

# The Two-Minute Walk Test as a Measure of Functional Capacity in Cardiac Surgery Patients

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**ABSTRACT.** Brooks D, Parsons J, Tran D, Jeng B, Gorczyca B, Newton J, Lo V, Dear C, Silaj E, Hawn T. The two-minute walk test as a measure of functional capacity in cardiac surgery patients. *Arch Phys Med Rehabil* 2004;85:1525-30.

**Objective:** To examine construct validity and sensitivity of the two-minute walk test (2MWT) in cardiac surgery patients.

**Design:** Measurements were made in patients preoperatively, during the postoperative in-hospital stay, and 6 to 8 weeks after discharge from hospital.

**Setting:** Ambulatory and hospitalized care.

**Participants:** Patients (N=122; mean age  $\pm$  standard deviation, 63 $\pm$ 9y) undergoing coronary artery bypass grafting.

**Interventions:** Not applicable.

**Main Outcome Measures:** The 2MWT, New York Heart Association (NYHA) functional classification for cardiac disease, the Nottingham Extended Activities of Daily Living scale, and the Medical Outcomes Survey 36-Item Short-Form Health Questionnaire (SF-36).

**Results:** Distance walked in 2 minutes decreased significantly postoperatively (from 138 $\pm$ 26m to 84 $\pm$ 33m,  $P<.001$ ), but increased again at follow-up (151 $\pm$ 31m,  $P<.0001$ ). Distance walked on the 2MWT correlated significantly to SF-36 (physical function subscale) preoperatively ( $r=.44$ ) and at follow-up ( $r=.48$ ) ( $P<.001$ ). There was a significant difference in distance walked between those with NYHA class I and II compared with those classified as III or IV ( $P=.04$ ). However, there was no significant difference in distance walked in 2 minutes between those who developed cardiac or pulmonary complications postoperatively ( $P\geq 0.2$ ).

**Conclusions:** The 2MWT was sensitive to change after cardiac surgery and showed moderate correlation with measures of physical functioning in this population. However, the 2MWT could not identify those who developed complications in the postoperative period.

**Key Words:** Cardiac surgery; Rehabilitation; Walking.

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Presented in part at the Better Breathing Conference, February 2002, Toronto, ON, Canada.

Supported by the Conaught and Dean Fund, University of Toronto, the Canadian Physiotherapy Cardio-Respiratory Society, the Lung Association, and the Canadian Institute for Health Research.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the author(s) is/are associated.

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0003-9993/04/8509-8771\$30.00/0

doi:10.1016/j.apmr.2004.01.023

**I**N THE SURGICAL LITERATURE on postoperative intervention for management of cardiac patients, there is a lack of a standardized definition or measure of postoperative complications.<sup>1</sup> With respect to postoperative pulmonary complications, trials use a variety of outcomes such as chest radiographs and auscultation and a variety of clinical findings and pulmonary function tests.<sup>1</sup> None of the studies use a measure of functional capacity or activities of daily living (ADLs), although mobility and ability to carry out ADLs are reflective of complications and are strongly emphasized as the most important criteria used to determine readiness for discharge from rehabilitation in the immediate postoperative period.<sup>2</sup> However, there is no objective measure of functional capacity that has been validated in the surgical population.

Walk tests are measures that potentially could be administered as part of an assessment to determine functional performance, to monitor overall treatment effectiveness, and to assess readiness for discharge.<sup>3</sup> Originally, the 12-minute performance (run) test was developed as a guide to physical fitness in healthy young men.<sup>4</sup> This test was later modified to an indoor 12-minute walk test for the assessment of exercise tolerance in those with chronic bronchitis.<sup>5</sup> Shorter versions of this walk test, mainly the six- and two-minute walk tests (6MWT, 2MWT), were also developed in similar populations.<sup>6</sup> In these tests, patients are instructed to walk back and forth between 2 markers on a measured course, covering as much ground as possible in the allotted time period.

