^[2,3] Carli and Mayo^[4] proposed a conceptual model for recovery and specifically referred to the concepts of the ability of mobility and activities of daily living (ADLs), which can be recovered after surgery in terms of short-term outcome measures, as well as the ability of reintegration and QoL, which can be recovered after surgery in terms of long-term outcome measures. In addition, based on their concept, and to develop a new measurement tool, the expected measure for recovery should be validated before being accepted as an indicator.

Postoperative fatigue and pain may deteriorate QoL, which includes both physical and psychological function during recovery.^[5] Moreover, QoL should be based on preserved functional capacity; consequently, the 2 are mutually related.^[6] As a result, functional capacity has been used to evaluate postsurgical recovery related to QoL.^[7] Peak oxygen consumption, as measured by symptom-limited cardiopulmonary exercise testing (CPET), is the gold standard for the evaluation of functional capacity. Although CPET is the most widely accepted method of measuring functional capacity, special equipment for gas analysis and personnel training are required. In addition, safety during testing must be specially monitored. Therefore, the 6-minute walk test (6MWT) might be a worthy alternative.^[8] Another reason for using the 6MWT is that most ADLs are executed under submaximal performance; thus, a proper

functional exercise intensity for ADLs can be simulated by the distance of the 6MWT.^[9]

The QoL questionnaire, a common evaluation tool, covers physical, psychological, economic, social, and many other dimensions, so it is widely applied in research related to cardiac surgery.^[10] The self-report quality-of-life questionnaire requires both excellent cognitive function and memory for evaluation; therefore, it is subject to poor executive efficiency in clinical applications. In contrast, the 6MWT conforms to the locomotion performance commonly used in daily activities, and it also has the advantages of convenience and efficiency. In addition, unlike a questionnaire, the 6MWT requires no reading ability. However, the 6MWT should be validated as an evaluation instrument of postoperative recovery, as there is a lack of research on the applicability of the 6MWT to patients who have received cardiac surgery. If the validation result of the 6MWT is feasible, it will contribute to the evaluation of recovery after cardiac surgery.

The main objective of this study was to investigate whether the 6MWT can be utilized to evaluate physical functioning and thus serve as an effective indicator postoperatively. However, considering the lack of a recognized gold standard on the measure of physical functioning, no so-called criterion standard test has been formulated to evaluate the degree of recovery. Therefore, concurrent criterion validity inspection cannot be conducted on the 6MWT. To address the above issue, this study developed evidence regarding the construct validity (including convergent, discriminant, and known-groups validity) and responsiveness of the 6MWT, and probed into the possibility of applying the 6MWT as a measure of physical functioning.

2. Methods

2.1. Subjects

This study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki and was approved by an institutional review board of Chung Shan Medical University Hospital (CSMUH: No. CS12173). The study was conducted in a medical center and recruited patients who were scheduled for cardiac surgery as the participants. After the research staff clarified the research process and objective for the participants, they agreed to participate in the study and signed a written consent form. The inclusion criteria for participation in the study were receipt of elective cardiac surgery, adequate awareness, and independent ambulation. Patients who were scheduled for surgery while juveniles and those diagnosed with cognitive disorders, mental disease, central nervous system diseases, peripheral arterial obstructive diseases, or muscle skeletal system issues of the lower limbs were excluded.

During the perioperative period, one physiotherapist measured and collected the data. The preoperative data were defined as the baseline. The demographic and clinical characteristics, which were collected before discharge, included medical history, New York Heart Association (NYHA) functional classification, left-ventricular ejection fraction (LVEF), biochemical data, the Society of Thoracic Surgeons (STS) score and perioperative information. All subjects were assessed with the 6MWT at the baseline, discharge, and 3 months after surgery. In addition, self-administered quality-of-life questionnaires were completed at baseline and 3 months after surgery. At admission, the study patients were provided an orientation on the perioperative rehabilitation program. Prior to discharge, all the subjects met with the physical therapist to receive phase I cardiopulmonary rehabilitation, including daily coughing training, deep-breathing

exercise, and functional training. In phase II, the subjects carried out a home-based exercise prescription taught to them previously by a physical therapist.

