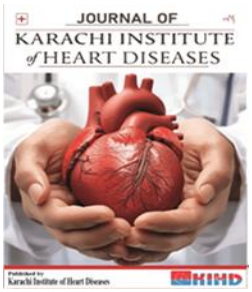

CORRELATION BETWEEN THE 6-MINUTES WALK TEST AND EXERCISE TOLERANCE TEST AFTER ANGIOPLASTY: A CROSS SECTIONAL STUDY

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ABSTRACT:

Background: Post percutaneous coronary intervention (PCI) measurement of functional capacity is vital to guide rehabilitation and recovery evaluation. Although the most commonly method used for this purpose is the exercise tolerance test (ETT) but may not be practical in all clinical settings. The six-minute walk test (6MWT)is a simple, low-cost substitute; as compare to ETT performance however, its relationship with ETT parameters among PCI patients has not been well recognized in our population..

Objectives: To evaluate the correlation between 6MWT and ETT parameters in post PCI patients.

Methods: Current cross-sectional study involved those PCI patients who were clinically stable at least four weeks after successful PCI. 6MWT technique was used to evaluate functional capacity along with a symptom-limited treadmill ETT performance. Different parameters of the 6MWT and ETT, including peak metabolic equivalents (METs), exercise duration, and hemodynamic responses, were recorded throughout. To evaluated the relationship between 6MW distance (6MWD) and ETT parameters Pearson's correlation co efficient analysis was used

Results: A significant positive correlation was observed between 6MWD and peak METs achieved on the ETT. The 6MWD demonstrated moderate correlations with exercise duration and maximum heart rate. These findings suggested that higher walking distance during the 6MWT performance reflects higher exercise capacity as measured by formal treadmill test.

Conclusions: A 6MWT showed a significant association with the outcomes of ETT test among post PCI patients. 6MWT may serve as a practical tool for assessing functional capacity and monitoring recovery in post-PCI patients due to its simplicity and feasibility, particularly in those setting where resources are limited.

Keywords: Six-minute walk test; Exercise tolerance test; Angioplasty; Functional capacity; Coronary artery disease

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INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death globally, approximately 18 million deaths yearly, major percentage of these deaths accounts for ischemic heart disease. [1]In last few years rapid rise occurred in coronary artery disease (CAD) due to increased incidence of hypertension (HTN), diabetes mellitus (DM), obesity, and sedentary lifestyles specially in Lower- and middle-income countries, including Pakistan.[2, 3] A key component of the treatment of coronary artery disease (CAD) is percutaneous coronary intervention (PCI), also referred to as angioplasty. PCI not only reduces ischaemic symptoms but also enhances patient quality of life. [4, 5] PCI patients may experience different improvements in their functional capacity even after successful revascularization. It is a strong predictor to assess prognosis of CAD patients which influence both short- and long-term outcomes, including recurrent ischemia, development of heart failure, and ultimately mortality. [6, 7] ETT performance based on Bruce or modified Bruce protocol is the standard for examine exercise capacity in post PCI patients. ETT provides an objective measures which involve peak metabolic equivalents (METs), exercise duration, maximum heart rate, and systolic and diastolic blood pressure response.[8] Nevertheless, its clinical efficacy is occasionally limited because specialized equipment requirement for e.g. trained staff, and patient cooperation, predominantly where healthcare setting have limited resource.[9]

In comparison to other methods of measuring physical activity, the 6 Min Walk Test (6MWT) is a cost-effective, easy-to-use tool that measures how far (in meters) a person can walk at their normal speed over 6 minutes. Although initially created for people with chronic lung conditions, the 6MWT has been validated as a valid predictor of submaximal functional ability for individuals with heart disease (such as after heart attack or heart surgery).[10,11] Unlike ETT the 6MWT is safe, can easily be perform in outpatient clinics, and reflective of regular physical activity.[12] Global studies have demonstrated moderate to strong correlations between 6MWT distance (6MWD) and peak exercise capacity, including peak METs and VO_2 max, represent its potential as a substitute for treadmill testing.[13-15] Despite its clinical significance, data to examine the relationship between 6MWT performance and ETT parameters specially post PCI is scarce, and even few studies have examined this correlation in South Asian populations.[16] In Pakistani population, standard reference values for the 6MWT is vary from those reported in Western cohorts because of various differences including body composition, lifestyle, and socioeconomic factors.[17] which emphasize the need of population-specific assessment tools for functional capacity.[18] Moreover, access through cardiac rehabilitation programs and treadmill-based testing remains limited in many tertiary and secondary healthcare settings.[19]

