ORIGINAL ARTICLE

THE TIMELESS UTILITY OF DUKE TREADMILL SCORE: A PROGNOSTIC TOOL FOR CORONARY ARTERY DISEASE SEVERITY ASSESSMENT

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Background: This cross-sectional study aimed to evaluate the correlation between Duke Treadmill Score (DTS) and SYNTAX score and assess the role of DTS in predicting the presence and severity of coronary artery disease (CAD) in patients with stable ischemic heart diseases. **Methods:** This study was conducted at a tertiary care cardiac center. The study included patients presenting to the outpatient department for the first time with angina and a positive exercise tolerance test (ETT), who underwent coronary angiogram. Correlation analysis was performed between DTS and SYNTAX score, and receiver operating characteristic (ROC) curve analysis was conducted for DTS to detect the presence (SYNTAX score ≥0) and severity (SYNTAX score ≥33) of CAD. **Results:** Out of 303 patients, 72.6% (220) were male, with a mean age of 53.31±10.11 years. CAD was detected in 79.9% (242) of patients. The mean SYNTAX score was 18.77±14.18, with 26.4% (80) categorized as high-risk. The mean DTS score was -6.09±4.5, with 13.9% (42) categorized as high risk. The Pearson correlation coefficient between DTS and SYNTAX score was -0.806 (p<0.001). The area under the curve (AUC) for DTS score in detecting the presence and severity of CAD was 0.992 [0.985–0.998] and 0.895 [0.860–0.929], respectively. **Conclusion:** A strong negative correlation was observed between SYNTAX score and DTS, highlighting the predictive value of DTS for assessing CAD severity. The DTS score demonstrated very high diagnostic accuracy in detecting the presence and severity of CAD.

Keywords: Myocardial ischemia; Duke Treadmill Score; Syntax Score

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INTRODUCTION

Myocardial ischemia, a condition causing significant morbidity and mortality worldwide, is responsible for approximately 17.8 million deaths each year, ranking it as the third leading cause of mortality globally.[1] Non-invasive tests are commonly employed to evaluate patients with a low to moderate risk of underlying coronary artery disease (CAD).[2,3] According to the guidelines provided by the American Heart Association (AHA), American College of Cardiology (ACCA), and European Society of Cardiology (ESC), exercise tolerance testing (ETT) is the preferred initial noninvasive test for risk stratification and diagnosis of suspected CAD patients.[4–6] Despite the availability of various testing options, ETT stands out as the most commonly used, cost-effective, and easily accessible noninvasive test for evaluating patients with suspected CAD.[6]

Exercise tolerance test has a sensitivity of 67% and specificity of 71% for CAD.[6,7] One commonly used parameter in ETT is the Duke Treadmill Score (DTS), which categorizes patients into low-risk (≥ +5), intermediate-risk (-10 to +4), and high-risk (≤ -11) groups.[7] While traditionally considered a prognostic score, the DTS has recently been found to have significant diagnostic and predictive value for CAD.[8,9] The SYNTAX score is an angiography-based scoring system widely utilized to assess the complexity and extent of CAD.[10] It aids in guiding treatment selection and predicting long-term outcomes in CAD patients, with its validity established in various studies.[6,7] A recent study demonstrated a strong correlation (correlation coefficient = –0.72) between the DTS and SYNTAX score.[10]

Duke Treadmill Score is a valuable non-invasive tool for identifying patients with a high risk of CAD, who may need immediate referral for invasive assessment and early intervention. However, there is currently a scarcity of comprehensive data on the reliability and practicality of DTS in various clinical scenarios. Therefore, the objective of this study was to evaluate the effectiveness of DTS in predicting the presence, severity, and extent of CAD, and to determine its correlation with the SYNTAX score. This investigation focuses on a contemporary group of patients from a tertiary care cardiac center in a developing country who have positive exercise treadmill test (ETT) results to evaluate the correlation between DTS and SYNTAX score and to assess the role of DTS in predicting the severity of CAD in these patients.

MATERIAL AND METHODS

This cross-sectional study was conducted at the National Institute of Cardiovascular Disease (NICVD), Karachi from July 2021 to June 2022. Patients were enrolled through a non-probability consecutive sampling technique. The inclusion criteria were; both male and female patients, between 18–65 years, presented to the outpatient department for the first time with angina and calculated to have intermediate pretest probability of CAD, and undergone ETT. The pretest probability of CAD was assessed based on the Diamond and Forrester (DF) proposed estimation of obstructive CAD based on age, sex, and symptoms.[11] During the study duration, a total of 472 ETT procedures were performed out of which 303 (64.2%) were found to have positive ETT findings, hence, included for further assessment. Patients with a prior diagnosis of CAD, those with underlying congenital heart disease or valvular heart diseases, any physical limitations for ETT, and baseline uninterpretable ECG were excluded from the study.