2.2. 6MWT

The 6MWT measures the walking distance of subjects within a fixed time to quantify the functional capacity of the subjects, which refers to the total distance the subjects walked within 6 minutes. In addition, the majority of research subjects can withstand the test, including relatively physically weak patients.^[8] Furthermore, the 6MWT does not require the patients to reach the maximum oxygen uptake, so it is classified as submaximal exercise testing.^[9] The 6MWT has been recommended for objective measurement of the submaximal exercise capacity of patients with heart failure,^[11] as it was suggested that it performs better than CPET in appropriately reflecting the functional status of a patient during daily activities.^[12] Moreover, it has excellent reproducibility for cardiac populations (ICCs of .97, .91, and .90, respectively).^[13–15] Regarding validity, the 6MWT appears to be moderately to highly correlated with the peak exercise capacity of chronic heart failure ($r = .54-.69$).^[15]

This study conducted the testing according to the 6MWT criteria published by the American Thoracic Society.^[8] Specifically, the patients were asked to walk back and forth in a 30 m hallway, and their farthest distance was calculated. To compensate for a possible learning effect, the patients completed the 6MWT twice, and the higher distance was selected.^[8,15,16] Patients rested for at least one hour between the 2 tests, and the predicted percentage of the total 6-minute walk distance was calculated based on a reference equation.^[17]

2.3. Physical functioning

Physical functioning is the ability to perform a variety of physical activities ranging from light to vigorous activities that require increasing levels of mobility, strength, or endurance.^[18] Consequently, this study adopted the self-administered Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36) to measure the domains of physical functioning and nonphysical functioning.^[19] The SF-36, which has excellent psychometric properties, is perceived as a popular health evaluation instrument. The 8 subscales focusing on these domains can be measured separately, or they can be integrated into 2 major component summaries, including the physical component summary (PCS) and the mental component summary (MCS).

To determine whether or not the changes in physical functioning were associated with the changes in the 6MWT, this study defined the changes in the SF-36 physical functioning subscale from baseline to 3-month follow-up to determine the recovery level of physical functioning after cardiac surgery. In accordance with the manual, if the physical functioning subscale at baseline is lower than 40, the minimum clinically important difference (MCID) is 2 points; if it is higher than 40, the MCID is 3 points.^[20] Based on the MCID of the baseline, all the subjects were divided into 3 different recovery levels: better, unchanged, and worse. When the absolute change of the physical functioning subscale was within the range of the MCID, the research subjects were categorized as unchanged. If the change was positive and its absolute value was larger than the MCID, the subjects were categorized as better. If the change was negative and its absolute value was larger than the MCID, the subjects were categorized as worse.

2.4. Statistical analyses

Statistical analyses were conducted in the Microsoft SPSS 14.0 software package. Descriptive statistics were calculated for demographic and medical variables. Continuous data are expressed as mean \pm SD or median (IQR), and categorical data as absolute and/or relative frequency. The Kolmogorov–Smirnov test was used to test the normality of the data distribution.

Construct validity refers to “how well a specific measure or scale captures a defined entity.”^[21] This study aimed to verify the validity of the 6MWT as a measure of physical functioning postoperatively. For convergent validity, we examined the correlations between SF-36 physical functioning subscales and the 6MWT. In contrast, the other subscales of the SF-36, which are not related to physical functioning, were examined for discriminant validity. 6MWT changes between the 3 recovery levels were compared, and one-way ANOVA with post-hoc Scheffe’s test was applied for statistical analysis. Then Pearson’s correlation coefficient (r) and Spearman’s rank correlation coefficient (r_s) were applied to evaluate their correlations. This study referred to the classification of Lacasse: a coefficient between 0 and .20 meant no correlation; a coefficient between .21 and .35, weak correlation; a coefficient between .36 and .50, moderate correlation; and a coefficient larger than .50, strong

correlation.^[22] To examine known-groups validity, one-way ANOVAs were used to compare the 6MWT among the groups of patients defined according to different NYHA classes (I/II vs III/IV group).