Understanding the association between 6MWT and ETT in the post-PCI population is critical due to several reasons. First, it can provide an accessible, low-cost tool for assessing functional recovery, identified those patients who may benefit from targeted rehabilitation or additional interventions. Second, it can help stratified risk, as reduced functional capacity is independently related with adverse cardiovascular outcomes. Third, population-specific data can be used in developing guidelines, will also support not only clinicians to establish 6MWT standard values but also aid in the implementation of home-based or community-centered rehabilitation plans, which are particularly valuable in those regions where resources or infrastructure are limited for cardiac rehabilitation.[20-22] Previous studies done on cardiac rehabilitation have stated significant associations between 6MWT distance and treadmill exercise capacity in post-coronary artery bypass grafting (CABG) and heart failure populations. [12, 23] However, these studies were accompanied in Western populations, and due to our demographic and cultural differences which affect functional and activity patterns these findings may not be generalize to our patients. Moreover, there is no study has done which can specifically evaluate the efficacy of 6MWT as a substitute of ETT post PCI among young and middle-aged adults. Present study aimed to assess the association between 6MWTand ETT parameters in post PCI patients. By examining this relationship, present study seeks to determine whether the 6MWT can serve as a practical and reliable tool for functional capacity assessment, clinical decision-making, rehab planning, and the prediction of long-term outcome in a context of limited resource.

METHODS

Study Design and Setting

In current cross-sectional study we enrolled adult patients who underwent PCI at tertiary cardiac hospital from January 2025 to September 2025. Patients were recruited consecutively who were eligible and fulfilled the inclusion criteria during routine outpatient follow-up visits: for instance Age between 30 to 75 years, clinically stable status, minimum four weeks post-successful PCI, ambulate independently without assistive devices on the other hand patients who visit due to unstable angina, decompensated heart failure, or acute myocardial infarction in previous four weeks, significant musculoskeletal or neurological conditions, limited walking ability, valvular heart disease or uncontrolled arrhythmias, cognitive impairment or unable to follow test instructions were excluded from the study.

Data Collection Procedures

Demographic data include age, gender, marital status educational level, medical history involved body mass index (BMI), hypertension(HTN), diabetes mellitus(DM), dyslipidemia, smoking status, medications, and procedure details like number of stents and target vessels. Anthropometric measurements height and weight obtained through standard protocols, and BMI was calculated as weight in kilograms divided by height in meters square. Baseline resting heart rate, blood pressure, and oxygen saturation were also measured prior to exercise test. The 6MWT performed according to the American Thoracic Society (ATS)guidelines (1). Participants were instructed to walk straight 30-meter or cover as much distance as possible in six minutes. Participants were allowed to slow down or may take rest where they feel necessary, and total distance during 6MWT was recorded in meters. While heart rate, oxygen saturation, and perceived exertion were measured pre- and post-test using the Borg scale. The test was performed twice on the same day with a 30-minute rest and the highest value of the two distances was used for analysis to reduce variability. A symptom-limited treadmill ETT was done within 48 hours of the 6MWT. A modified Bruce protocol used which is appropriate for post-PCI patients, started at a low speed and gradually increasing intensity after every three minutes. Electrocardiographic monitoring was continuously performed throughout the test, and blood pressure was assessed at each stage. Peak exercise capacity was concluded as METs accomplished at the end of test. Maximum heart rate (HRmax), systolic and diastolic blood pressure at the peak level of exercise, and total exercise duration was also recorded. The test terminated as per standardized criteria, which involved angina, significant ECG changes, hypotension, or on patient request. All exercise tests were supervised by a cardiologist and trained cardiac technologist. Emergency equipment were also available on site during test including defibrillators and resuscitation medications. Adverse events during or immediate after test were also monitored. No serious adverse event occurred during the whole study. Ethical approval was obtained from the institutional review boards hospitals and prior to enrollment written informed consent was obtained from all participants.

