Indonesian Journal of Cardiology
Indonesian J Cardiol 2026:47
pISSN; 2830-3105 / eISSN: 2964-7304
doi: 10.30701/ijc.1969

Original Article

Correlation Between Six-Minute Walk Test and Treadmill Exercise in Post-Coronary Artery Bypass Phase II Rehabilitation Patients: A Cross-Sectional Study

Tresia Fransiska Ulianna Tambunan[1,2], Audrey Witari[1,2], Helisa Rachel Patricie Sianipar[3]

Abstract

Background: Coronary Artery Bypass Grafting (CABG) improves survival in advanced Coronary Artery Disease (CAD) but is often associated with reduced functional capacity during recovery. Phase II cardiac rehabilitation improves physical performance, yet accessible and reliable tools are needed to monitor progress. Treadmill Cardiopulmonary Exercise Testing (CPET) is the gold standard for assessing aerobic capacity, but it is resource-intensive and not widely available in many settings. The Six-Minute Walk Test (6MWT) is a simple alternative, but its validity compared with treadmill testing in Indonesian post-CABG patients remains underexplored.

Methods: This cross-sectional study was conducted at the National General Hospital Dr. Cipto Mangunkusumo in Jakarta between May 2023 and October 2024. Post-CABG patients who completed an eight-week Phase II cardiac rehabilitation program, were clinically stable, and able to perform both assessments were included. Functional capacity was determined by estimated VO_2Max from the 6MWT and directly measured VO_2Max from a symptom-limited treadmill test using the Modified Bruce protocol. Descriptive statistics summarized baseline characteristics. Spearman correlation coefficient was used to evaluate the relationship between the two tests, with statistical significance set at $p<0.05$.

Results: Fifteen post-CABG patients completed the study. Most were male (73.3%) with a mean age of 59 years. Overweight status was common (46.7%), with hypertension (80.0%), dyslipidemia (66.7%), and diabetes mellitus (53.3%) as frequent comorbidities. Mean 6MWT distance increased from 307.8 ± 85.7 m pre-rehabilitation to 498.5 ± 140.7 m post-rehabilitation. The estimated VO_2Max from the 6MWT followed a normal distribution and is reported as a mean of 18.9 mL/kg/min (SD = 4.2). In contrast, the treadmill-measured VO_2Max was non-normally distributed and is therefore reported as a median of 21.4 mL/kg/min. A significant moderate positive correlation was found between 6MWT and treadmill VO_2Max ($r = 0.689$, $p = 0.005$).

Conclusions: The 6MWT demonstrated a strong, significant correlation with treadmill-based VO_2Max, supporting its use as a practical and cost-effective alternative for functional capacity assessment in post-CABG Phase II rehabilitation. Routine integration of the 6MWT may facilitate individualized exercise prescription and enhance patient monitoring, particularly in resource-limited settings.

(Indonesian J Cardiol, 2026;47)

Keywords: Coronary Artery Bypass, Cardiac Rehabilitation, Exercise Test, Walking Test, Oxygen Consumption.

[1]Physical Medicine and Rehabilitation Unit, University of Indonesia Hospital, Depok, Indonesia.
[2]Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia.
[3]Faculty of Medicine, Universitas Indonesia, Depok, Indonesia.

Correspondence:
Tresia Fransiska Ulianna Tambunan,

Physical Medicine and Rehabilitation Unit, University of Indonesia Hospital, Depok/Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia.

Email: fransiska_ut@yahoo.com.au

Introduction

Coronary Artery Bypass Grafting (CABG) remains the preferred revascularization strategy for patients with complex multivessel Coronary Artery Disease (CAD). Despite its survival benefits, the procedure is frequently associated with significant postoperative sequelae, including prolonged immobility, sternal instability, and a marked reduction in functional capacity.[1-2] Cardiac rehabilitation plays a pivotal role in mitigating these effects by enhancing physical tolerance and reducing mortality.[3] To prescribe safe and effective exercise intensity, accurate functional assessment is essential. Maximal exercise testing with gas analysis (Cardiopulmonary Exercise Testing [CPET]) or standard treadmill protocols is considered the gold standard for this purpose; however, its implementation in developing regions is often limited by high costs, the need for specialized equipment, and the technical complexity of the procedures.[4]

In resource-limited settings, the Six-Minute Walk Test (6MWT) has emerged as a practical, low-cost alternative that reflects functional capacity for daily living activities. While the 6MWT is widely used, its correlation with maximal treadmill testing has largely been established in Western populations. Applying these findings directly to Indonesian patients is problematic due to well-documented ethnic differences in anthropometry and stride length, which significantly influence walking distance and VO_2Max estimation.[5-6] Recent evidence indicates that the 6MWT is feasible and well-tolerated in adults and older patients immediately following CABG, while other studies have confirmed the reliability of treadmill-based 6MWT protocols across diverse cardiovascular cohorts.[7-8] Despite this reinforcing evidence for the test's general validity, specific validation data regarding its correlation with maximal treadmill testing in Indonesian post-CABG patients is currently lacking.

Consequently, relying on foreign reference standards may lead to inaccurate risk stratification and exercise prescription in the local context. This study aims to explore the correlation between 6MWT and treadmill testing among post-CABG patients in phase II rehabilitation, specifically by: (1) identifying the characteristics of post-CABG patients undergoing phase II cardiac rehabilitation, (2) estimating their functional capacity in terms of VO_2Max using both the 6MWT and treadmill test, and (3) determining the correlation between the 6MWT results and treadmill test outcomes in this patient population. By establishing this relationship, we seek to validate the 6MWT as a reliable surrogate tool for functional assessment in Indonesian cardiac rehabilitation centres where maximal testing is unavailable.

