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CORRELATION OF CORONARY ARTERY DISEASE ON CORONARY ANGIOGRAPHY WITH DUKES TREADMILL SCORE IN PATIENTS UNDERGOING EXERCISE TOLERANCE TEST

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ABSTRACT:

BACKGROUND: *The exercise tolerance test (ETT) is a widely used, non-invasive diagnostic tool for evaluating coronary artery disease (CAD). Exercise testing, commonly referred to as an exercise tolerance test (ETT), is a widely utilized, non-invasive diagnostic modality for patients presenting with cardiac symptoms. Its utility extends across multiple dimensions of cardiovascular evaluation. The Duke Treadmill Score (DTS), one of the most extensively validated indices in exercise testing, was initially developed as a prognostic tool. Its original purpose was to predict long-term outcomes in patients with suspected coronary artery disease (CAD).*

AIMS & OBJECTIVE: *To determine the correlation between Duke's treadmill score & coronary angiography to detect CAD in patients presented with chest pain.*

MATERIAL & METHODS: *This study was designed as a cross-sectional analysis; conducted at Faisalabad Institute of Cardiology, Faisalabad for 6 months. Sample size of 96 patients was included through simple random sampling. Patients subjected to treadmill exercise and Duke's treadmill score was calculated. The DTS typically sorts from -25 to +15. Then coronary angiography was performed in these patients. Each coronary lesion resulting in a ≥50% diameter stenosis in vessels with a diameter of ≥1.5 mm was assessed individually to propose the overall SyntaxScore. Predesigned questionnaire was filled.Data was entered and analyzed through SPSS v. 21. In this study, Pearson's correlation coefficient (r) was employed to evaluate the strength and direction of linear relationships between continuous variables. P-value≤0.05 wasconsidered as significant.*

RESULTS: *The study included 96 patients. Of them, 10 (10.4%) patients were female and 86(89.6%) were males. Groups comprised as low-risk group, 48 patients (50%); intermediate-risk group, 20 patients (21%); and high-risk group, 28 patients (29%).*

CONCLUSION: *Our verdict proposes that surrogate markers derived from exercise treadmill testing (ETT) such as Duke Treadmill Score (DTS), ST deviation at peak and at recovery demonstrate strong correlations with the extent of CAD and development of MACE during follow-up. These markers highlight their potential utility as non-invasive indicators for risk stratification, and predicting adverse cardiovascular outcomes.*

KEY WORDS: *DTS (Dukes treadmill score), CAD (Coronary artery disease), ETT(exercise tolerance test), LMCA (Left mainstem coronary artery), RPP (rate pressure product), IHD (ischemic heart disease), BMI (Body mass index)*

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INTRODUCTION:

Coronary artery disease (CAD), particularly when manifesting as acute coronary syndrome (ACS), remains the leading cause of mortality worldwide. Its significant burden underscores the urgent need for improved diagnostic, preventive, and therapeutic strategies.[1] CAD is a leading cause of death globally, accounting for approximately 16.7 million deaths annually. Its significant impact on public health is projected to intensify, with estimates from the World Health Organization (WHO) predicting that: by 2020, annual deaths attributable to CAD would escalate to 25 million[2].

Ischemic heart disease (IHD), also known as coronary heart disease (CHD) or CAD, refers to heart conditions caused by the narrowing of coronary arteries, which impairs blood flow to the heart muscle. IHD is caused by the buildup of plaque (atherosclerosis) in the coronary arteries. Plaque consists of lipids, cholesterol, calcium, and cellular debris, leading to the progressive narrowing of the arterial lumen. Other causes of narrowing are thrombosis (blood clot), vasospasm (constriction of the coronary artery, though less common, can reduce blood flow significantly) and progression to Myocardial Infarction (MI) when the blood supply to the heart muscle is completely blocked, myocardial ischemia progresses to MI, where heart muscle cells undergo irreversible damage and death.In the early stages of CHD, where narrowing of the coronary arteries is less than 50%, most individuals remain asymptomatic, and blood flow is typically sufficient to meet the heart's oxygen demands under normal conditions [3, 4].