Statistical Analysis

The sample size was calculated to detect a moderate correlation (r = 0.5) between 6MWT distance and peak METs with 80% power at a significance level of 0.05, result in a minimum of 85 participants. To increase study reliability 120 patients were initially approached, but 100 participants were willing to participate in the study and completed all assessments. Shapiro-Wilk test for normality used for continuous variables. Normally distributed continuous variables were presented as mean ± standard deviation (SD), while skewed variables were reported as median and interquartile range (IQR). Frequencies and percentages were used for categorical variables. Pearson's correlation coefficient used to analyze the strength and direction of linear relationships between continuous variables for instance 6MWD, peak METs, HR-max, exercise duration, and blood pressure. To evaluate whether 6MWD predicted ETT parameterssimple linear regression was applied. Subgroup analyses based on sex, age categories (<50 years vs ≥50 years), and BMI categories (normal, overweight, obese) were conducted to examine effect modification. A two-sided p-value <0.05 was considered statistically significant. Data analysis was performed using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY).

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RESULTS

Table 1: Baseline Characteristics of Participants by Gender (n = 100)

Variable	Total (n 100)	Male (n 68)	Female (n 32)
Age (years), mean ± SD	56.2 ± 9.8	55.4 ± 9.5	57.8 ± 10.2
BMI (kg/m²), mean ± SD	25.4 ± 3.9	25.6 ± 4.0	25.1 ± 3.7
BMI categories, n (%)			
Normal weight (<22.9)	30 (30%)	20 (29%)	10 (31%)
Overweight (23–24.9)	45 (45%)	30 (44%)	15 (47%)
Obese (≥25)	25 (25%)	18 (27%)	7 (22%)
Hypertension, n (%)	62 (62%)	42 (62%)	20 (62%)
Diabetes mellitus, n (%)	48 (48%)	32 (47%)	16 (50%)
Dyslipidemia, n (%)	40 (40%)	27 (40%)	13 (41%)
Current smoker, n (%)	22 (22%)	22 (32%)	0 (0%)
Single-vessel PCI, n (%)	58 (58%)	40 (59%)	18 (56%)
Multi-vessel PCI, n (%)	42 (42%)	28 (41%)	14 (44%)

Table I identified that the mean age of study participants was 56.2 ± 9.8 years, with 68% male and 32% female. Baseline cardiovascular risk factors included hypertension (62%), diabetes mellitus (48%), dyslipidemia (40%), and current smoking (22%). Mean BMI was 25.4±3.9 kg/m². All participants were post PCI,58% with single-vessel stenting and 42% multi-vessel stenting.

Table 2. 6MWT and ETT Outcomes

Parameter	Mean ± SD	Range
Six-minute walk distance (m)	456 ± 62	310–590
Exercise duration (min)	7.8 ± 1.5	5.0–12.0
Peak METs	8.2 ± 1.7	5.0–12.0
Maximum HR (bpm)	137 ± 14	110–165
Peak systolic BP (mmHg)	168 ± 22	140–210

Table 2 define the mean 6MWD was 456 ± 62 meters, ranging from 310 to 590 meters and other ETT parameter in a similar way.

Table 3. Six-Minute Walk Test and Exercise Tolerance Test Outcomes by Gender and BMI

Parameter	Male (n 68)	Female (n 32)	BMI <22.9 (n = 30)	BMI 23-24.9 (n = 45)	BMI ≥25 (n = 25)
6MWD (m)	472 ± 58	426 ± 60	472 ± 60	460 ± 58	431 ± 57
Exercise duration (min)	8.1 ± 1.4	7.3 ± 1.5	8.0 ± 1.3	7.8 ± 1.4	7.4 ± 1.6
Peak METs	8.5 ± 1.6	7.6 ± 1.7	8.4 ± 1.5	8.2 ± 1.6	7.7 ± 1.8
Maximum HR (bpm)	139 ± 13	133 ± 15	138 ± 14	136 ± 13	133 ± 15
Peak systolic BP (mmHg)	170 ± 21	164 ± 23	169 ± 21	167 ± 22	165 ± 23

Table 3 concluded that the averaged peak METs, HRmax and peak systolic BP achieved during ETT was higher in males as compared to female. Similarly, higher BMI participants had lower 6MWD peak METs HRmax and systolic BP than normal BMI.