Methods

Study Design

This study used an observational analytic cross-sectional design to assess the correlation between the 6MWT and treadmill exercise testing in post-CABG patients undergoing phase II cardiac rehabilitation at the National General Hospital Dr. Cipto Mangunkusumo, Jakarta. The study was conducted at the Integrated Cardiocerebrovascular Service Unit, Medical Rehabilitation Outpatient Clinic, with data collection taking place from May 2023 to October 2024, following a preparation period from December 2022 to July 2023. Data analysis was scheduled for October to November 2024, with reporting planned for December 2024.

Participants

Participants were included if they were between 18 and 60 years of age and had completed an eight-week Phase II cardiac rehabilitation program following CABG. Patients were excluded if they had musculoskeletal or neurological disorders that impaired their ability to walk, were unable to understand or follow test instructions as indicated by a Montreal Cognitive Assessment Indonesian version (MoCA-INA) score below 26, or had active pulmonary disease, arrhythmia, fever or active infection, a Timed Up and Go (TUG) score greater than 12 seconds, high fear of falling, a frailty score of 3 or more based on the Fried Frailty Scale, or hemoglobin levels below 10 mg/dL. Participants were withdrawn from the study if they experienced test termination criteria during either the 6MWT or treadmill test, such as intolerable chest pain, dyspnea, leg cramps, dizziness, pallor, confusion, cold sweats, cyanosis, or nausea. Subjects who refused to complete the assessment procedures were also considered dropouts.

The sample size used in this study is calculated using a formula for correlational analytic studies. The sample size is determined based on the correlation coefficient (r) with the following formula:

$$n = ((Z\alpha + Z\beta) / (0.5 \times \ln((1 + r)/(1 - r))))^2 + 3$$

Explanation:

α = Type I error, set at 0.05, so $Z\alpha = 1.96$

β = Type II error, set at 0.20 (giving 80%

power), so $Z\beta = 0.842$
r = correlation coefficient
n = required sample size

The correlation coefficient (r) based on the six-minute walk test against Metabolic Equivalents of Task (METs) during treadmill training by Saba et al.[2] is 0.77, resulting in n = 13.38, thus a minimum of 14 subjects.

The study sample consisted of the accessible population who met the inclusion criteria and did not meet any of the exclusion criteria. Sampling was carried out using non-probability sampling, specifically purposive sampling, among individuals from the accessible population who fulfilled both the inclusion and exclusion requirements.

Ethical Considerations

Research ethics approval was issued by the Research Ethics Commission of the Faculty of Medicine, University of Indonesia, with a Letter of Approval from the Research Ethics Committee No. KET- 491 / UN2.F1 / ETIK / PPM.00.02 / 2023 and a Research Permit Letter at National General Hospital Dr. Cipto Mangunkusumo No. YR.02.01 / 2.6.1 / 0915/2023.

Intervention

Each eligible subject was provided with detailed information regarding the study's purpose, procedures, and potential benefits. Written informed consent was obtained prior to participation. Baseline assessments included demographic data (name, age, gender, phone number, religion, and education level), clinical history, and anthropometric measurements (weight, height, and vital signs). Subjects were instructed to wear comfortable clothing and athletic footwear. They then underwent the 6MWT following standardized instructions. The primary outcome from this test was the Six-Minute Walking Distance (6MWD), measured in meters. From this, estimated VO_2Max and METs were calculated along with documentation of any subjective symptoms. Specifically, estimated VO_2Max was calculated using the equation: $VO_2Max = (0.03 \times \text{distance in meters}) + 3.98$, and METs were derived as $VO_2Max/3.5$.

Outcome Measures

The main variables in this study were the predicted VO_2Max and METs derived from the 6MWT as independent variables, and VO_2Max and METs obtained from the treadmill test as dependent variables. Potential confounding variables included age, sex, Body Mass Index (BMI), and height. These factors were considered in both the data collection and analysis phases. The 6MWT standard protocols are described in Supplementary Data 1.

Following the 6MWT, patients received education regarding the treadmill test protocol and were referred to the cardiovascular division of internal medicine for treadmill testing, which was scheduled within 48 hours to 7 days of the initial test. The assessment followed the Modified Bruce Protocol, beginning with a warm-up stage (1.7 mph at 0% grade), followed by progressive 3-minute stages increasing in speed and grade (Stage 1: 1.7 mph, 10% grade; Stage 2: 2.5 mph, 12% grade, etc.), until volitional exhaustion or termination criteria were met. The full procedure is described in Supplementary Data 2.

The test score was defined as the total time (T) in minutes, which was converted into estimated VO_2Max (mL/kg/min) using specific population-based formulas: General: $14.76 - (1.379 \times T) + (0.451 \times T^2) - (0.012 \times T^3)$; Women: $(2.94 \times T) + 3.74$; Young Women: $(4.38 \times T) - 3.9$; Men: $(2.94 \times T) + 7.65$; and Young Men: $(3.62 \times T) + 3.91$. Final outcomes included measured VO_2Max, METs, and any reported symptoms.

Statistical Analysis

Data processing and statistical analysis were performed using IBM SPSS Statistics version 26 for Macintosh. Descriptive analysis was conducted to evaluate the baseline characteristics and 6MWT outcomes. Categorical data were presented as frequencies and percentages, while continuous data were assessed for normality using the Kolmogorov-Smirnov test. Normally distributed data were reported as means, while non-normally distributed data were presented as medians. The primary analysis assessed the correlation between outcomes of the 6MWT and the treadmill test using the Spearman correlation test, as data were not normally distributed. Correlation strength was classified as weak ($r < 0.40$), moderate ($r = 0.40\text{-}0.69$), or strong ($r \geq 0.70$).