Exercise tolerance test (ETT) is a non-invasive test can be performed either by using physiologic stress as in treadmill exercise also called Bruce protocol or by pharmacological stress by the use of dobutamin stress or the use dipyridamole[5]. ETT is a widely utilized non-invasive diagnostic and prognostic tool for evaluating patients with suspected or known IHD. It provides valuable insights into myocardial ischemia, functional capacity, and cardiovascular risk.During physical exertion, the metabolic demands of the myocardium increase significantly as the heart works harder to supply oxygen and nutrients to maintain systemic blood flow. To accommodate this, coronary blood flow must proportionally increase. However, in cases of coronary artery disease (CAD) or significant atherosclerosis, this ability to increase blood flow can be compromised[6, 7].

A 12-lead electrocardiography (ECG) is done at the same time while the patient performs treadmill exercise. This test predicts the CAD conversely its specificity and sensitivity is 71% and 67% respectively asassociated to imaging techniques[8].The workload achieved by a patient during the test is commonly expressed in units of Metabolic Equivalents of Task (METs). This standardized measure provides a way to quantify exercise intensity and assess a patient's functional capacity[9]. The Bruce protocol is one of the most widely used exercise testing protocols in Exercise Treadmill Testing (ETT). It provides a structured way to assess a patient's functional capacity and cardiovascular response to incremental exercise[10].Various scoring system have been introduced to increase its sensitivity and specificity. Duke's treadmill score (DTS) is the most validated score which was initially had prognostic value but became a tool for the diagnosis of CAD. It proved to be the best predictor of CAD with ST-segment depression[11].

Coronary angiography is reflected to be the gold standard in the diagnosis of CAD by American Heart Association as well as European Society of Cardiology. Syntax score which determines the severity of CAD is also incorporated to find out the extent of coronary disease in patients with dukes treadmill score.[12] Rationale of this research was to determine the correlation between Duke's treadmill score and coronary angiography to identifyCAD in patients presented with chest pain. Exercise tolerance test is a non-invasive test in the diagnosis of CAD. The DTS, most validated index, was originally developed as a prognostic index to estimate the risk of cardiovascular events. However, its role has since expanded to function as a diagnostic tool in the assessment of CAD.But controversial data has been extracted from literature regarding relationship between DTS and angiography score. So we need to conduct this study to find the validation in local population. The topic of the present study is unique and it has not been study in Pakistan. The aim of this research was to examine thecorrelation between Duke's treadmill score and coronary angiography to detect CAD in patients presented with unstable angina.

MATERIAL AND METHODS:

This cross-sectional study was conducted in Faisalabad Institute of Cardiology, Pakistan for duration of 06 months.Random sampling technique was used for patients sampling. The sample size was evaluated with 5% & 10% type I & II error respectively and taking probable value to correlation i.e. r= -0.173 between DTS and coronary angiography by using following formula:

$$N = \left(\frac{z_\alpha + z_\beta}{C(r)}\right)^2 + 3$$

Where; Zα = 1.96 (at 5% type I error), Zβ = 1.282 (at 10% type II error) and r = -0.173.

The DTS is calculated using the following formula:

DTS = Exercise time − (5 × ST deviation) − (4 × exercise angina)

Where:

- Exercise time is the total duration (in minutes) of the treadmill test.
- ST deviation refers to the amount of ST-segment deviation (in millimeters) from baseline during the test, which indicates myocardial ischemia.
- Exercise angina is scored as:

0 = No angina

1 = Non-limiting angina (i.e., mild chest pain that does not prevent continued exercise)

2 = Exercise-limiting angina (i.e., moderate or severe chest pain that limits or halts exercise)

INCLUSION/EXCLUSION CRITERIA:

Patients aged between 30 to 70 years of both genders presenting with history of chest pain planned to undergo coronary angiography were included. While the patients showed ECG suggesting left ventricular (LV) hypertrophy or left bundle-branch block (LBBB), previous coronary artery bypass grafting (CABG) or angioplasty (on medical record), previous MI (on medical record) and inability to perform exercise due to any orthopedic cause were excluded.

