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The Synergistic Relationship Between Erectile Dysfunction and Frontal QRS-T Angle in Predicting Coronary Artery Disease Severity: A Prospective Observational Study

ABSTRACT

Background: Erectile dysfunction (ED) and coronary artery disease (CAD) frequently coexist, sharing common risk factors and pathophysiological mechanisms. The frontal QRS-T angle (fQRSTa), a novel electrocardiographic marker reflecting ventricular depolarization-repolarization heterogeneity, has been linked to adverse cardiac outcomes. However, the combined prognostic value of ED and fQRSTa in predicting CAD severity remains unexplored. The aim was to investigate whether the coexistence of ED and widened fQRSTa is associated with increased CAD severity, and to evaluate their individual and combined utility in identifying patients with advanced CAD.

Methods: This prospective observational study included 236 male patients undergoing first-time coronary angiography for suspected CAD. Patients were stratified into 4 groups based on ED status (International Index of Erectile Function–5 [IIEF-5] ≤21) and fQRSTa (cutoff: 52.5°). Coronary artery disease severity was assessed using the Gensini and SYNTAX scores. Hierarchical regression and correlation analyses were performed to evaluate associations.

Results: Erectile dysfunction prevalence was 62.7%, and patients with both ED and high fQRSTa exhibited significantly reduced ejection fraction and the highest Gensini and SYNTAX scores (all $P < .001$). Regression analyses demonstrated that ED (β = 11.927, $P = .009$, 95% CI: 2.014-21.839), high fQRSTa (β = 9.906, $P = .012$, 95% CI: 2.710-22.523), and their interaction (β = 17.233, $P = .028$, 95% CI: 1.906-32.560) were independent predictors of higher Gensini scores after full adjustment. Similar results were observed for SYNTAX scores. A moderate inverse correlation was found between IIEF-5 and fQRSTa ($r = -0.436$, $P < .001$).

Conclusion: Erectile dysfunction and widened fQRSTa are independently and synergistically associated with more severe CAD. Their coexistence identifies a high-risk subgroup with pronounced angiographic abnormalities.

Keywords: Cardiovascular risk score, coronary artery disease, electrocardiography, erectile dysfunction, risk assessment

ORIGINAL INVESTIGATION

INTRODUCTION

Erectile dysfunction (ED) is defined as the inability to achieve and/or maintain a penile erection sufficient for satisfactory penetrative sexual intercourse.[1] Both ED and coronary artery disease (CAD) are common conditions that share overlapping pathophysiological mechanisms, including autonomic nervous system dysfunction and endothelial dysfunction.[2,3] Factors such as advanced age, dyslipidemia, hypertension, diabetes mellitus, metabolic syndrome, obesity, smoking, and a sedentary lifestyle have been identified as risk factors common to both ED and CAD.[1,3-5] The correlation between ED and CAD has been explained by the "artery size hypothesis," which suggests that atherosclerosis affects smaller arteries earlier than larger ones. Accordingly, ED may serve as an early indicator of systemic atherosclerosis and a precursor to overt CAD.[1,4,6-8]

The frontal QRS-T angle (fQRSTa) is defined as the angular difference between the direction of ventricular depolarization (QRS complex) and ventricular

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Pınar Özmen Yıldız[1]
Mert Hamza Özbilen[2]

[1]*Department of Cardiology, Health Sciences University, Adana City Training and Research Hospital, Adana, Türkiye*
[2]*Department of Urology, Health Sciences University, Adana City Training and Research Hospital, Adana, Türkiye*

Corresponding author:
Pınar Özmen Yıldız
✉ pinarymnn@hotmail.com

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repolarization (T wave). It serves as a novel marker of myocardial depolarization-repolarization heterogeneity, reflecting electrical instability in the ventricular myocardium.[9,10] Transient myocardial ischemia due to obstructive coronary artery stenosis may also contribute to ventricular axis changes, predisposing patients to ventricular arrhythmias.[9,10] Recent studies have demonstrated that a high fQRSTa is a predictor of all-cause and cardiac mortality, particularly in patients with CAD.[9,11-13]

However, the potential role of the coexistence of high fQRSTa and ED in patients with CAD remains unexplored. To this end, this study was conducted to investigate the relationship between fQRSTa and ED in the context of CAD severity and to determine whether their coexistence is associated with more severe forms of CAD.