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Table 4. Subgroup Analysis: Correlation Between 6MWT and Peak METs (Asian BMI Criteria)

Subgroup	r	p-value
Gender		
Male	0.73	<0.001
Female	0.68	<0.001
Age group		
<50 years	0.75	<0.001
≥50 years	0.66	<0.001
BMI category (Asian cut-offs)		
Normal weight (<23.0 kg/m²)	0.76	<0.001
Overweight (23.0–24.9 kg/m²)	0.71	<0.001
Obese (≥25 kg/m²)	0.63	<0.001

Table 4 described that although both gender was statistically significant ($p < 0.01$) but correlations between 6MWD and peak METs were slightly stronger in males ($r = 0.73$) as compared to females ($r = 0.68$), Age-stratified analysis revealed that participants <50 years had a higher correlation coefficient ($r = 0.75$) compared to those ≥50 years ($r = 0.66$). Obese participants (BMI ≥25 kg/m²) had a slightly lower correlation between 6MWD and peak METs ($r = 0.62$) than non-obese participants ($r = 0.74$).

Table 5. Relationship between Six-Minute Walk Distance and Exercise Tolerance Test Outcomes

ETT Outcome	Mean ± SD	Pearson r with 6MWD	β (95% CI)	p-value
Peak METs	8.2 ± 1.7	0.71	017 (0.013-0.0	<0.001
Exercise duration (min)	7.8 ± 1.5	0.64	014 (0.010-0.0	<0.001
Maximum HR (bpm)	137 ± 14	0.58	058 (0.035-0.0	<0.001
Peak systolic BP	160 ± 20	0.32		0.02

In Table 5 Pearson correlation analysis revealed a significant positive correlation between 6MWD and peak METs ($r = 0.71$, $p < 0.001$), which indicated that longer distance was associated with higher exercise capacity. Whereas 6MWD showed moderate correlations with exercise duration ($r = 0.64$, $p < 0.001$) and HRmax ($r = 0.58$, $p < 0.001$). Additionally, peak systolic blood pressure during ETT was weakly correlated with 6MWD ($r = 0.32$, $p = 0.02$).The regression coefficient ($\beta = 0.017$) indicates a positive association between the 6MWT and the ETT outcome, with each one-unit increase in the 6MWT associated with an approximately 1.7% increase in METs after adjustment for covariates.

DISCUSSION

Current study demonstrates that functional capacity monitored by 6MWT, strongly reflects workout performance quantified by standard treadmill, which include peak METs, exercise timeline, and response of heart rate. This result finding supports the narrative of previous evidence suggested that the 6MWT can be served as an alternative for formal exercise test, specifically in clinical setups where treadmill assessments are not available usually or are not feasible.[13] Previous evidence from multiple studies have consistently stated that submaximal functional activity assessments effectively related to maximal or symptom-limited exercise test. Initially Bittner et al. highlighted the prognostic and functional capacity based relation with the 6MWT among population with cardiovascular diseases, while subsequent researches confirmed its effectiveness in patients with ischemic heart disease and PCI.[24, 25] Similar finding has been highlighted in Asian cohort study, reflecting the cross population validity of this test.

The mean of 6MWD observed in this study was consistent with preceding studies done on cardiac populations of South Asia, which were slightly lower than the reference values of the West, emphasized the population based differences present in functional capacity (1, 2). Men, young subjects and those with the BMI towards lower indices evidently performed. [3, 4]

Age is an evident marker of functional capability because of physiological differences such as decrease cardiac output, reduce muscles and higher comorbidity burden. Even after age induced differences, previous evidences demonstrated that relationship between 6MWT and standard treadmill exercise capacity remains similar across different age groups.[26] The finding of this study remain align with the literature suggested that the 6MWT has clinical relevance across a wide range of age spectrum in PCI patients. Global researches done on post cardiac surgery as well as on rehabilitation patients have highlighted correlation coefficients between 6MWD and peak METs.[27] Similarly, this study finding confirm the external validity of 6MWT in assessing functional capacity. While previous studies were mainly focused on western population, this research provides evidence in the context of local population, where ethical, cultural and lifestyle factors may effect functional capacity outcomes**.**