DATA COLLECTION PROCEDURE:

The approval from the ethics committee of the hospital was taken. After approval, the patients fulfilled selection criteria were enrolled in the study.The patients were informed about the procedure and its possible significance in terms of advantages and disadvantages. Demographic profile was obtained including name, age, sex, BMI, diabetes, IHD, smoking, family history

and duration of angina. Then patients Duke's treadmill score was calculated. All patients underwent symptom-limited exercise testing following the standard Bruce protocol, which is a widely used, incremental exercise test designed to assess cardiovascular response during physical activity. Before initiating exercise, BP and heart rate were recorded in both the supine and standing positions & 12-Lead ECG. Continuous monitoring allows the detection of changes in cardiovascular status, ischemic patterns, or abnormal responses during exercise. The exercise test was discontinued if any of the following were observed: exertional hypotension (a significant drop in blood pressure during exercise), malignant ventricular arrhythmias (arrhythmias that could compromise hemodynamics), marked ST depression (≥3 mm) and limiting chest pain (symptoms suggestive of ischemia). These abnormalities are indicative of myocardial ischemia or other underlying cardiac dysfunctions. Exercise-induced ST-segment deviation was measured to the nearest 0.25 mm for horizontal and down-sloping ST depression and ST-segment elevation. This precision in measurement allows for accurate quantification and comparison across patients. The Duke Treadmill Score uses the following formula: DTS= duration of exercise (in minutes) - (5 x ST segment deviation) - (4 x exercise angina) Where:
> Exercise Time = Duration (in minutes) a patient was able to exercise during the test.
> ST Deviation = ST-segment change (in mm) observed during exercise.
> Exercise Angina shown by numbers 0 if no angina, 1 for non-limiting angina, 2 for exercise-limiting angina. DTS was categorised as low risk(DTS +5), Intermediate risk(DTS -10 to +4) and high risk (DTS -11). In this study, coronary lesions with a 50% or greater diameter stenosis in vessels ≥1.5 mm were scored individually and summed to determine the overall Syntax Score. The Syntax Score is a standardized scoring system used to evaluate the complexity and severity of coronary artery disease (CAD). It provides insight into the anatomical burden of CAD and can guide interventional strategies and risk stratification.The Syntax Score was calculated prospectively using the Syntax Score algorithm, a validated tool for objectively assessing lesion severity. Predesigned questionnaireswere filled.

DATA ANALYSIS:

All the information was documented in a proforma devised by the principal investigator. Data was entered and evaluated through SPSS version 21.Quantitative variables comparable age, weight, height, BMI, duration of angina, Duke's score and syntax score were calculated as mean ± SD. Qualitative variables like gender, h/o diabetes, IHD, smoking, family history, dyslipidemia, obesity wereobtainable as % and frequency. Pearson's correlation coefficients werecalculated. P-value ≤0.05 was considered as significant. Data was stratified for age, gender, BMI, h/o diabetes, IHD, smoking, family history, dyslipidemia, obesity. Post-stratification, Pearson's correlation coefficient was calculated for each stratum.

RESULTS:

The study included 96 patients who satisfied the inclusion criteria. Of them, 10 (10.4%) patients were female. The number of patients in each group was as follows: low-risk group, 48 patients (50%); intermediate-risk group, 20 patients (21%); and high-risk group, 28 patients (29%). The average age of the study people was 42±8 years.