Data was collected after the approval of the ethical review committee and consent for participation and procedures was obtained from all the patients. Exercise Tolerance Test was performed in all recruited patients as per the standard Bruce protocol. Those with 1 mm or more of horizontal or down-sloping ST depression on exercise ECG were considered positive for a stress test and subsequently underwent coronary angiography for further assessment of ischemia. The DTS was calculated for all patients using the formula proposed by Shaw LJ *et al*.[8]; DTS = exercise time – (5×ST deviation) – (4× exercise angina). Exercise-induced angina was classified as one of three levels: 0, none; 1, non-limiting; and 2, exercise-limiting. DTS was categorized into three groups; low ≥ +5, intermediate -10 to +4, and high risk ≤ -11.

Left heart catheterization (LHC) was performed using the modified Seldinger technique through both radial and femoral approaches. Angiogram was performed by an experienced interventional cardiologist and interpreted by another interventional cardiologist who was unaware of the study. The coronary lesion was considered significant if > 70% stenosis in a vessel other than left main, whereas cutoff of left main was 50% or more and SYNTAX score was calculated for each angiogram, for which online syntax score calculator was used (www.syntaxscore.com). SYNTAX score is categorized into low (0–22), intermediate (23–32), and high score (33 or high).[10] Patients were categorized into two groups based on the angiographic evidence of the presence of CAD (SYNTAX score ≥0). Clinical data for the two groups were compared by computing the appropriate summary statistics such as frequency (percentages) or mean ± standard deviations (SD)/median [interquartile range (IQR)] and appropriate statistical tests were adopted such as Chi-square test or Mann-Whitney U test/ independent samples t-test at 5% level of significance. The Pearson correlation coefficient was computed between the DTS and SYNTAX score and presented with the help of scatter plot. The receiver operating characteristic (ROC) curve analyses were performed for the DTS to detect the presence of CAD (SYNTAX score ≥0) and severity of CAD (SYNTAX score ≥33) and area under the curve (AUC) along with 95% confidence interval (CI) was estimated. All the analyses were performed with the help of IBM SPSS version 21.

RESULTS

A total of 472 patients were registered for ETT procedures during the study period and 303 patients with positive ETT were included in this analysis. Out of 303 patients, 72.6% (220) were male, and mean age of the study sample was 53.31 ± 10.11 years. The presence of CAD was confirmed in 79.9% (242) of patients on left heart catheterization. Mean age for the patients with CAD was nearly 15 years older than that of patients without CAD, 56.19 ± 7.99 vs. 41.85 ± 9.55; $p<0.001$ respectively. Conventional risk factors, such as diabetes mellitus (4.9% vs. 49.2%), hypertension (36.1% vs. 56.6%), smoking (21.3% vs. 44.6%), dyslipidaemia (3.3% vs. 14.9%), family history of IHD (0% vs. 11.2%), were predominantly higher among CAD groups as compared to non-CAD group, respectively. The CAD on angiogram was detected in a smaller proportion of ETT-positive females than males with 63.9% vs. 85.9%, respectively (<0.001). Demographic and clinical characteristics of patients stratified by the presence of coronary artery disease on angiogram are presented in table-1. Overall mean SYNTAX score was 18.77 ± 14.18 with 46.5% (141) patients in low-risk (≤22), 27.1% in intermediate-risk (23–32), and 26.4% in high-risk (≥33) category. Coronary angiogram was normal in 20.1% (61) of the patients, among the remaining patients, 21.5% (65) had single vessel disease, 26.1% (79) had two vessel disease, and 32.3% (98) patient had three vessel disease. Mean DTS score was -6.09 ± 4.5 with 13.9% categorized as high risk and the remaining 86.1% as intermediate or low risk. The mean DTS score was significantly lower for CAD group as compared to non-CAD group with mean of -7.83 ± 2.91 vs. 0.82 ± 2.72; $p<0.001$ respectively. A strong negative correlation between DTS score and syntax score was observed with a Pearson correlation coefficient of -0.806 ($p<0.001$) (Figure 1). Also, there observed a strong negative relationship between DTS score and disease burden and severity of CAD (Figure 2). Very high diagnostic accuracy of DTS score has been observed for the detection of the presence of CAD with AUC of 0.992 [95% CI: 0.985 to 0.998] and detection of severe CAD (SYNTAX score ≥33) with AUC of 0.895 [95% CI: 0.860 to 0.929]. ROC analysis of DTS for detection of the presence of CAD and severe CAD is presented in Figure 3.