METHODS

Study Design and Setting

This study was designed as a prospective observational study. The study protocol was reviewed and approved by the Ethics Committee of Health Sciences University, Adana City Training and Research Hospital (Date: April 10th, 2025; No.: 12/458). The study was conducted at the Departments of Cardiology and Urology at Adana City Training and Research Hospital, between April 10th, 2025, and June 9th, 2025, per the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all patients.

Population and Sample

The study population consisted of male patients aged 18 years or older who presented to the cardiology outpatient clinics with chest pain. Following clinical assessment, patients were scheduled for their first coronary angiography for suspected CAD based on indications outlined in current cardiology guidelines, such as the presence of ischemia on noninvasive stress tests (e.g., exercise electrocardiography, myocardial perfusion scintigraphy) or high pre-test probability for CAD. Patients with a history of CAD, including prior coronary angiography, coronary artery bypass grafting, or percutaneous coronary intervention, severe comorbidities such as stage 4 or higher chronic kidney disease, liver failure, atrial fibrillation, a history of prostate or vertebral surgery, hormonal disorders associated with ED, psychiatric or neurological diseases, Peyronie's disease, and patients who have been using medications known to influence erectile function or electrocardiographic (ECG) parameters, e.g., antiarrhythmics, beta-blockers, phosphodiesterase-5 inhibitors, were excluded from the study. In the end, the study sample consisted of 236 patients.

HIGHLIGHTS

- Erectile dysfunction and high frontal QRS-T angle demonstrated synergistic association with coronary artery disease severity.
- Patients with both conditions exhibited the highest angiographic scores.
- Combined assessment provides incremental prognostic value beyond traditional cardiovascular risk factors.
- The interaction remained significant after multivariable adjustment.
- This dual-marker approach offers practical cardiovascular risk stratification.

Electrocardiographic and Echocardiographic Evaluation

All patients underwent standard 12-lead ECG before undergoing angiography. The ECG parameters assessed included heart rate and fQRS-Ta. The fQRSTa was calculated automatically as the absolute value of the angular difference between the frontal QRS axis and the T wave axis. If the calculated value was greater than 180°, fQRSTa was adjusted to the minimum angle by subtracting the absolute value of the difference between fQRSTa and the T axis from 360°.[11] Echocardiographic (ECHO) parameters examined included left ventricular ejection fraction, end-diastolic and end-systolic diameters, and interventricular septal and posterior wall thicknesses.

Assessment of the Erectile Function

To assess the presence and severity of ED, patients were asked to complete the International Index of Erectile Function–5 (IIEF-5), a validated self-administered questionnaire.[14] It consists of 5 items on sexual functions, including orgasm, erectile function, desire for sex, post-intercourse, and overall satisfaction, each scored from 0 to 5.[6] A total IIEF-5 score of 21 or less indicates ED. Accordingly, patients with IIEF-5 scores of 17 to 21, 12 to 16, 8 to 11, and 8 or less were classified as patients with mild, mild-to-moderate, moderate, and severe ED, respectively.[6]

Coronary Angiography and Coronary Artery Disease Severity

All patients underwent diagnostic coronary angiography. Patients' CAD severity was quantified using Gensini scores (GS).[15,16] To this end, each lesion was assigned a score according to the percentage of stenosis: 1 for 25% stenosis, 2 for 50%, 4 for 75%, 8 for 90%, 16 for 99%, and 32 for total occlusion. Gensini scores of each patient was obtained by summing up the values obtained via multiplication by the coefficient defined for each major coronary artery and each segment, as described previously.[15,17] Consequently, patients with a GS between 1 and 20 and those with a GS of 20 or more were defined as having mild and severe CAD, respectively.[18]

Patients' synergy between percutaneous coronary intervention with taxus and cardiac surgery (SYNTAX) scores were calculated using the SYNTAX score calculator, version 2.28 (available at https://syntaxscore.org/calculator/syntaxscore/frameset.htm) to provide a secondary measure of disease burden. Accordingly, patients with SYNTAX scores of less than 23 and those with scores of 23 and above were considered to have a low and moderate-to-high disease burden, respectively.[11] Coronary artery disease presence was defined as ≥50% luminal stenosis in at least 1 major coronary artery, and non-CAD as <50% stenosis, in accordance with previous angiographic studies.[19,20]

Patient Groups

To establish a data-driven threshold for the fQRSTa, a receiver operating characteristic (ROC) curve analysis was

performed to predict the presence of CAD. The analysis revealed an area under the curve of 0.716 (95% CI: 0.639-0.794, $P < .001$), indicating a significant predictive value. The optimal cutoff point was identified as 52.5°, which provided a sensitivity of 69.9% and a specificity of 70.0%.