Theory/calculation

Low 6MWD and treadmill test performance have been associated with poorer cardiovascular prognosis, and this can be explained by several physiological mechanisms. One key contributor is left ventricular dysfunction. A reduced VO_2Max, determined by both oxygen delivery (including cardiac output and peripheral vascular function) and oxygen utilization (primarily skeletal muscle efficiency), contributes to decreased exercise tolerance. Submaximal functional capacity may be limited either by resting ventricular dysfunction or by dysfunction induced during submaximal exertion.

However, the relationship between exercise capacity and left ventricular function is also influenced by factors such as age, gender, and BMI.[9]

Another important mechanism is myocardial ischemia, indicated by ST-segment depression or elevation during exercise testing.[10] Ischemia occurring at submaximal or maximal workloads may impair myocardial contractility and contribute to lower test outcomes in both VO_2Max and walking distance, as the impaired contractile response may limit cardiac performance under exertion, directly reducing measurable aerobic capacity.[11]

Endothelial dysfunction is also implicated in limiting oxygen delivery. It affects vascular tone, promotes thrombotic events, and alters the vascular wall composition, all of which contribute to a reduced VO_2Max and increased risk of recurrent cardiovascular events.[12] Moreover, poor functional capacity may also reflect an unfavorable cardiovascular risk profile, including dyslipidemia, hypertension, insulin resistance, systemic inflammation, autonomic dysfunction, and prothrombotic states. Together, these factors increase the likelihood of future adverse cardiac events.[13-14]

In this study, functional capacity is assessed using the 6MWT and treadmill exercise testing, both of which provide distance-based outcomes that reflect the integrated physiological responses of multiple organ systems involved in physical exertion, namely the pulmonary, cardiovascular, hematologic, neuromuscular, and muscular-metabolic systems. The 6MWT is chosen for its simplicity, validity, reproducibility, and tolerability, particularly among patients with CAD. Meanwhile, the treadmill test is a maximal-effort assessment and is considered the gold standard for evaluating aerobic capacity. Key indicators such as VO_2Max and METs, derived from these tests, serve as critical parameters for clinical diagnosis and prognostication. The conceptual framework underlying this assessment approach is illustrated in Figure 1.

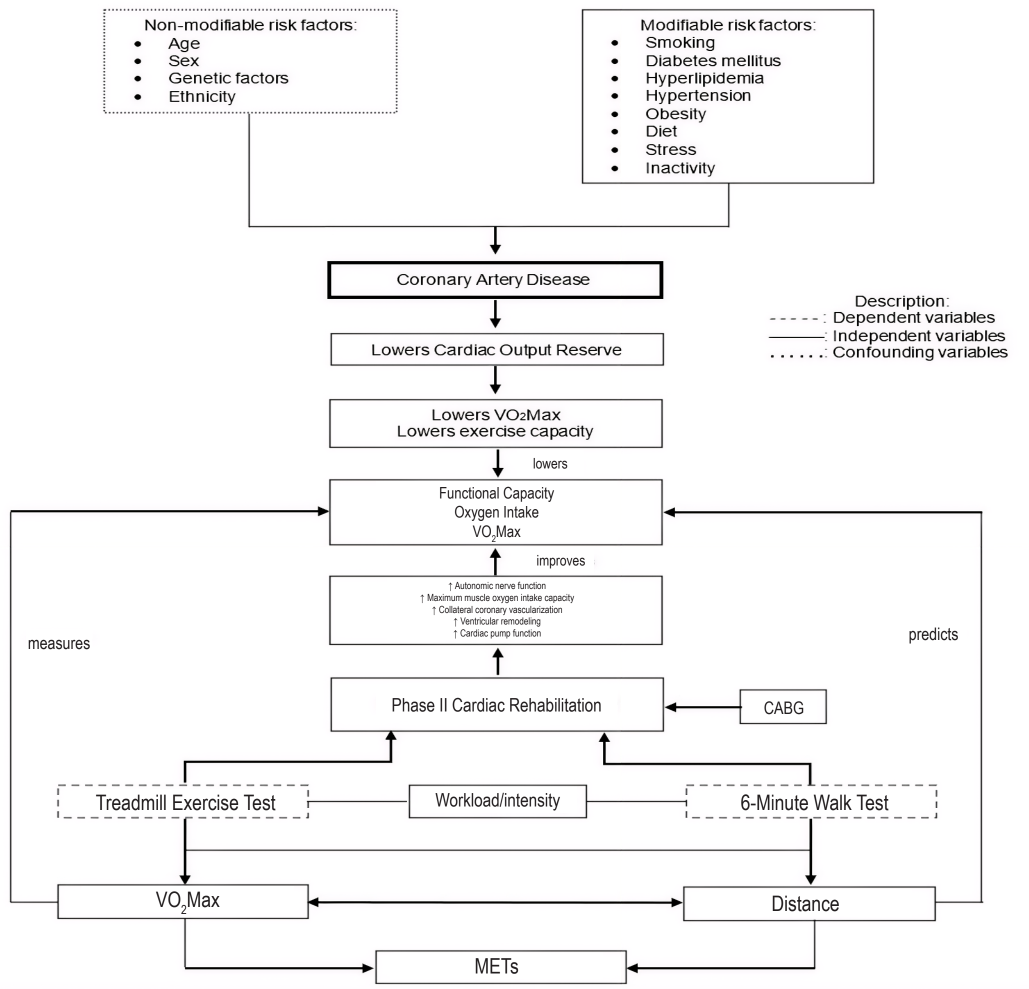

Figure 1. Conceptual Framework of Cardiac Rehabilitation in CAD.
This diagram shows how risk factors lead to coronary heart disease and reduced exercise capacity. Phase II cardiac rehabilitation improves functional capacity, measured by VO_2Max and walking distance, through structured exercise and testing.