The purpose of this study was to examine the construct validity and sensitivity (or responsiveness) of the 2MWT in patients who have had cardiac surgery. We chose to investigate this particular measure, because it is the most feasible and efficient measure of functional capacity. In addition, it may prove more clinically useful than the 6-minute version, because we have found that some patients are unable to ambulate more than 2 minutes (secondary to cardiac symptomatology). In addition, studies have shown this measure is comparable with the more well-established 6MWT.<sup>6,7</sup>

We examined cross-sectional construct validity (convergent, known groups, discriminant) as well as sensitivity to change or responsiveness of the 2MWT. Sensitivity to change is the ability of a measure to assess change over time.<sup>8</sup> The sensitivity was examined by comparing the distance walked preoperatively with the distance walked at discharge from hospital and on follow-up 6 to 8 weeks later. Construct validity is defined as "the degree to which a test behaves in accordance with hypothesis concerning how it should behave."<sup>8</sup> Cross-sectional construct validity refers to the assessment of validity at 1 point in time, in this case preoperatively and then again at follow-up.

There are 3 types of construct validity: convergent, known groups, and discriminant.<sup>8</sup> Convergent validity looks at the extent to which a measure agrees with the result of another measure.<sup>8,9</sup> In this study, we examined the correlation between the 2MWT and the Medical Outcomes Survey 36-Item Short-Form Health Questionnaire<sup>10</sup> (SF-36; physical functioning subscale) and Nottingham Extended Activity of Daily Living<sup>11</sup>

(NEADL) scale. Our hypothesis was that the distance walked in 2 minutes would correlate moderately to the physical functioning subscale of the SF-36 and the NEADL. We expected the correlation to be only moderate because the physical functioning subscale is a measure of overall physical function (including the use of the upper extremity), whereas the 2MWT walk assesses the ability to walk.

Known groups looks at the results in 2 or more distinct groups.<sup>8</sup> We examined performance on the 2MWT in those with New York Heart Association (NYHA) functional classification for cardiac disease of I or II versus III or IV, as well as between those who developed and did not develop postoperative complications. Discriminant validity examines the extent to which a measure correlates with another measure that reflects a completely different construct.<sup>8</sup> We examined the correlation between the 2MWT and the SF-36 social functioning subscale.

## METHODS

### Participants

Subjects consisted of patients who were undergoing coronary artery bypass graft (CABG) surgery at 1 of 3 tertiary hospitals in the same city. A convenience sample of patients in preadmission clinic was recruited. Inclusion criteria were patients undergoing elective CABG surgery, able to provide consent, and without significant musculoskeletal or neurologic problems that affected their ability to ambulate for 2 minutes. Because the 2MWT has not been used in this population, no a priori power calculations were performed.

### Protocol

The study was approved by research ethics boards at the 3 hospitals where data were collected, as well as at the affiliated university. Informed written consent was obtained from all subjects.

Preoperatively, demographic data such as age, sex, pathology, and comorbidities were recorded. The NYHA functional classification for cardiac disease, the 2MWT, and the NEADL were completed.

Postoperatively in-hospital, we recorded the incidence of cardiac and respiratory postoperative complications. Immediately before discharge from hospital (within 1d), we administered a second 2MWT. The NEADL and SF-36 were not administered in-hospital because of their limited relevance in that environment.

At follow-up, 6 to 8 weeks after hospital discharge, subjects were reassessed at follow-up clinic. We administered the 2MWT, SF-36, and NEADL. Subjects were also asked standardized questions regarding any cardiac or respiratory signs or symptoms that required medical intervention or mobility issues after discharge from hospital.

### Measures

**The 2MWT.** To control for learning and practice effects with the 2MWT, all subjects performed 2 practice trials before measurements were recorded preoperatively.<sup>12</sup> A physical therapy student administered the test in a quiet uncarpeted corridor where subjects were asked to walk back and forth in a premeasured corridor, covering as much ground as possible in 2 minutes without any further encouragement.<sup>12</sup> The test administrator walked behind the subject to minimize the effect of pacing. Subjects were provided with clear instructions and were allowed to rest during the 2-minute time period, if required. Distance walked (in meters), heart rate, blood pressure,

oxygen hemoglobin saturation, perceived dyspnea using the modified Borg scale,<sup>13</sup> the number of rests taken, and the duration of rests were monitored and recorded. Subjects used their normal walking aids for all walk tests.