This study anticipated that, due to surgical factors, the 6MWT prior to discharge would be lower than that at baseline, and the 6MWT at 3-month follow-up might approach or even exceed that of the baseline. Therefore, this study calculated the effect sizes among the 3 time points to examine the responsiveness of the 6MWT. We calculated the effect size (d) by dividing the mean change scores by the standard deviation of the change scores in the same subjects. In reference to the categorization of Cohen, responsiveness between 0.2 and 0.5 was considered small; that between 0.5 and 0.8, medium; and that exceeding 0.80, large.^[23]

3. Results

3.1. Participants

From March 2013 to March 2016, 125 patients scheduled for cardiac surgery were recruited for this study. The clinical characteristics of the participants are listed in Table 1. The sample mainly consisted of patients with NYHA classes I to III

Table 1
Demographic and medical characteristics of the participants.

	All patients (N = 125)	Valvular surgery (n = 80)	Nonvalvular surgery (n = 45)	P
Preoperative data				
Age, years, mean (SD)	64.0 (12.0)	64.5 (11.9)	67.2 (9.2)	.190
Sex, male/female, n (%)	92/33 (74/26)	58/22 (73/27)	35/10 (78/22)	.516*
Height, mean (SD)	161.4 (7.5)	161.2 (8.2)	162.6 (7.2)	.371
Weight, mean (SD)	62.9 (12.0)	62.0 (10.5)	67.9 (15.2)	.039
Body mass index, mean (SD)	24.2 (3.9)	23.7 (3.8)	25.3 (3.7)	.016
NYHA, I–II/III–IV, n	63/62	43/37	20/25	.380*
LVEF, %, mean (SD)	52.9 (11.9)	52.9 (12.8)	52.8 (10.2)	.831
Arrhythmia, n (%)	47 (37.6)	39 (48.8)	8 (17.8)	.001*
Hypertension, n (%)	76 (60.8)	37 (46.3)	39 (86.7)	<.001*
Diabetes, n (%)	49 (39.2)	20 (25.0)	29 (64.4)	<.001*
Hemoglobin, g/dL, mean (SD)	12.9 (2.2)	12.8 (2.4)	13.1 (2.0)	.518
Creatinine, mg/dL, mean (SD)	1.7 (1.6)	1.6 (1.4)	2.0 (2.0)	.328
Albumin, g/dL, mean (SD)	3.9 (0.5)	3.8 (0.6)	4.0 (0.5)	.092
The Society of Thoracic Surgeons score				
Risk of mortality, %, median (IQR)	1.6 (0.87–3.28)	1.8 (1.1–4.0)	1.1 (0.87–3.28)	<.001
Morbidity or mortality, %, median (IQR)	16.6 (11.6–26.5)	17.8 (13.0–28.7)	14.6 (9.5–22.5)	.008
Long length of stay, %, median (IQR)	6.6 (3.8–11.2)	7.7 (5.3–12.7)	4.0 (2.3–6.9)	<.001
Perioperative data				
On pump surgery, n (%)	85 (68.0)	80 (100.0)	5 (11.1)	<.001*
Bypass time*, minutes, mean (SD)	179.3 (77.6)	179.4 (79.0)	177.7 (16.6)	.582
Operation time, minutes, mean (SD)	315.9 (88.7)	318.5 (87.9)	310.4 (91.0)	.587
Day of mechanical ventilation duration, median (IQR)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	.002
Day of ICU stay, median (IQR)	4.0 (3.0–5.0)	4.0 (3.0–5.0)	4.0 (3.0–5.0)	.864
Day of hospital stay, median (IQR)	12.0 (9.0–19.0)	18.8 (9.0–19.0)	12.0 (9.0–19.0)	.056
Six-minute walk test				
Baseline, mean (SD)	308.9 (77.3)	312.6 (84.4)	307.8 (69.3)	.903
Discharge, mean (SD)	277.3 (85.4)	277.6 (87.2)	266.9 (90.2)	.525
3-months follow-up, mean (SD)	378.1 (95.2)	380.2 (103.1)	375.1 (75.5)	.725
Physical functioning of SF-36				
Baseline, mean (SD)	71.6 (20.8)	72.3 (21.5)	70.1 (21.1)	0.725
3-months follow-up, mean (SD)	82.8 (14.4)	81.2 (15.4)	83.9 (10.9)	0.625

Significant differences (* $P < .01$) were found between the 2 groups.

Data are expressed as number (%), mean (SD) or median (IQR).

A comparison of the valvular and nonvalvular surgery was analyzed. Statistical significance was set at $P < .05$.

LVEF = left-ventricular ejection fraction, NYHA = New York Heart Association.