Demographic and laboratory findings of the groups classified as per SYNTAX score. The echocardiographic examination results of the groups were similar in respect to LVEF was recorded before proceeding to ETT. Although ETT duration, ETT workload, BP at rest, and angina development during ETT were similar overall groups; percentage of maximum heart rate achieved, RPP at peak, maximum ST deviation, and DTS differed significantly between the groups (Table 1).

SYNTAX score was calculated as per given criteria by ACCA. The high-risk group received significantly more surgical revascularization associated with the additional groups (p<0.001). The low-risk group received more percutaneous coronary intervention than the other groups (p<0.001). Although the number of MACE

Table.1: The findings of echocardiographic examination and ETT among the group.

	Low risk (n=48)	Intermediate risk (n=20)	High risk (n=28)	p value
LVEF	60±3	59±3	56±3	0.361
Exercise duration (min)	10±3	8±3	5±3	0.098
Exercise workload (METs)	9.2±2.1	8±2.3	7±1.1	0.189
Percentage of HR achieved	87±3	90±8	74±2	0.032
Resting BP	120/80±10/10	130/90±10/10	110/70±10/10	0.229
Peak exercise BP	150/100	150/90	102/70	0.001
Angina (%) during ETT	10 (20.8)	13 (65)	20 (71.4)	0.891
Maximum ST deviation during ETT	1.2±1.1	2.2± 1.2	3.7±1.3	0.011
Duke score	-3.7	-7.8	-13.7	0.000

Table. 2: The coronary angiographic findings of the groups were expressed

	Low risk n=48	Intermediate risk n=20	High risk n=28	p value
CAG result (%)				
Normal	6 (12.5)	0 (0)	0 (0)	0.000
Non obstructive CAD	4 (8.3)	0 (0)	0 (0)	0.000
SVD	18 (37.5)	4 (20)	0 (0)	0.000
2VCAD	14 (29.2)	8 (40)	0 (0)	0.000
3VCAD	6 (12.5)	4 (20)	8 (28.6)	0.000
LMS Disease	0 (0)	0 (0)	4(14.3)	0.000
LMS with SVD	0 (0)	0 (0)	0 (0)	0.000
LMS with DVD	0 (0)	0 (0)	4 (14.3)	0.000
LMS with TVD	0 (0)	0 (0)	12 (42.9)	0.000
SYNTAX Score	8.2±6.1	20.0±2.3	29.8±5.9	0.000
MACE at follow-up (%)	1 (4.2)	1 (10.1)	4 (28.5)	0.100
Follow-up Duration (months)	6	4	2	

events was higher in the high-risk group, the difference was not statistically significant (p=0.100). Follow-up durations were 6,4 and 2 months for low, intermediate and high risk groups respectively. Coronary angiographic findings, follow-up durations, and treatment modalities of the patients were expressed as appropriate in each group. The high risk group achieved maximum heart rate (74±2%) was significantly lower when compared with low-risk group (87±3%) (p=0.032) and the intermediate-risk group (90±8%) (p=0.034).

Although high risk group developed higher ST deviation associated with the intermediate group, no strong evidence to confirm a definitive relationship between the variables analyzed (p=0.011). However, a higher maximum ST deviation was observed in the high-risk group compared with the low-risk group (p<0.001). DTS was significantly lower in the high-risk group than in the intermediate-risk group (p=0.047) and low-risk group (p<0.001). (Table-2)

DISCUSSION:

This study highlights critical exercise treadmill test (ETT) parameters and their association with severe CAD and MACE. Here's an expanded summary of the findings: Patients with higher SYNTAX scores, reflecting more complex and severe CAD, demonstrated significant differences in ETT outcomes[13]. Duke Treadmill Score (DKS) this risk stratification tool correlated strongly with the extent of CAD, underscoring its value in predicting outcomes. Shorter ETT duration was observed in patients with severe CAD, potentially reflecting diminished exercise tolerance due to ischemia. Rate pressure product (RPP) at peak exercise, represent demand of myocardial oxygen, was significantly different in patients with left main coronary artery (LMCA) disease or higher SYNTAX scores. The ability to link non-invasive ETT parameters with angiographic measures like the SYNTAX score and high-risk anatomical findings such as LMCA disease supports the utility of ETT as a preliminary diagnostic tool[14]. These parameters could guide clinicians in prioritizing patients for further invasive diagnostics and interventions. Longitudinal analysis linking these parameters to the incidence of MACE at follow-up emphasizes the prognostic value of ETT beyond initial diagnosis[15,16].