**SF-36 health survey.** The SF-36 health survey is a subjective generic measure of health-related quality of life that is completed by the patient and requires between 5 and 10 minutes.<sup>8,10</sup> The instrument consists of 36 questions relating to 8 domains: physical functioning, physical role, bodily pain, general health, emotional role, social functioning, mental health, and vitality. For each item, higher scores represent better health. Raw scores were transformed to 0 to 100 scale. Subscale scores were calculated according to the computerized scoring algorithms supplied by Ware et al.<sup>10,14</sup>

**NEADL.** There is no disease-specific instrument to measure ADLs in cardiac surgery patients. The NEADL is a subjective measure that assesses 21 activities within 4 categories: mobility, kitchen activities, domestic activities, and leisure activities. It is a simple self-administered questionnaire that can be completed by the patient. This tool was established as a postal questionnaire to monitor patients after stroke rehabilitation in the community.<sup>15</sup> More recently, it has been established as a discriminative tool in terms of sensitivity and negative predictive values for differentiating elderly subjects with respiratory disability from those with normal lung function.<sup>11</sup> This tool was chosen for this study because of its established properties in those with respiratory disability and its ease of application, requiring no more than 15 to 20 minutes to complete. The NEADL index ranges from 0 to 21, with higher scores reflecting greater independence in ADLs.

**Postoperative pulmonary complications.** There is no standardized definition for and measure of postoperative pulmonary complications. For our purposes, we chose to adopt the definition of postoperative pulmonary complications used by Hall et al.<sup>16-18</sup> They define postoperative pulmonary complications as "the presence of clinical features consistent with collapse/consolidation, plus an otherwise unexplained temperature above 38°C, and either a positive chest radiograph or evidence of infection from sputum microbiology."<sup>18 (p149)</sup>

**Postoperative cardiac complications.** There is no standardized list of postoperative cardiac complications. We arbitrarily defined major postoperative cardiac complications including death (secondary to any major cardiac event), postoperative myocardial infarction, serious ventricular or supraventricular dysrhythmias (eg, ventricular tachycardia, supraventricular arrhythmias of >160bpm), rapid atrial fibrillation requiring cardioversion, cardiac tamponade, or hemorrhage requiring repeated surgery. Minor postoperative cardiac complications included benign dysrhythmias such as atrial fibrillation (rates, <140bpm) and episodes of hypertension or angina.

**NYHA functional classification for cardiac disease.** This classification consisted of 4 classes<sup>19</sup>:

- Class I: Patients with documented cardiac disease, but no limitation of physical activity. Ordinary intensities of activity do not produce undue fatigue, palpitations, dyspnea, or anginal pain.
- Class II: Patients with slight limitation in physical activity. Comfortable at rest, but ordinary levels of activity produce fatigue, palpitations, dyspnea, or angina.
- Class III: Patients with marked limitations in physical activity. Comfortable at rest, but less than ordinary activities causes fatigue, palpitations, dyspnea, or angina.

**Table 1: Demographics of Study Sample**

Sample size	122
Mean age $\pm$ SD (y)	63.4 $\pm$ 8.6
Male/female (%)	87/13
Previous myocardial infarction	45%
Smoker	69%
NYHA class I or II*	49%
NYHA class III or IV*	28%

Abbreviation: SD, standard deviation.

\*Missing data on 23% of sample.

Class IV: Patients unable to carry on any physical activity without discomfort. Fatigue, palpitations, dyspnea, and angina may be present, even at rest. Symptoms worsen with any activity.

**Other outcomes.** After discharge from hospital, we used 5 standardized questions to determine whether the subjects developed any cardiac or respiratory complications postoperatively that required medical intervention (eg, Since your discharge from hospital, have you had any respiratory or cardiac symptoms that have required medical attention?). The other questions were used only if symptoms had occurred; if so, further information on the symptom and its management was requested.