*Between the 2 groups analyzed by Chi-Square test.

The group of nonvalve surgery included CABG (91%) and the other surgery (9%).

Table 2

Correlation between SF-36 subscales and 6MWT.

SF-36 subscales	6MWT, Baseline (N=99)		6MWT, 3-month follow-up (N=99)	
	Spearman coefficients (95% CI)	P	Spearman coefficients (95% CI)	P
Physical functioning	.44 (.24-.61)	<.001 [†]	.54 (.39-.67)	<.001 [†]
Physical role functioning	.34 (.15-.51)	<.001 [†]	.33 (.15-.50)	.001 [†]
Bodily pain	.08 (-.12-.29)	.429	.05 (-.17-.26)	.694
General health perceptions	.27 (.08-.43)	.007 [†]	.20 (-.02-.39)	.046
Vitality	.30 (.13-.46)	.002 [†]	.16 (-.04-.34)	.120
Emotional role functioning	.24 (-.04-.42)	.019 [†]	.24 (.05-.43)	.016 [†]
Social role functioning	.35 (.17-.51)	<.001 [†]	.21 (.01-.40)	.038 [†]
Mental health	.20 (-.01-.37)	.197	-.02 (-.22-.21)	.886
PCS	.40 (.22-.55)	<.001 [†]	.34 (.15-.53)	.001 [†]
MCS	.35 (.18-.50)	<.001 [†]	.20 (.01-.40)	.047 [†]

MCS=mental component summary, PCS=physical component summary.
[†]P<.05.

(83.2%) and males (73.6%). In total, 111 (89%) and 106 (86%) subjects completed both the 6MWT and the SF-36 at baseline and at 3-month follow-up, respectively. The mean 6MWT was 308.9 ± 77.3 m at baseline, fell to 277.3 ± 85.7 m at discharge, and returned to 378.1 ± 95.2 m at 3-month follow-up. One way ANOVA revealed statistically significant differences in the 6MWT among the 3 time points ($F_{(2,296)}=35.206, P<.001$). The predicted percentages of the 6MWT at the 3 time points were 40.8 ± 9.4%, 36.6 ± 10.5%, and 50.0 ± 11.7%, respectively.

3.2. Convergent and discriminant construct validity

Table 2 presents the moderate to strong correlations between the 6MWT and the physical functioning subscales, which were .44 and .54, respectively. In contrast, no or weak correlations were found between the 6MWT and the other subscales. The changes in the 6MWT among the 3 recovery levels had statistically significant differences from baseline to discharge and from baseline to 3-month follow-up ($F_{(2,98)}=4.653, P=.012$ and $F_{(2,98)}=7.500, P=.001$, respectively) (Table 3). In post-hoc comparisons, the 6MWT changes were greater for the better group than for the worse group ($P<.05$). This difference indicated that the recovery level was associated with the change in the 6MWT. Additionally, the 6MWTs among the 3 time points demonstrated strong correlations with one another ($r=.73$ to $.81$). The measures of characteristics, which included the preoperative and postoperative data, mostly had weak correla-

tions with the SF-36 physical functioning at baseline and at 3 months after surgery.

3.3. Known-groups validity

Figure 1 showed that the NYHA classes were significantly associated with preoperative 6MWT and 3-month postoperative 6MWT ($F_{(1,101)}=31.981, P<.001$ and $F_{(1,101)}=7.506, P=.007$, respectively). During their hospital stays, 11 patients experienced 13 postoperative complications, including heart failure (2), cardiac tamponade (1), respiratory failure (7), infection (1), and bleeding (2). However, no statistically significant differences were found in

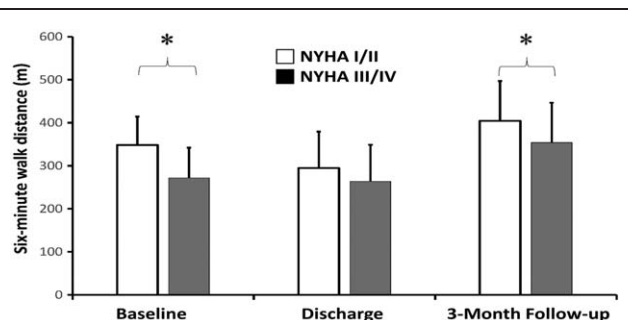


Figure 1. Comparison of the 6-minute walk distances at different time points between NYHA I/II and III/IV groups.