Results

Participant Characteristics

The study subjects were post-CABG patients who met the inclusion and exclusion criteria and consented to participate. The recruitment process and outcomes are illustrated in Figure 2. A total of 40 patients were initially screened. Of these, 22 eligible participants (55.0%) failed to attend the baseline assessment. Specifically, ten participants did not attend the first visit for the 6MWT, one had undergone amputation, one experienced urethral rupture, two had strokes, three passed away, and five returned to their hometowns after the procedure.

Eighteen subjects signed the informed consent form. However, three dropped out due to loss to follow-up. Ultimately, 15 subjects completed the post-intervention assessments. This number meets the minimum sample size estimated during the study design phase. Participants underwent Phase II cardiac rehabilitation, consisting of supervised exercise sessions three times per week for eight weeks, totaling 24 sessions.

Several logistical challenges were encountered during the implementation of the study protocol. Initially, data collection was scheduled to be completed by December 2023. However, due to insufficient subject recruitment by the end of that year, the study duration was extended to October 2024. The primary challenge was identifying eligible participants who met the study criteria. No participants experienced adverse events during the exercise sessions, 6MWT, or treadmill exercise testing. Subject characteristics were evaluated to identify potential confounding variables, including age, sex, and BMI. Additional variables assessed were educational attainment and comorbidities. The detailed characteristics are presented in Table 1.

In this study, age was not normally distributed, with a median of 59 years and a range of 39-60 years. The majority of participants were male (73.3%). The mean BMI indicated that 46.7% of participants were overweight. Most participants had completed high school education (46.7%). The most common comorbidities were hypertension, followed by dyslipidemia and diabetes mellitus.

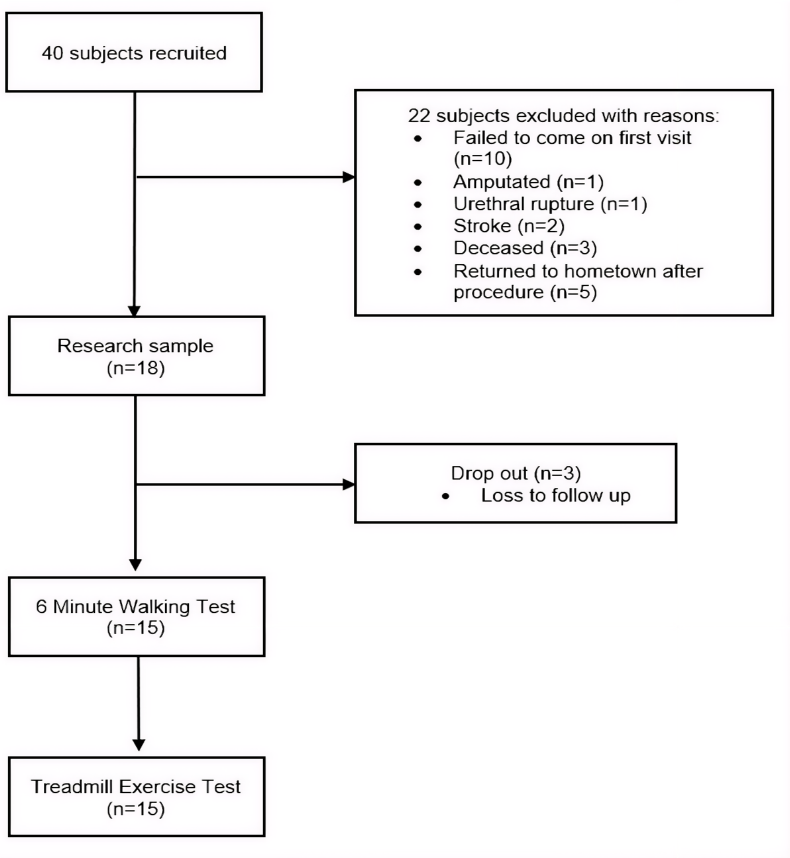

Figure 2. Subject Recruitment Process.
This flowchart outlines the recruitment and retention of study participants.

Table 1. Characteristics of Study Subjects.

Characteristic	n=15
Age (years), median (min-max)	59 (39-60)
Sex, n (%)	
Male	11 (73.3%)
Female	4 (26.7%)
Education Level, n (%)	
Primary School	1 (6.7%)
Middle School	1 (6.7%)
High School	7 (46.7%)
Diploma/Bachelor's Degree	6 (40.0%)
Body Weight (kg), mean (SD)	65.5 (8.8)
Height (cm), mean (SD)	162.5 (6.3)
BMI (kg/m²), n (%)	
Normal	7 (46.7%)
Overweight	7 (46.7%)
Obesity I	1 (6.7%)
Obesity II	–
Medical History, n (%)	
Hypertension	12 (80.0%)
Diabetes Mellitus	8 (53.3%)
Dyslipidemia	10 (66.7%)
Kidney Failure	5 (33.3%)
6-Minute Walk Distance (m), mean (SD)	
Before	307.8 (85.7)
After	498.5 (140.7)

BMI: Body Mass Index; m: meter.

Functional Capacity Based on VO_2Max in the 6MWT and Treadmill Exercise Test

After completing eight weeks of Phase II cardiac rehabilitation, participants demonstrated a substantial improvement in 6MWD, with a mean increase of 190.7 meters from baseline. The estimated VO_2Max from the 6MWT (which was normally distributed) is reported as a mean of 18.9 mL/kg/min (SD = 4.2). In contrast, the treadmill-measured VO_2Max (which was non-normally distributed) is reported as a median of 21.4 mL/kg/min (range: 15.7-35.7). The complete functional capacity data stratified by sex are presented in Supplementary Data 3, and the final summary of results is provided in Table 2.