### Analysis

To examine sensitivity of the 2MWT, repeated-measures 1-way analysis of variance was performed comparing preoperative, postoperative, and follow-up values. Pairwise comparisons were done using the least significant difference. Because the SF-36 and NEADL were only measured on 2 occasions, paired *t* tests were used to assess the change over time.

To evaluate cross-sectional construct concurrent validity of the 2MWT, Pearson correlations (*r*) were calculated with the SF-36 physical functioning subscale and the NEADL scale. To examine cross-sectional construct discriminant validity, the Pearson correlation between the 2MWT and SF-36 social functioning subscale was calculated. Interpretation of the strength of correlations was based on a grading scheme used by Lacasse et al.<sup>20</sup> Specifically, correlation coefficients ranging from 0 to .20 were considered a negligible correlation; .21 to .35, a weak correlation; .36 to .50, a moderate correlation; and greater than .50, a strong correlation.<sup>20</sup>

To examine cross-sectional construct known groups validity, *t* tests were used to compare 2MWT between the different NYHA classifications and between those who developed or did not develop complications postoperatively.

Statistical analysis was conducted using SPSS software, version 10,<sup>a</sup> for Windows. Significance level was set at *P* less than .05.

## RESULTS

### Participants

A total of 122 patients undergoing CABG surgery participated in the study. The demographics of the sample are shown in table 1. As a group, the patients were mostly men, with a large percentage having a history of smoking (69%) and at least 1 comorbidity (79%), with peripheral vascular disease being the most prevalent. However, none of these comorbidities was reported to have an impact on walking ability. Preoperatively,

the mean distance walked in 2 minutes (on the third trial) was 138 $\pm$ 26m.

During the postoperative period, the majority of the subjects (61%) did not experience any postoperative cardiac or pulmonary complications. Of those who experienced complications (39%), dysrhythmias were the most common. The mean distance walked in 2 minutes before discharge from hospital was 84 $\pm$ 33m.

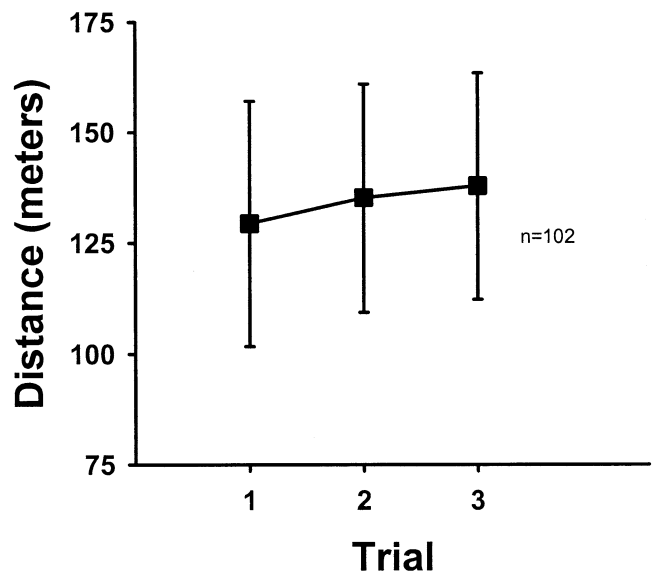
We lost 20 subjects during follow-up due to unwillingness to return for measures; therefore, we obtained data on 102 subjects. Eighteen of 102 reported cardiac complications and 29 of 102 reported respiratory complications. The mean distance walked in 2 minutes at follow-up was 151 $\pm$ 31m.

### Learning Effect

Preoperatively, subjects were asked to perform three 2MWTs to examine the effect of learning or training. There was an increase in distance walked with each of the 3 trials, indicating a training effect (129 $\pm$ 28m preoperatively, 135 $\pm$ 26m postoperatively, 138 $\pm$ 26m on follow-up; *P*<.0001; fig 1). All pairwise comparisons were significant (*P*<.004), although the greatest difference was between trials 1 and 2, not between 2 and 3 (fig 1).