The correlation between 6MWT and peak systolic blood pressure in ETT was found to be weak, directing that 6MWT mainly reflects aerobic capacity rather than hemodynamic response due maximal stress. This outcome is aligned with previous studies directing that submaximal tests may not exclusively capture peak cardiovascular stress but is remain essential for assessing clinical functionality.[7] Gender based differences in physical performance levels have reported widely that females usually display lower functional performance than men. These disparities have been related to differences in body composition, hemoglobin concentration, hormonal influences and usual physical activity.[28] Moreover, prior studies directed that despite difference in physical performance, the correlation between functional walking capacity and treadmill exercise indicator remains similar in both genders.[21] The present finding consistent with this concept, through applicability of the 6MWT in both male and female patients.

Multiple studies proposed that the association between 6MWD and ETT remains preserved among BMI all categories.[29] The current study supports this evidence, reflecting the reliability of 6MWT across Asian-specific BMI classifications.

BMI plays an important role in determining physical performance endurance, specifically among Asian populations whom cardiovascular risk occurs at lower thresholds of BMI. Researches from South Asia and East Asia have displayed that elevated adiposity adversely affects exercise performance because it deregulates cardio-respiratory performance and augment metabolic needs.[30] Even though functional performance is low within population who is overweight or obese, multiple studies reflects that the relation between 6MWD and ETT remains still among all BMI ranges.[31]The current study consistent

with this evidence, reflecting the reliability of 6MWT within Asian BMI classifications.

The relationship between 6MWT and ETT through age, gender, and BMI categories emphasized the clinical efficacy of the 6MWT. The 6MWT offers a cost-effective and practical substitute for functional capacity measurement and recovery from post PCI specially in lower- and middle-income countries such as Pakistan, where is limited access to advanced exercise test and structured cardiac rehabilitation programs. [8, 21] 6MWT can be utilized in outpatient clinics, community health centers, and home-based rehabilitation programs to monitor recovery from post-PCI. Furthermore, population-specific 6MWT reference values can be set which will allow clinicians to stratify patients by functional capacity, identify those at risk for poor outcomes, and can be prescribe customized exercise regimens.

In South Asia cardiovascular disease is characterized by early onset of disease, higher burden of metabolic risk factors, and dissimilar anthropometric profiles. Studies conducted in Pakistani and regional populations have emphasized that there is the need for population-specific assessment tools that are meaningful from both practical and prognostic aspect.[2] Present study enhances the applicability of its findings to local clinical practice by incorporating Asian BMI criteria.

STRENGTH OF THE STUDIES

Multiple strengths include in this study mainly it focused on Pakistani population, provide relevant local data; rigorous adherence to standardized 6MWT and ETT protocols; and inclusion of a wide age range and Asian BMI ranges, augment generalizability. Additionally, all tests were done under supervision of cardiologists and cardiac technologist, which ensure patients safety and validity.

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LIMITATIONS

The study is limited by its cross-sectional design and longitudinal assessment of functional capacity changes cannot be assessed at baseline or followed over time. The gold standard for assessing VO_2 max is cardiopulmonary exercise testing (CPET), was not employed in our study, which may provide more precise measurement of maximum aerobic capacity. Another limitation include the sample was drawn from single tertiary cardiac care institute, potentially limiting generalizability. Finally, many other factors which may influence 6MWT performance like psychosocial factors and physical activity outside the clinic, were not formally assessed.

Future studies should explore the longitudinal prognostic value of 6MWT in predicting adverse cardiovascular outcomes in post PCI patients. Additionally, incorporating functional capacity assessment with patient-reported outcomes and cardiac rehabilitation response may further improve individualized risk stratification strategies in our populations.

CONCLUSION

In conclusion, the 6MWT demonstrates a strong and clinically meaningful correlation with treadmill ETT parameters in post-PCI patients. It is practically, safe, and cost-effective tool for assessing functional capacity, guiding rehabilitation, and monitoring recovery, especially where limited access to formal exercise test. Incorporating 6MWT into routine post-PCI care may improve patient outcomes and facilitate population-specific cardiovascular management strategies.

Conflict of interest

Authors declare no conflict of interest.

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