Table 3

The relationships between recovery levels by change in physical functioning of SF-36 and 6MWT from baseline to 3-month follow-up.

Recovery level (N)	6 MWT, meters			Mean change of 6MWT, meters					
	Baseline	Discharge	3-Month follow-up	Baseline—discharge	d	Baseline—3-month follow-up	d	Discharge—3-month follow-up	d
Better (64)	301.4 (76.2)	282.3 (90.7)	385.4 (96.7)	-19.1 (63.1) ^{*,†}	-0.30	84.1 (66.3) ^{*,†}	1.27	105.2 (60.7)	1.73
Unchanged (20)	328.2 (86.1)	284.7 (77.6)	389.9 (97.8)	-43.6 (47.2) [*]	-0.92	61.7 (62.8) [*]	0.98	103.2 (57.4)	1.80
Worse (15)	314.9 (69.6)	246.5 (71.3)	330.9 (74.9)	-68.4 (58.8) [*]	-1.16	15.9 (36.0) [*]	0.44	84.3 (61.1)	1.38
Mean of Total (99)	308.9 (77.3)	277.3 (85.4)	378.1 (95.2)	-31.5 (61.9)	-0.51	69.2 (66.1)	1.05	100.7 (58.4)	1.72

Cohen's d effect size is defined as the difference between 2 means divided by a standard deviation of mean change.

6MWT=6-minute walk test.

^{*}P<.05, ANOVA statistics testing whether 6MWT change differs among the 3 recovery levels.

[†]Post-hoc comparisons using Scheffe's test indicated that the mean score for the better group was significantly different from that of the worse group.

the 6MWT between the patients with and without complications at discharge or at 3-month follow-up.

3.4. Responsiveness

As can be seen in Table 3, there was a significant decline in the 6MWT from baseline to discharge ($d = -.51$). In contrast, there was a significant increase in the 6MWT from baseline to 3-month follow-up ($d = 1.05$). In addition, the 6MWT was lowest at discharge and obviously increased from discharge to 3-month follow-up ($d = 1.72$). Among the 3 time points, the 6MWT changes in each recovery level were also sensitive to change. The 6MWT change from baseline to discharge in the worse group (15/99 [15.2%]) was the greatest, decreasing by 68.4 ± 58.8 m on average ($d = -1.16$). That from baseline to 3-month follow-up in the better group (64/99 [64.6%]) was the greatest, increasing by 84.1 ± 66.3 m on average ($d = 1.27$).

4. Discussion

Studies on cardiac populations have presented the acceptable psychometric properties of the 6MWT.^[15,24] However, although the 6MWT has the potential to serve as a measure, its psychometric properties in a post cardiac surgical group have not been sufficiently studied. In the present study, we provide evidence in support of the construct validity and responsiveness of the 6MWT in cardiac surgery patients.

Some research has pointed out that the walk test is associated with the physical functioning subscale of the SF-36. Brooks et al. observed CABG groups and found that the 2-minute walk test and the physical functioning subscale were moderately correlated with this distance in the preoperative period and at 6 to 8 weeks after surgery ($r = .44$ and $.48$).^[25] Similar findings in a cardiac rehabilitation population and survivors of critical illness indicated that the 6MWT and the physical functioning of SF-36 had moderate to high correlation ($r = .47$ to $.62$).^[13,16] The correlations between the 6MWT and the SF-36 physical functioning at baseline and at 3-month follow-up were moderate ($r_s = .44$ and $.54$) in the present study. However, these correlations are lower than that of another study indicating high correlation between the 6MWT and the SF-36 physical functioning of postoperative patients before rehabilitation ($r = .62$, $P < .001$).^[13] In that study, only 14.9% of the subjects had received cardiac surgery, which differs from the present study, in which all the subjects had done so. In addition, the correlations are comparable to that of the study by Brooks et al., in which the correlations at baseline and 6 to 8 weeks after CABG were similar, despite difference in the cardiac populations ($r_s = .44$ and $.54$ vs $r = .44$ and $.48$).^[25] However, the objective of that study was to verify the validity of the 2-minute walk test instead of the 6MWT.