ETT is validated as a widely used, non-invasive, and cost-effective diagnostic tool for evaluating cardiac complaints, particularly in intermediate-risk patients. Its application in this study aligns with guidelines recommending ETT in similar clinical scenarios. Sensitivity and Specificity was based on the performance of ETT varies with population characteristics (e.g., pretest probability of CAD)[17]. The study's reliance on ETT for ruling out obstructive CAD demonstrates its practical role but underscores the importance of tailoring its use to population-specific factors. Middle-aged adults were the focus of the study, reflecting the common demographic for CAD evaluation. The male predominance in the cohort is attributed to the immigrant-based, male-dominant sociodemographic structure of the region. This contextual factor may influence the external validity of the findings. The underrepresentation of female patients is a notable limitation. Despite including all eligible patients, the study's applicability to women may be restricted due to potential sex-specific differences in CAD presentation, diagnostic accuracy of ETT, and outcomes. The study design aims to reflect real-world practice at the tertiary center, which enhances its relevance for similar healthcare settings but may limit generalizability to diverse populations. While the study provides valuable insights, future research could aim for a more balanced gender distribution or stratify results by sex to explore differential outcomes. Acknowledging these limitations is essential when extrapolating findings, particularly in populations with different sociodemographic or clinical characteristics[18].

By excluding patients with previous cardiac history or structural heart disease, the study focused on a relatively homogenous group, eliminating confounding factors like prior myocardial damage or valvular disease. This strengthens the reliability of comparisons across SYNTAX score groups[19]. The similarity in echocardiographic findings across groups ensures that differences in ETT parameters are less likely influenced by pre-existing structural abnormalities, isolating the impact of CAD severity. The absence of significant differences in ETT duration and workload among groups classified by SYNTAX score may reflect the population's baseline characteristics or subtle disease presentations. These parameters are widely recognized as prognostic indicators of better outcomes in CAD patients. Their similarity across groups might suggest that SYNTAX score, as an anatomical measure, does not always correspond directly with functional capacity limitations measured by ETT [20]. Other ETT parameters that significantly differ in the high-risk group (e.g., lower DKS or abnormal RPP) could be more reliable predictors of severe CAD, particularly in the absence of ETT duration and workload differences. These parameters may reflect nuanced physiological changes associated with higher SYNTAX scores or LMCA disease. Thus, other ETT parameters that differ significantly in the high-risk group can be assumed to be high-risk indicators. The DTS is indeed a broadly recognized and valuable tool for risk assessment and triage in patients undergoing exercise treadmill testing (ETT)[21].

The correlation between the Duke Treadmill Score (DTS) and the SYNTAXscore in our study is a significant finding, underlining the complementary roles of functional and anatomical assessments in CAD management.The ability of DTS to categorize patients into high-, intermediate, and low-risk groups aids in optimizing care pathways, including; same-day admission for those at high risk of adverse cardiac events, early outpatient appointments for intermediate-risk cases needing close monitoring or additional testing and elective follow-up for low-risk patients to avoid unnecessary escalation[22].