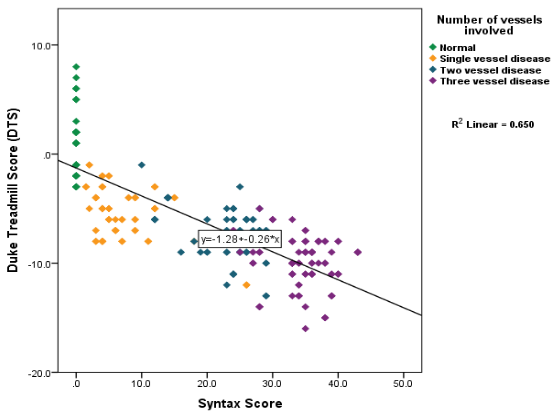

Figure-1: Correlation between SYNTAX Score and DTS and their association with the number of diseases vessels

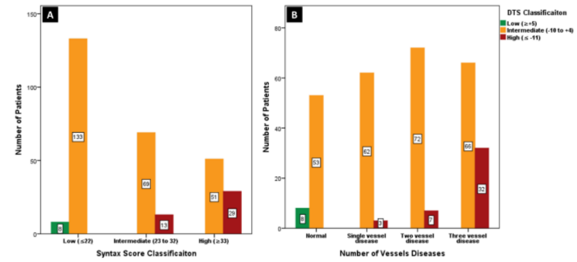

Figure-2: Association between DTS and severity of CAD (A) and number of vessels disease (B)

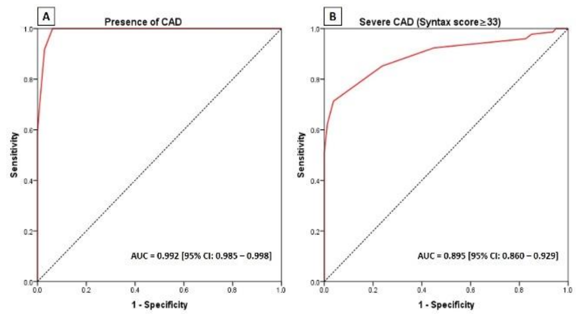

Figure-3: ROC analysis of DTS for presence of CAD (A) and detection of severe CAD (B)

Table-1: Comparison of demographic data and clinical findings between the patients with and without the evidence of coronary artery disease on angiogram

Characteristics	Total	Coronary Artery Disease		*p*-value
		Absent	Present	
Total (N)	**303**	**61 (20.1%)**	**242 (79.9%)**	**-**
Gender				
Male	72.6% (220)	50.8% (31)	78.1% (189)	<0.001*
Female	27.4% (83)	49.2% (30)	21.9% (53)	
Age (years)	53.31±10.11	41.85±9.55	56.19±7.99	<0.001*
Young (≤ 45 years)	23.8% (72)	75.4% (46)	10.7% (26)	<0.001*
Middle (46 to 65 years)	70.3% (213)	24.6% (15)	81.8% (198)	
Old (> 65 years)	5.9% (18)	0% (0)	7.4% (18)	
Weight (kg)	64.68±7.97	59.02±7.74	66.1±7.39	<0.001*
Height (cm)	165.5±7.12	162.62±5.62	166.23±7.28	<0.001*
Body mass index (kg/m^2)	23.59±2.41	22.24±2.04	23.93±2.38	<0.001*
Co-morbid conditions				
Diabetes mellitus	40.3% (122)	4.9% (3)	49.2% (119)	<0.001*
Hypertension	52.5% (159)	36.1% (22)	56.6% (137)	0.004*
Smoking	39.9% (121)	21.3% (13)	44.6% (108)	0.001*
Dyslipidemia	12.5% (38)	3.3% (2)	14.9% (36)	0.015*
Family history of IHD	8.9% (27)	0% (0)	11.2% (27)	0.006*
Duke Treadmill Score (DTS)	-6.09±4.5	0.82±2.72	-7.83±2.91	<0.001*
Low (≥+5)	2.6% (8)	13.1% (8)	0% (0)	<0.001*
Intermediate (-10 to +4)	83.5% (253)	86.9% (53)	82.6% (200)	
High (≤ -11)	13.9% (42)	0% (0)	17.4% (42)	
SYNTAX Score	18.77±14.18	0±0	23.5±11.85	<0.001*
Low (≤22)	46.5% (141)	100% (61)	33.1% (80)	<0.001*
Intermediate (23 to 32)	27.1% (82)	0% (0)	33.9% (82)	
High (≥33)	26.4% (80)	0% (0)	33.1% (80)	

IHD = ischemic heart diseases. *Significant at 5%

DISCUSSION

The ETT is a non-invasive method used to diagnose and assess the prognosis of cardiovascular disease, particularly CAD. Our study focused on highlighting the significance of the in evaluating the presence and severity of CAD. The findings from our study demonstrated a strong correlation between the DTS score and the syntax score (r = -0.806), indicating that as the DTS score decreases, the burden of ischemia increases. This suggests that the DTS score can serve as a valuable predictor of coronary artery lesions. Notably, our research revealed that the DTS score has excellent predictive value in detecting both the presence (AUC of 0.992 [95% CI: 0.985 to 0.998]) and severity (AUC of 0.895 [95% CI: 0.860 to 0.929]) of CAD.