Correlation Between 6MWD and Treadmill VO_2Max in Post-CABG Patients

A Spearman correlation analysis revealed a statistically significant moderate positive correlation between 6MWD and VO_2Max measured via treadmill testing in post-CABG patients ($r = 0.689$, $p = 0.005$). This finding indicates that a greater 6MWD is associated with higher treadmill VO_2Max, and vice versa. The correlation results are summarized in Table 2.

A scatter plot illustrating the relationship between 6MWD and treadmill VO_2Max is shown in Figure 3. The graph demonstrates that patients with higher VO_2Max values also achieved longer 6MWD walking distances. This reinforces the significant positive association between the two functional capacity indicators.

Discussion

Participants Characteristics

The average age of participants was 59 years (range: 39-60), categorized as late productive age. This finding is comparable to one research in Medan, Indonesia, which reported a mean age of 57.4 years (SD = 5.7) among post-CABG patients.[15] Similarly, another study identified an average age of 66 years (range: 59-72) in male patients post-open-heart surgery.[16] Older age is associated with a gradual decline in cardiorespiratory capacity, which

Table 2. Functional Capacity Outcomes and Correlation Analysis.

Variable	Value	Statistic
6MWT Distance (meters)	498.5 ± 140.7	Mean ± SD
6MWT Estimated VO_2Max (mL/kg/min)	18.9 ± 4.2	Mean ± SD
Treadmill Measured VO_2Max (mL/kg/min)	21.4 (15.7 – 35.7)	Median (Q1-Q3)
Correlation (Spearman's Rho)	0.689	
p-value	0.005	

Data are presented as Mean ± SD for normally distributed variables and Median (Q1-Q3) for non-normally distributed variables.

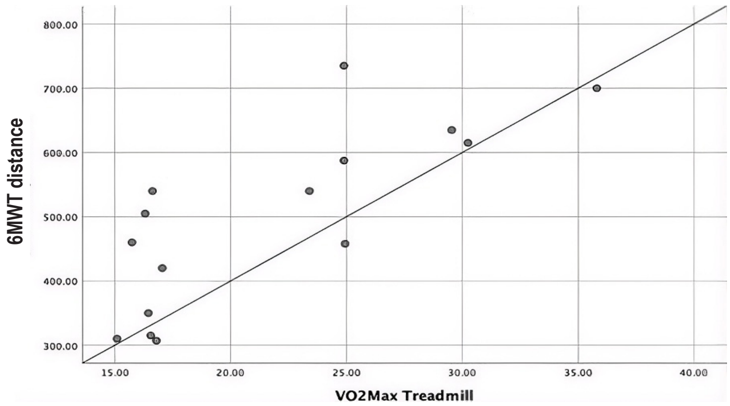

Figure 3. Scatter Plot of 6MWT and Treadmill Exercise Test.
The plot demonstrates that better treadmill exercise performance (higher VO_2Max) is generally associated with better walking endurance, as measured by the 6MWT distance. This supports the use of the 6MWT as a simple, practical indicator of cardiovascular fitness.

may result in slower postoperative improvement. Another significant difference is the proportion of male (11 participants) versus female (4 participants) subjects in this study, which may be considered a study limitation, even though it reflects the general trend in the proportion of CABG patients.[17] The small sample size of female participants may hinder accurate representation of women's responses to rehabilitation and limit the validity of statistical analyses comparing outcomes between the two sexes.

Male participants accounted for 73.3% of the sample, consistent with the literature reporting a higher prevalence of CABG procedures among men.[17-18] Males are associated with greater baseline cardiorespiratory fitness, muscular strength, and skeletal muscle mass, which may influence exercise test outcomes.[19-20]

Nearly half of the participants (46.7%) were classified as overweight, while hypertension was the most prevalent comorbidity (80.0%), followed by dyslipidemia (66.7%) and diabetes mellitus (53.3%). These comorbidities can negatively impact baseline functional capacity and the effectiveness of rehabilitation. This is in line with a multicenter study that found 44% of 7,498 CABG patients were overweight.[21] As was previously studied, overweight status is strongly associated with hypertension, dyslipidemia, and insulin resistance, key risk factors for CAD.[22]

Most participants had a high school education (46.7%), a factor that may influence comprehension of instructions, adherence to rehabilitation protocols, awareness of the benefits of the program, and capacity for independent management.[23]

Impact on 6MWD

Following 8 weeks of cardiac rehabilitation, the mean 6MWD increased significantly from 307.8 meters (SD = 85.7) to 498.5 meters (SD = 140.7), representing a mean improvement of 190.7 meters. The physiological mechanisms underlying these improvements include increased stroke volume and cardiac output, reduced resting heart rate, improved myocardial contractility, and enhanced coronary perfusion through angiogenesis.[24] Peripheral adaptations, such as improved endothelial function, increased nitric oxide production, decreased arterial stiffness, and enhanced skeletal muscle capillarization, also play a critical role in improving peripheral resistance.[25]

At the cellular level, consistent physical training stimulates mitochondrial biogenesis and volume expansion, thereby improving aerobic metabolism and oxidative enzyme activity.[26] These adaptations enhance peripheral oxygen extraction and improve neurohumoral balance by reducing sympathetic activity and enhancing vagal tone.[27] Skeletal muscle adaptations include hypertrophy, increased oxidative capacity, and optimized fiber-type distribution through pathways such as Peroxisome Proliferator-Activated Receptor Gamma Coactivator 1-Alpha (PGC-1α) expression and AMP-activated protein kinase (AMPK) activation.[28] Exercise also reduces systemic inflammation and modulates pro-inflammatory cytokines.[3] Collectively, these mechanisms contribute to the observed improvement in 6MWD.