### Sensitivity of the Measures

Distance walked in 2 minutes decreased postoperatively but exceeded preoperative levels on follow-up (*P*<.0001, all pairwise comparisons *P*<.001; fig 2). Only 1 subject required rest during the 2MWT preoperatively, 5 required rest postoperatively, and none did at follow-up. Similarly, the SF-36 physical function subscale score improved at follow-up compared with preoperatively (*P*<.0001; fig 2). The change in NEADL was rather counter to expectation (ie, it worsened slightly at follow-up; *P*=.003; fig 2). The reason for this may be that the ceiling effect of the NEADL com-



**Fig 1. Effect of learning on distance walked in 2 minutes preoperatively.** Mean and standard deviations (SDs) for the first 3 trials are presented. Only subjects for whom all 3 data points were available are represented. There was a significant improvement in distance walked among the 3 trials (*P*<.0001; all pairwise differences significant at *P*<.004).

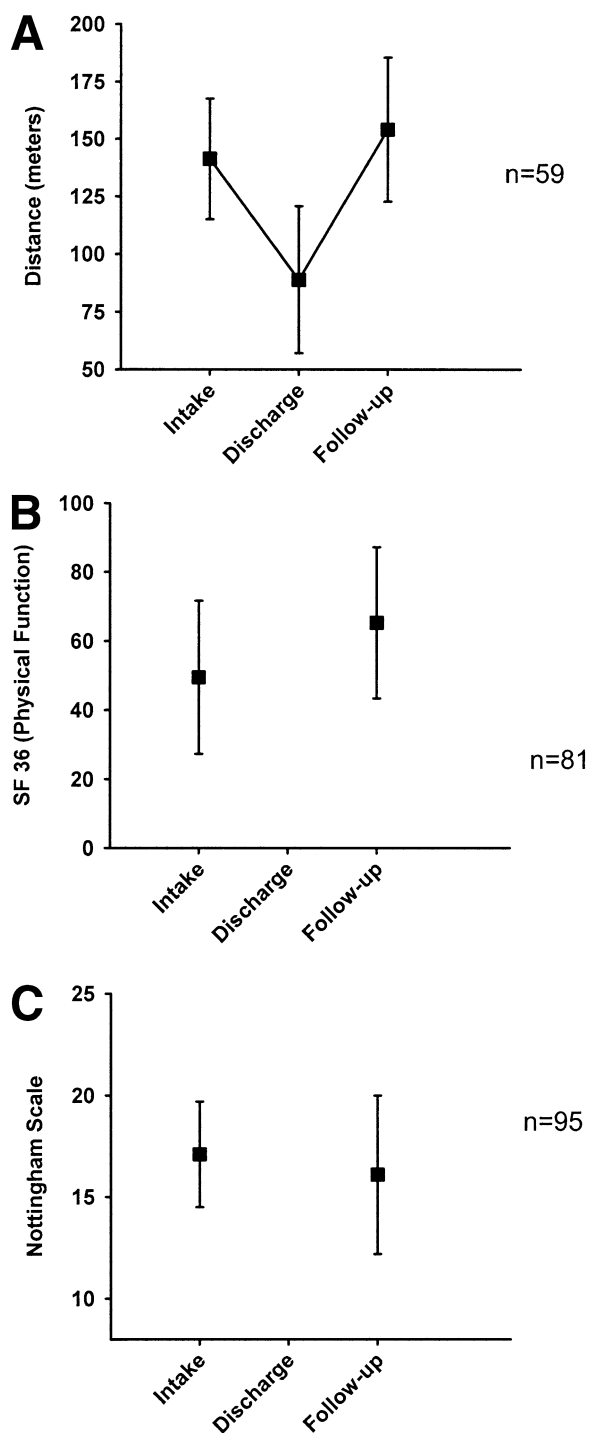


Fig 2. (A) Mean and SD for distance walked in 2 minutes, (B) SF-36 (physical functioning), and (C) NEADL index in cardiac surgery patients before and after surgery. Note that the SF-36 and NEADL index were not performed at discharge from hospital. There were significant changes over time for the distance walked ( $P<.0001$ ), SF-36 (physical function) (all pairwise,  $P<.001$ ), and the NEADL ( $P=.003$ ). The sample values (n) represent the number of subjects with complete data sets.

promises its sensitivity to change. Preoperatively, the mean NEADL was  $17 \pm 3$  (25th percentile, 16; 50th percentile, 18; 75th percentile, 20) (fig 2).