This approach streamlines resource allocation, enhances patient outcomes, and reduces strain on healthcare systems. The SYNTAX score quantifies the complexity and severity of CAD based on angiographic findings, particularly in patients with multi-vessel disease or LMCA involvement. In this study, the significant correlation between DTS and SYNTAX score suggests. High-risk groups (e.g., those with severe CAD) exhibit lower DTS values, reflecting impaired exercise capacity and greater ischemic burden. This alignment between functional impairment DTS and anatomical severity (SYNTAX) reinforces the prognostic value of ETT. Combining DKS and SYNTAX score can provide a holistic view of patient risk, integrating physiological and anatomical perspectives. For example, a patient with a low DKS and high SYNTAX score might benefit from immediate intervention, while a patient with a high DKS and low SYNTAX score could be managed conservatively. This correlation cares the usage of DKS as a non-invasive precursor to more definitive imaging or invasive diagnostics, particularly for intermediate-risk patients[23].

This analysis provides valuable insights into the significance of ST-segment deviations during the ETT and introduces a potentially novel marker for CAD severity. The amplitude of maximum ST-segment deviation directly contributes to the Duke Treadmill Score (DTS), serving as a surrogate for ischemic burden. In this study despite similar frequencies of angina and ETT durations across groups, greater ST deviation was seen in the high-risk group. This aligns with the understanding that ST-segment changes are indicative of myocardial ischemia, which correlates with CAD severity. More severe CAD was seen in patients who showed ST segment deviation in more leads (e.g., higher SYNTAX scores or LMCA disease). This parameter likely reflects more extensive myocardial ischemia, a hallmark of advanced obstructive CAD. Incorporating the number of leads with ST deviation into existing frameworks like the DKS could enhance the predictive accuracy for CAD severity. This parameter might serve as an additional metric for identifying high-risk patients needing urgent evaluation[24].

Whitman and Jenkins[25] demonstrated a correlation between peak RPP and cardiovascular measuresin a long-term follow-up (5.3±2.6 years). However: Their findings were not validated against the actual CAD status of the study population. They included patients with and without a history of CAD, which could confound the results. Patients who developed MACE during the follow-up period (45 months) had significantly lower peak RPP, supporting its role as a prognostic marker. While our study population and follow-up duration did not yield enough MACE cases for multivariate analysis, the correlation between peak RPP and SYNTAX score strengthens its association with CAD severity. RPP at the 3rd Minute of Recovery was significantly higher in high-risk patients (e.g., those with higher SYNTAX scores). This parameter demonstrated a strong correlation with CAD severity, introducing a new dynamic marker for ischemic burden. Prolonged or elevated RPP during the recovery phase may indicate impaired autonomic regulation or residual ischemia, both markers of advanced CAD. Adding recovery-phase RPP to traditional parameters like peak RPP and DKS could enhance early identification of high-risk individuals. Future studies with larger populations and extended follow-ups could validate the prognostic role of recovery-phase RPP[16].

The detection of LMCA lesions during ETT is indeed critical for expediting treatment and improving outcomes in patients with cardiac indications[26]. In the literature, previous studies have mostly focused on electrocardiographic changes, especially lead aVR[27]. In our study, we excluded lead aVR from the analysis to assess the significance of ST deviations in other leads independently. To further investigate this, patients were re-grouped into two categories: obstructive CAD without LMCA and obstructive CAD with LMCA disease. The exclusion of lead aVR and the emphasis on other multi-lead ST deviations, combined with functional markers such as DKS, peak and recovery RPP, and ETT duration, provides a promising pathway for identifying LMCA-related ischemia and global ischemic burden. This novel approach broadens the scope of ETT interpretation and warrants further investigation to establish diagnostic thresholds and predictive algorithms.

CONCLUSION

Our findings suggest that surrogate markers derived from exercise treadmill testing (ETT) such as Duke Treadmill Score (DTS), ST deviation at peak and at recovery demonstrate strong correlations with the extent of CAD, LMCA lesions, and the development of major adverse cardiovascular events (MACE) during follow-up. These markers highlight their potential utility as non-invasive indicators for risk stratification, and predicting adverse cardiovascular outcomes. This conclusion emphasizes both the diagnostic promise of these ETT parameters and the need for further validation through well-designed, large-scale prospective research.

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