This phase II cardiac rehabilitation program has been shown to improve functional capacity, as evidenced by a 190.7-meter increase in the 6MWD. This improvement far exceeds the Minimal Clinically Important Difference (MCID) established by the European Respiratory Society/American Thoracic Society, which is 30 meters for minimal change in 6MWD.[29] Contributing factors influencing successful 6MWT outcomes include age, baseline 6MWD, exercise session attendance, supervision and encouragement during the test, and underlying cardiac pathology.[30] While both the 6MWT and treadmill test evaluate aerobic capacity, the 6MWT primarily reflects submaximal functional capacity relevant to daily activities, whereas the treadmill test assesses maximal cardiovascular performance.

Functional Capacity in the form of VO_2Max from the 6MWT and Treadmill Test

The mean VO_2Max derived from the 6MWT was 18.9 mL/kg/min (SD = 4.2), while that from the treadmill test was 21.4 mL/kg/min (range: 15.7-35.7). Saba et al.[2] reported a more significant difference between the two methods, with 6MWT VO_2Max at 11.3 mL/kg/min and treadmill-derived VO_2Max at 23.4 mL/kg/min, a difference of 12.1 mL/kg/min. In contrast, Zanini et al.[31] reported a smaller discrepancy: 18.8 mL/kg/min (SD = 6.1) from the 6MWT versus 19.5 mL/kg/min (SD = 3.6) from treadmill testing, a difference of only 0.7 mL/kg/min. Discrepancies in findings may be attributed to differences in participant demographics, post-operative timelines, and assessment methodologies. Additionally, anthropometric differences between Indonesian and international populations could influence exercise test performance. In general, VO_2Max values derived from treadmill testing tend to be higher than those estimated from the 6MWT. This is expected, given that the 6MWT assesses submaximal endurance, while treadmill testing measures peak aerobic capacity.

The mean METs during the 6MWT was 5.4 (SD = 1.2), while the treadmill test yielded a mean of 6.1 (range: 4.5-10.2). These results indicate a sufficient functional capacity for daily activities such as brisk walking, sweeping, or playing with children. However, activities must be introduced gradually and with proper monitoring.

Correlation Between 6MWD and Treadmill-Derived VO_2Max in Post-CABG Patients

This study demonstrated a statistically significant moderate positive correlation ($r = 0.689$) between the 6MWD and treadmill-derived VO_2Max in post-CABG patients undergoing Phase II cardiac rehabilitation. These results align with the researcher's expectations, as both tests assess functional capacity, albeit through distinct physiological mechanisms.

The moderate correlation can be attributed to the distinct characteristics of each test: the 6MWT is a submaximal, self-paced assessment, whereas the treadmill test is maximal and standardised. These findings are consistent with more recent evidence. For example, a meta-analysis found a significant correlation between VO_2Max and 6MWD ($r = 0.65$) in patients with cardiopulmonary conditions.[32]

Previous research demonstrates a strong correlation between 6MWT performance and treadmill test results in cardiac rehabilitation settings. In one updated study, the 6MWT showed a moderate-to-strong correlation ($r = 0.70$-0.80) with VO_2Max as measured by a treadmill test.[33] These findings reinforce the validity of the 6MWT as a practical tool for evaluating functional capacity. In populations with significant physical limitations, the 6MWT may approximate maximal exertion, further supporting its clinical utility.

While the 6MWT cannot fully replace treadmill testing, it remains an effective tool for screening and monitoring progress in cardiac rehabilitation programmes.[34] This is particularly relevant in clinical settings with limited access to treadmill or CPET facilities, and supports the adoption of the 6MWT as a practical alternative for monitoring functional progress over time. Its simplicity in implementation does not diminish its clinical reliability as a valid assessment tool.

Strengths and Limitations of the Study

Several limitations must be acknowledged. First, the use of purposive sampling may limit the generalizability of findings to the broader

Indonesian post-CABG population. Second, due to the limited sample size (n=15), the estimates may be subject to wide confidence intervals, and multivariate regression analysis to adjust for potential confounders (age, sex, BMI) could not be performed. Future studies with larger, randomized cohorts are needed to statistically isolate the effects of these variables.

Thirdly, this study did not use the gold-standard CPET. Sampling limitations were also present, as many patients at National General Hospital Dr. Cipto Mangunkusumo, reside outside Jakarta, and some were unable to complete the program. Additionally, incomplete data posed a challenge, particularly the lack of post-operative ejection fraction data prior to Phase II cardiac rehabilitation, as this parameter was not included in the standard operating procedures of the hospital.

Despite these limitations, this study presents several strengths. To our knowledge, it is the first to assess the correlation between the 6MWT and treadmill-based testing in post-CABG patients within an Indonesian population. Furthermore, the findings provide evidence that the 6MWT can be reliably administered in healthcare facilities without treadmill infrastructure, thereby broadening access of functional capacity assessments in cardiac rehabilitation programs.

Conclusion

These results indicate that the 6MWT is a practical, accessible, and valid measure of functional capacity in post-CABG patients during Phase II cardiac rehabilitation. Its strong correlation with treadmill-derived VO_2Max underscores its utility as a reliable alternative to more complex exercise testing. Consequently, the 6MWT can effectively guide individualized exercise prescription, monitor patient progress, and facilitate rehabilitation planning in clinical settings where resource constraints may limit access to advanced CPET. Integrating the 6MWT into routine post-CABG rehabilitation protocols may enhance patient outcomes by providing timely, objective assessments of cardiovascular fitness and functional improvement.