Table 2: Correlation Between Distance Walked and Other Measures of Function

	r	P	n
2MWT and SF-36 PF			
Preoperatively	.44	<.001	97
Follow-up	.48	.011	71
2MWT and SF-36 SF			
Preoperatively	.12	.20	95
Follow-up	-.03	.80	71
2MWT and NEADL			
Preoperatively	.34	.001	102
Follow-up	.31	.01	66

Abbreviations: PF, physical functioning subscale; SF, social functioning subscale.

**Cross-Sectional Construct Validity: Concurrent and Discriminant**

Preoperatively and at follow-up, there were moderate correlations between the 2MWT and the SF-36 physical functioning subscale but not the SF-36 social functioning subscale, demonstrating construct validity (convergent and discriminant) (table 2). There were also significant but weaker correlations between the 2MWT and the NEADL preoperatively and at follow-up (table 2).

**Cross-Sectional Construct Validity: Known Groups**

Because of difficulty discriminating between the 4 classes of NYHA because many subjects were given a range (eg, 1 to 2) rather than 1 number, we collapsed the NYHA classes into 2 categories: classes I and II versus III and IV. There was a difference in distance walked between the 2 categories of NYHA (classes I and II vs III and IV) (fig 3) ( $P=.044$ ). However, there were no differences in distance walked be-

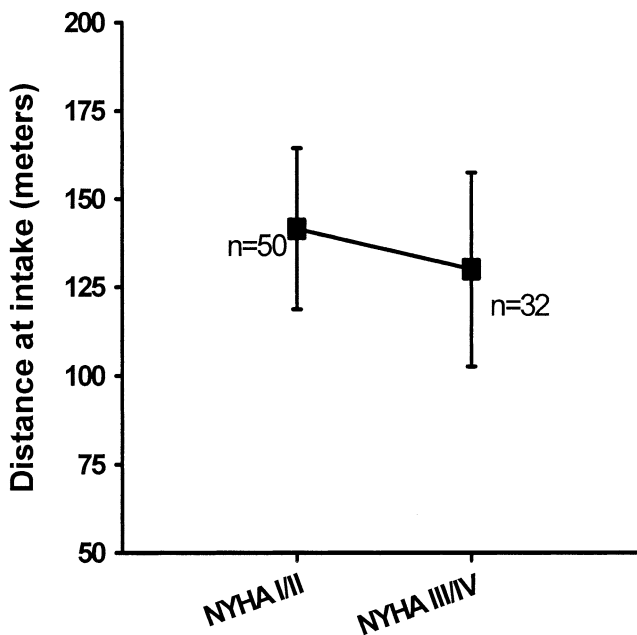


Fig 3. Mean and SD for distance walked in 2 minutes preoperatively for those with NYHA class of I or II versus III or IV. There were significant differences between the 2 groups ( $P=.044$ ). The sample values represent the number of subjects with complete data sets.

tween those who developed complications and those that did not ( $P \geq 0.2$ ).

## DISCUSSION

We chose to investigate the 2MWT because it is a practical and feasible test in patients before and after CABG surgery. The literature on the measurement properties of the 2MWT is limited<sup>3</sup> and none of the studies has been performed in the surgical population. The results of this study demonstrate that the 2MWT is sensitive to change after CABG surgery and shows moderate correlation with measures of physical functioning in this population.

In examining construct validity, Butland<sup>6</sup> and Bernstein<sup>7</sup> and colleagues demonstrated strong correlations between distances walked in each of the 2-, 6-, and 12-minute time intervals. Bernstein<sup>7</sup> further showed that the 2MWT distance correlated moderately to strongly with measures of oxygen consumption. Brooks et al<sup>21</sup> also provided evidence of construct convergent validity in an amputee population by demonstrating moderate correlations with the SF-36 physical functioning subscale. Although no studies have been done on the construct validity of the 2MWT in the cardiac population, some studies have examined the properties of the 6MWT in this population.<sup>3</sup> LaPier<sup>22</sup> found a significant correlation ( $r = .67$ ) between the SF-36 physical functioning subscale and the 6MWT in 36 cardiac patients less than 3 months after hospitalization from coronary heart disease. The greater correlation coefficients observed by LaPier<sup>22</sup> as compared with our study may be explained by differences in the measure (6MWT vs 2MWT) or the sample population because LaPier included both surgical and nonsurgical patients. Despite significant correlations, our study of cardiac surgery patients showed that the 2MWT and the SF-36 physical functioning subscale did not provide the same information regarding functional status because the correlation was only moderate. Therefore, it may be important to include both measures in the assessment of these patients.