For responsiveness, the effect size showed that the 6MWT is sensitive to change from the preoperative period to the short-term postoperative period, and finally, to the long-term postoperative period. From baseline to discharge, and from baseline to 3-month follow-up, the effect sizes were $-.51$ and 1.72 , respectively, indicating that it can sensitively reflect the changes in recovery during the perioperative period. Particularly, the 6MWT change from discharge to 3-month follow-up had the greatest responsiveness among these time intervals ($d = 1.72$). This seems to imply the importance of measuring the 6MWT soon after cardiac surgery.^[26-28] While progress was made on all 3 recovery levels from baseline to 3-month follow-up, the worse group had the

lowest progress (effect size, 0.44). A possible reason is that the regression in the worse group from baseline to discharge was the greatest (effect size, -1.16). While the NYHA classes were associated with the 6MWT, the 6MWT at discharge was not associated with basal NYHA classes. It is possible that the surgery made the declines on the 6MWT from baseline to discharge in the NYHA I-II group greater than those in the NYHA III-IV group. This effect of the surgery would explain why the 6MWT at discharge was not different between the 2 groups. In addition, our unpublished pilot research ($n = 30$) demonstrated that the 3 time points in the perioperative period had excellent relative reliability (ICCs of $.984$, $.978$, and $.967$, respectively). The relative reliability at discharge approximated that of the research by Olper et al.^[29] (ICCs of $.978$ and $.96$, respectively). However, it had higher absolute reliability, which was referred to as the standard error of measurements of 11.4 and 18.5 , respectively.

In the present study, the results found statistical differences in the 6MWT among 3 time points ($P < .001$). It indicates that the 6MWT will descend significantly from baseline to discharge and then rise significantly from discharge to 3-month follow-up. This pattern is in agreement with a study by Brooks et al.^[25] The present outcomes show that the mean 6MWT at discharge is 277 ± 86 m, which is similar to the values of 260 ± 89 m and 296 ± 111 m reported in other studies.^[26,30] However, Fiorina et al.^[28] presented that the statistical mean of the 6-minute walk distance of cardiac surgery patients within the 15 days subsequent to the surgery was 304 ± 89 m. Comparatively speaking, the distance presented in this study is close to the values of these prior studies, but slightly lower, possibly due to differences in demographic characteristics (such as ethnicity, height, and leg length). Previous studies have demonstrated that postoperative 6MWT can provide prognostic information after cardiac surgery.^[31-33] One study demonstrated that a preoperative 6MWT distance of >300 m was the only independent variable related to decreased risk of composite events (death, myocardial infarction and stroke) in patients undergoing aortic valve replacement.^[34] Another study also demonstrated that a postoperative 6MWT distance of more than 300 m independently protects against mortality in elderly patients undergoing coronary artery bypass graft (CABG) before rehabilitation.^[31] These findings are consistent with our findings, suggesting that the 6MWT has independent prognostic relevance to re-hospitalization and mortality within the 2 years after surgery. We used 300 m as the cut-off point for our study because previous research had established a walking distance of 300 meters as having a good ability to discriminate patients with different risks.^[31,34] After adjustment for all selected covariates, including age, LVEF, creatinine, ICU days, and length of hospital stay, 6MWT > 300 m at discharge (hazard ratio = $.116$, 95% CI: $.15-.88$, $P = .037$) and LVEF (hazard ratio = $.89$, 95% CI: $.85-.93$, $P < .001$) remained significantly associated with the clinical outcome. It is indicated that the associated 6MWT > 300 m at discharge was proportional to hospitalization and mortality. Routine measurement of the 6MWT at discharge after cardiac surgery would screen out patients at risk of re-hospitalization and death 2 years after cardiac surgery.