List of Abbreviations

6MWT	Six-Minute Walk Test
6MWD	Six-Minute Walking Distance
AMPK	AMP-activated protein kinase
BMI	Body Mass Index
CABG	Coronary Artery Bypass Grafting
CAD	Coronary Artery Disease
CPET	Cardiopulmonary Exercise Testing
MCID	Minimal Clinically Important Difference
METs	Metabolic Equivalents of Task
MoCA-INA	Montreal Cognitive Assessment – Indonesian Version
PGC-1α	Peroxisome Proliferator-Activated Receptor Gamma Coactivator 1-Alpha
TUG	Timed Up and Go Test
VO_2Max	Maximal Oxygen Uptake

Ethical Clearance

Research ethics approval was issued by the Research Ethics Commission of the Faculty of Medicine, University of Indonesia, with a Letter of Approval from the Research Ethics Committee No. KET- 491 / UN2.F1 / ETIK / PPM.00.02 / 2023 and a Research Permit Letter at National General Hospital Dr. Cipto Mangunkusumo No. YR.02.01 / 2.6.1 / 0915/2023.

Publication Approval

All authors have approved the publication of this manuscript.

Authors Contributions

AW and TFUT contributed to the conception and design of the study. AW performed data collection, conducted the analysis and interpretation of data, and drafted the initial manuscript. HRPS contributed to the interpretation of data, translated the manuscript into English, and critically revised it for important intellectual content. TFUT supervised the study, contributed to critical revision of the manuscript, and provided final approval of the version to be published. All authors meet the ICMJE authorship criteria and have read and approved the final manuscript.

Acknowledgments

The authors would like to acknowledge the support and guidance received from their institution during the preparation of this manuscript.

Conflict of Interest

None.

Availability of Data and Materials

The study protocols are provided in the Supplementary Materials (Supplementary Data 1 and 2).

Funding

None.

Copyright/Permissions for Figures

Not applicable.

Generative AI and AI-Assisted Technologies in the Writing Process

Authors acknowledge that artificial intelligence (AI) tools were only used to assist in language editing and did not generate or alter the scientific content, analyses, or conclusions presented in this manuscript.

References

1. Almashrafi A, Elmontsri M, Aylin P. Systematic review of factors influencing length of stay in ICU after adult cardiac surgery. BMC Health Services Research.2016;16:318
2. Saba MA, Goharpey S, Attarbashi Moghadam B, Salehi R, Nejatian M. Correlation Between the 6-Min Walk Test and Exercise Tolerance Test in Cardiac Rehabilitation After Coronary Artery Bypass Grafting: A Cross-sectional Study. Cardiology and Therapy.2021;10:201-9
3. Ambrosetti M, Abreu A, Corrà U, Davos CH, Hansen D, Frederix I, et al. Secondary prevention through comprehensive cardiovascular rehabilitation: From knowledge to implementation. 2020 update. A position paper from the Secondary Prevention and Rehabilitation Section of the European Association of Preventive Cardiology. European Journal of Preventive Cardiology.2021;28:460-95
4. Taylor JL, Myers J, Bonikowske AR. Practical guidelines for exercise prescription in patients with chronic heart failure. Heart Failure Reviews.2023;28:1285-96
5. Oliveira MJ, Marçôa R, Moutinho J, Oliveira P, Ladeira I, Lima R, Guimarães M. Reference equations for the 6-minute walk distance in healthy Portuguese subjects 18–70 years old. Pulmonology.2019;25:83-9
6. Nusdwinuringtyas N. Six Minute Walking Distance Cut-off Point in Indonesian (Mongoloid) Population. Journal Of The Indonesian Medical Association.2018;68:389-94
7. Wu Y, Ren B, Li J, Chi L, Li P, Wu J. Physical performance on the early 6-minute walk test in coronary artery bypass grafting patients during inpatient cardiac rehabilitation. Frontiers in Cardiovascular Medicine.2025;12
8. Nevelikova M, Dosbaba F, Pepera G, Felsoci M, Batalikova K, Su JJ, Batalik L. Validity and reliability of automated treadmill six-minute walk test in patients entering exercise-based cardiac rehabilitation. Annals of Medicine.2023;55:2304664
9. Grewal J, McCully RB, Kane GC, Lam C, Pellikka PA. Left ventricular function and exercise capacity. JAMA.2009;301:286-94
10. Lim YC, Teo S-G, Poh K-K. ST-segment changes with exercise stress. Singapore Medical Journal.2016;57:347-353
11. Carvalho de Arruda Veiga E, Ferreira Levy R, Sales Bocalini D, Maria Soares Junior J, Chada Baracat E, Carvalho Cavalli R, dos Santos L. Exercise training and experimental myocardial ischemia and reperfusion: A systematic review and meta-analysis. International Journal of Cardiology. Heart & Vasculature.2023;46:101214
12. Sun H-J, Wu Z-Y, Nie X-W, Bian J-S. Role of Endothelial Dysfunction in Cardiovascular Diseases: The Link Between Inflammation and Hydrogen Sulfide. Frontiers in Pharmacology.2019;10:1568
13. Kosmas CE, Bousvarou MD, Kostara CE, Papakonstantinou EJ, Salamou E, Guzman E. Insulin resistance and cardiovascular disease. The Journal of International Medical Research.2023;51:03000605231164548
14. Chakraborty S, Verma A, Garg R, Singh J, Verma H. Cardiometabolic Risk Factors Associated With Type 2 Diabetes Mellitus: A Mechanistic Insight. Clinical Medicine Insights: Endocrinology and Diabetes.2023;16:11795514231220780
15. Matondang RAP. *Pemulihan Denyut Jantung Paska Rehabilitasi Jantung Fase II Sebagai Prediktor Kematian dan Rehospitalisasi 3 Bulan pada Pasien Paska Bedah Pintas Arteri Koroner.* 2020
16. Hubisz MM, van der Stouwe JG, Ziob M, Steiner S, Uzun N, Weibel S, Lesan V, Erni D, Meier-Ruge L, Rodriguez Cetina Biefer H, Dzemali O, Vontobel J, Niederseer D. A comparati-