Our findings regarding the strong predictive value of DTS are consistent with studies conducted worldwide. For instance, a study by Zeki Yüksel Günaydın *et al*.[12] demonstrated a strong negative correlation between SYNTAX score and DTS. In their study, the area under the ROC curve for DTS was 0.83 (p<0.001), indicating its effectiveness in predicting the presence of underlying ischemic heart diseases. An optimal cut-off value of -3.7 was identified, suggesting the presence of underlying ischemia. Gabaldon *et al*.[13] found that patients with high-risk DTS scores often had significant or severe CAD. Additionally, another study[14] revealed the incremental diagnostic value of DTS through ROC analysis in predicting the presence of coronary artery disease with ≥75% stenosis or severe CAD involving 3-vessel disease.

The elevated DTS observed in our study may be attributed to the inclusion of a population with multiple comorbidities and a lower number of females. Furthermore, the exclusion of patients with low pretest probability and the focus on those with intermediate probability could have contributed to the higher DTS values.

The ETT has limited accuracy in women for assessing ischemia due to a higher percentage of false-positive results. Multiple studies have shown that ST-segment depression on exercise ECG testing is less specific in women compared to men.[11,15] Our study also found similar results, with angiographic confirmation of CAD in 63.9% of female patients compared to 85.9% of male patients. In female patients, ST changes can be caused by factors such as coronary artery spasms, anxiety, or hyperventilation, leading to false-positive ETT results.[16]

It's worth noting that out of 61 (20.1%) patients, despite positive ETT results, there was no evidence of CAD. This underscores a significant rate of false positivity associated with the ETT. While our study lacked specific investigations into potential causes of false positive ETT results in these patients, various patient- and procedure-related factors could contribute to such outcomes. Suboptimal test protocols featuring inadequate exercise intensity, improper adjustments of treadmill speed or incline, insufficient exercise duration, or incorrect electrode placement can collectively contribute to false positive results. Additionally, certain medications like beta-blockers might modify heart rate and blood pressure responses, possibly obscure underlying heart conditions and resulting in false positives. Anxiety or stress experienced during the test could also lead to a heightened physiological response, potentially misinterpreted as a cardiac issue. Inactive individuals might experience deconditioning, while various non-cardiac medical conditions such as hypertension, lung disease, musculoskeletal problems, anaemia, or thyroid disorders could elicit symptoms like breathlessness or chest discomfort during exercise, resembling heart-related problems.[17–21]

Conversely, negative ETT results alongside typical symptoms are cause for concern in real-life clinical practice. Generally, these patients are managed through medical interventions, although some may undergo coronary angiograms to exclude underlying CAD. It's important to note that a negative ETT doesn't rule out the possibility of other cardiac or non-cardiac conditions contributing to the symptoms. In these cases, a comprehensive investigation of symptomatology, risk factors, and clinical history is crucial. Additional non-invasive investigations like stress echocardiography, nuclear perfusion imaging, and coronary calcium assessments can also be considered. Close monitoring and follow-up for such patients, coupled with risk factor modification, can help prevent potential cardiovascular events.[22] Young individuals with both conventional and non-conventional risk factors—such as impaired glycemic control and renal profiles—should undergo stringent follow-up to ensure tight management of comorbid conditions, thus mitigating or delaying the progression of CAD.

The study has some limitations that should be considered. Firstly, the sample was drawn from a single hospital, which primarily serves individuals from the low to middle economic class. This demographic may have limited awareness of cardiovascular disease. Secondly, the sample size was relatively small. Additionally, lack of a control group for the assessment of the diagnostic accuracy of ETT. To ensure the broader applicability of the findings, it would be beneficial to conduct multicenter studies with larger sample sizes.

CONCLUSION

Our study has found a significant negative correlation between the DTS and syntax score, indicating that as the DTS decreases, the syntax score tends to increase. Moreover, the DTS demonstrates a high level of diagnostic accuracy in detecting the presence and severity of CAD. This suggests that the DTS can serve as a valuable non-invasive tool for promptly identifying patients with high-risk CAD who may need immediate referral for invasive assessment and early management.

AUTHORS' CONTRIBUTION

LR, MKB, MNM, RK, JA and SMH: Contributed to the concept and design of the study. LR, MKB, JAS, TS, and MK: Data collection, analysis, interpretation. LR, MKB, MNM, RK, JA, and MK: Drafting. MKB, JAS, TS, MK: Critical analysis. All authors have read and approved the manuscript.

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