We found that there was a learning effect with the performance of the 2MWT in cardiac surgery patients. Repeated testing in pediatric patients with cystic fibrosis revealed no significant difference in distance walked.<sup>23</sup> In contrast, Guyatt et al<sup>12</sup> demonstrated that, in repeated testing of patients with chronic airflow limitation and/or chronic heart failure, there is a learning or training effect that stabilizes after 2 trials. Similarly, Brooks et al<sup>24</sup> found a learning effect in amputees that did not plateau after 3 trials. In our study, although the difference between trials 2 and 3 was less than between trials 1 and 2, there was still a significant difference between the last 2 trials, indicating that learning may not have stabilized by the third trial. We assumed that 3 trials were sufficient for learning based on previous studies; in retrospect, we should have included a fourth trial to ensure a true plateau. However, a fourth trial might have resulted in a greater distance walked, providing further evidence of this measure's sensitivity to change postoperatively. Because of the subject's status postoperatively, it was impossible to perform any additional learning trials at that time.

The 2MWT differed significantly between patients with NYHA class I or II and those with NYHA class III or IV. Similarly, in patients with heart failure, the 6MWT has been shown to discriminate between the levels of the NYHA functional classification.<sup>25-27</sup> However, the 2MWT did not differ between those who developed respiratory or cardiac complications in the postoperative period and those who did not. It is possible that the 2MWT may not be demanding enough to discriminate between those who did and did not develop complications. Because the complication rate was relatively low

and ranged from mild to severe, we may have lacked power to detect a difference. An alternative explanation may be related to the multifactorial nature of postoperative complications; exercise capacity may be only 1 of many variables influencing the occurrence of complications, rendering it difficult to observe a difference.

There are no normative values for the 2MWT but there are 2 studies<sup>28,29</sup> that have reported distances walked in 6 minutes in healthy subjects. In healthy elderly (age range, 60–65y), the distances walked in 6 minutes ranged from 494 to 631m, which translates to 165 to 210m in 2 minutes. These values are higher than those observed in our sample where the distances walked in 2 minutes ranged from  $84 \pm 33$ m (immediately postoperatively) to  $151 \pm 31$ m (6–8wk after surgery). Functional status may be impaired after CABG surgery due to the primary effects of cardiac disease and secondary effects of surgery (eg, blood loss, limb weakness where the donor vessel was taken).<sup>22</sup> However, caution must be used in comparing our results with those of healthy individuals, because normative data are only available for the 6MWT. Extrapolating the 2MWT distance from the 6MWT distance assumes a constant speed throughout the test. The distance walked during the 2MWT may be greater than the distance walked in the first 2 minutes of the 6MWT, because subjects may pace themselves during a longer test.

This study included only patients undergoing elective CABG surgery. Therefore, the findings are not generalizable to other cardiac surgeries or to those undergoing urgent surgery. The properties of the SF-36 and other ADL tools need further evaluation as outcome measures for cardiac surgery patients. Clearly, the NEADL showed a ceiling effect and is not a sufficiently responsive measure in this patient population. Other measurement properties of the 2MWT, such as interpretability and reliability, need to be established in this population as well as determining whether performance on the 2MWT plateaus after 3 training trials.

## CONCLUSIONS

There is a dearth of validated functional outcome measures for cardiac surgery patients. The 2MWT is practical, simple, quick, and easy to administer. In this longitudinal study, we found the 2MWT to be sensitive to change and to correlate adequately with measures of physical functioning in this population.

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