ve analysis of open heart surgery and minimally invasive cardiac surgery in exercise-based cardiac rehabilitation. Journal of Cardiothoracic Surgery.2024;19:390
17. Matyal R, Qureshi NQ, Mufarrih SH, Sharkey A, Bose R, Chu LM, Liu DC, Senthilnathan V, Mahmood F, Khabbaz KR. Update: Gender differences in CABG outcomes-Have we bridged the gap? PloS One.2021;16:e0255170
18. Harik L, Perezgrovas-Olaria R, Jr Soletti G, Dimagli A, Alzghari T, An KR, Cancelli G, Gaudino M. Sex differences in coronary artery bypass graft surgery outcomes: a narrative review. Journal of Thoracic Disease.2023;15:5041-54
19. Al-Mallah MH, Juraschek SP, Whelton S, Dardari ZA, Ehrman JK, Michos ED, Blumenthal RS, Nasir K, Qureshi WT, Brawner CA, Keteyian SJ, Blaha MJ. Sex Differences in Cardiorespiratory Fitness and All-Cause Mortality: The Henry Ford ExercIse Testing (FIT) Project. Mayo Clinic Proceedings.2016;91:755-62
20. Belzunce MA, Henckel J, Di Laura A, Horga LM, Hart AJ. Similarities and differences in skeletal muscle and body composition between sexes: an MRI study of recreational cyclists. BMJ Open Sport & Exercise Medicine.2023;9:e001672
21. Johnson AP, Parlow JL, Whitehead M, Xu J, Rohland S, Milne B. Body Mass Index, Outcomes, and Mortality Following Cardiac Surgery in Ontario, Canada. Journal of the American Heart Association.2015;4:e002140
22. Manoharan MP, Raja R, Jamil A, Csendes D, Gutlapalli SD, Prakash K, Swarnakari KM, Bai M, Desai DM, Desai A, Penumetcha SS. Obesity and Coronary Artery Disease: An Updated Systematic Review 2022. Cureus.2022;14:e29480
23. Gaalema DE, Savage PD, O'Neill S, Bolívar HA, Denkmann D, Priest JS, Khadanga S, Ades PA. The Association of Patient Educational Attainment With Cardiac Rehabilitation Adherence and Health Outcomes. Journal of Cardiopulmonary Rehabilitation and Prevention.2022;42:227-34
24. Hellsten Y, Nyberg M. Cardiovascular Adaptations to Exercise Training. Comprehensive Physiology.2015;6:1-32
25. Green DJ, Smith KJ. Effects of Exercise on Vascular Function, Structure, and Health in Humans. Cold Spring Harbor Perspectives in Medicine.2018;8:a029819
26. Hood DA, Memme JM, Oliveira AN, Triolo M. Maintenance of Skeletal Muscle Mitochondria in Health, Exercise, and Aging. Annual Review of Physiology.2019;81:19-41
27. Yang X, Li Y, Ren X, Xiong X, Wu L, Li J, Wang J, Gao Y, Shang H, Xing Y. Effects of exercise-based cardiac rehabilitation in patients after percutaneous coronary intervention: A meta-analysis of randomized controlled trials. Scientific Reports.2017;7:44789
28. Perry CGR, Hawley JA. Molecular Basis of Exercise-Induced Skeletal Muscle Mitochondrial Biogenesis: Historical Advances, Current Knowledge, and Future Challenges. Cold Spring Harbor Perspectives in Medicine.2018;8:a029686
29. Matos Casano HA, Ahmed I, Anjum F. Six-Minute Walk Test. In: StatPearls. StatPearls Publishing, Treasure Island (FL). 2025
30. Wicks JR, Turner GT, Leslie SL, Jayasinghe R. Changes Observed in the 6-minute Walk Test in Response to Exercise-based Cardiac Rehabilitation. Exercise Medicine.2022;6:2
31. 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. Journal of Cardiopulmonary Rehabilitation and Prevention.2019;39:E19-E25
32. Chae G, Ko EJ, Lee SW, Kim HJ, Kwak SG, Park D, Ra SW. Stronger correlation of peak oxygen uptake with distance of incremental shuttle walk test than 6-min walk test in patients with COPD: a systematic review and meta-analysis. BMC pulmonary medicine.2022;22:102
33. Jalili M, Nazem F, Sazvar A, Ranjbar K. Prediction of Maximal Oxygen Uptake by Six-Minute Walk Test and Body Mass Index in Healthy Boys. The Journal of Pediatrics.2018;200:155-9
34. Cavero-Redondo I, Saz-Lara A, Bizzozero-Peroni B, Núñez-Martínez L, Díaz-Goñi V, Calero-Paniagua I, Matínez-García I, Pascual-Morena C. Accuracy of the 6-Minute Walk Test for Assessing Functional Capacity in Patients With Heart Failure With Preserved Ejection Fraction and Other Chronic Cardiac Pathologies: Results of the ExIC-FEp Trial and a Meta-Analysis. Sports Medicine - Open.2024;10:74