The SF-36, which covers both mental and physical components, is applied in the evaluation of post cardiac surgical recovery.^[35] In addition, the questionnaire score is associated with walking ability. First, considering that walking is a fundamental human activity and plays a key role in the participation of patients, it covers the majority of activities of daily living as its evaluation content. Second, surgical interven-

tion leads to physical stress, such as cardiopulmonary impairment, pain, fatigue, and muscle weakness.^[1] These problems, which impact mobility and ADLs, further influence the individual's quality of life. Therefore, the 6MWT should be reasonably used as a postoperative recovery indicator. In addition, according to a literature report on chronic heart failure, the clinically meaningful change of the 6MWT is about 32 m.^[36] In this study, the number of patients whose reduction from discharge to 3-month follow-up exceeded this value accounted for 90.9% (90/99), and the number of patients whose reduction from baseline to 3-month follow-up exceeded this value accounted for 69.7% (69/99). These results indicate that the change in the 6MWT of the majority of patients exceeded the clinically meaningful change. Mobility will decrease in the early stage, but it will tend to improve in the recovery period subsequent to discharge. On the whole, recovery progress is evident at 3-month follow-up. In addition, the 6MWT has the advantage of execution convenience and thus is an easily managed evaluation tool. The patients are informed of the evaluation results in the early postoperative period, so the difference between the actual result and the originally anticipated distance can be compared.^[32] Clinicians will be able to observe whether the walked distance subsequent to surgery can reach anticipated levels and implement a more intensive and tailored rehabilitation program for patients with a poor prognosis.

4.1. Strengths and limitations

Because of the physical limitations soon after surgery, it is necessary to use a suitable and validated measure for supervising the recovery. This study is the first to verify the validity of the 6MWT as a measure of physical functioning after cardiac surgery. Unlike a questionnaire score, which relies on subjective perceptions of health, depends on reading ability to fill in the QoL questionnaire, and requires more time, the 6MWT directly measures actual walking performance, which conforms to daily activities and is administratively efficient. Therefore, the 6MWT can achieve quick quantification of postsurgical recovery. This aspect is attractive to clinicians and researchers. In addition, the 6MWT has standardized implementation methods and is widely applied in clinics worldwide.^[17] Consequently, the 6MWT has its merits in measuring postsurgical recovery.

However, this study has some limitations. First, the exercise and rehabilitation frequency of the participants from discharge to 3-month follow-up were not recorded, possibly leading to bias in the results. This bias may explain the lack of statistical differences in the change in the 6MWT from discharge to 3-month follow-up among the 3 recovery levels ($F_{(2, 98)} = .702, P = .498$) (Table 3). Second, all the subjects in this study were patients who received elective cardiac surgery in a single medical center; thus, the conclusions of this study can only be applied to similar populations. Thus, additional research recruiting larger samples from multiple centers would be worthwhile to further probe the psychometric properties. Third, we should distinguish between valvular surgeries and nonvalvular surgeries to provide more convincing evidence due to differences in the clinical presentation and evolution of symptoms. Finally, the data collected in this study to obtain the differences in the 6MWT among groups under different complication rates were far from sufficient and thus cannot further support the difference. In fact, as the 6MWT is an independent postsurgical recovery indicator, it is not able to cover the entire construct. In addition to physical functioning, postsurgical recovery includes multiple aspects, such as social-

psychological support and emotional recovery; therefore, these indicators should be investigated.

5. Conclusions

The results of this study provide evidence for the construct validity of the 6MWT; therefore, clinicians and researchers can apply it to the evaluation of physical functioning in patients undergoing cardiac surgery, as it can distinguish differences in recovery between different groups, as well as changes in recovery at different time points.

Author contributions

Conceptualization: Yueh-Chi Chen, Li-Hua Lu, Yi-Liang Wu, Te-Jen Lai, Chun-Hou Wang.

Data curation: Yueh-Chi Chen, Li-Hua Lu.

Formal analysis: Yueh-Chi Chen, Kun-Chung Chen, Li-Hua Lu, Yi-Liang Wu, Te-Jen Lai, Chun-Hou Wang.

Investigation: Yueh-Chi Chen, Yi-Liang Wu.

Methodology: Yueh-Chi Chen, Kun-Chung Chen, Yi-Liang Wu, Te-Jen Lai, Chun-Hou Wang.

Project administration: Yueh-Chi Chen, Te-Jen Lai.

Supervision: Te-Jen Lai, Chun-Hou Wang.

Validation: Kun-Chung Chen, Chun-Hou Wang.

Writing – original draft: Yueh-Chi Chen, Kun-Chung Chen, Li-Hua Lu, Yi-Liang Wu, Te-Jen Lai, Chun-Hou Wang.

Writing – review & editing: Yueh-Chi Chen, Kun-Chung Chen, Li-Hua Lu, Yi-Liang Wu, Te-Jen Lai, Chun-Hou Wang.

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