Patients were subsequently stratified into 4 groups according to their fQRSTa (low angle vs. high angle, based on fQRSTa cutoff value of 52.5°) and ED status (ED-positivity based on IIEF score ≤21 vs. ED-negativity based on IIEF score >21):

- Group 1 (n = 63): Low fQRSTa, no ED.
- Group 2 (n = 57): Low fQRSTa, with ED (mild, moderate, or severe).
- Group 3 (n = 25): High fQRSTa, no ED.
- Group 4 (n = 91): High fQRSTa, with ED (mild, moderate, or severe).

Randomization was not employed in the allocation of these groups.

Data Collection

Patients' sociodemographic characteristics, i.e., age, weight, height, body mass index (BMI), education level, and marital status, and clinical characteristics, i.e., smoking status, alcohol use, comorbidities such as hypertension, diabetes mellitus, hyperlipidemia, chronic kidney disease, and chronic obstructive pulmonary disease, familial history of CAD, concomitant medication use, including statins, calcium channel blockers, angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, and thiazide diuretics, were collected using a standardized case report form.

Laboratory tests performed on patients included complete blood count (hemoglobin, leukocyte, and platelet counts), lipid profile (total cholesterol, high-density lipoprotein, low-density lipoprotein, and triglyceride), fasting glucose and hemoglobin A1C (HbA1C), serum creatinine tests, estimated glomerular filtration rate (eGFR), and electrolyte tests (calcium and potassium). No blinding was employed during data collection or analysis.

Statistical Analysis

Statistical analyses were performed using Jamovi (version 2.3.28) and JASP (Jeffreys's Amazing Statistics Program, version 0.19.2) software. Descriptive statistics were presented as mean ± SD for normally distributed variables, median [minimum-maximum] for non-normally distributed variables, and as frequency (n) and percentage (%) for categorical variables. The normality of data distribution was assessed using the Shapiro-Wilk test and visual inspection of histograms. Depending on the data distribution, group comparisons for continuous variables were performed using one-way ANOVA with Tukey's post-hoc test or the Kruskal–Wallis H test with Dunn's post-hoc test. Categorical variables were compared using Pearson's chi-square or the Fisher–Freeman–Halton test, as appropriate. A *P*-value of ≤.05 was considered statistically significant.

RESULTS

The prevalence of ED in the sample was 62.7%. Fifty (33.7%) patients had mild-to-moderate ED, 39 (26.4%) moderate ED, 38 (27.7%) mild ED, and 21 (14.2%) had severe ED. There were no significant differences between the study groups in terms of age, weight, height, BMI, marital status, smoking status, alcohol consumption, or comorbidities (*P*-values ranged from .052 to .983) (Table 1). On the other hand, a significant difference was found between the study groups in terms of education level ($P = .015$). Accordingly, there were significantly more patients who had graduated from an elementary school at the latest in Group 4 than in other groups. Additionally, in terms of echocardiographic parameters, only the ejection fraction (EF) showed a statistically significant difference between the groups ($P < .001$). Post hoc analysis revealed that EF was significantly lower in Group 4 than in Groups 1 and 2 ($P = .004$ and $P = .006$, respectively). No significant differences were found between the groups in heart rate, left ventricular diameter, or wall thickness (*P*-values ranged from .092 to .875).

Of the 236 patients included in the study, 176 (74.6%) were diagnosed with CAD, while 60 (25.4%) were categorized as non-CAD (<50% stenosis). Angiographic scoring revealed significant differences between the study groups in both Gensini and SYNTAX scores ($P < .001$ for both) (Table 2). Accordingly, Group 4 had significantly higher GS and SYNTAX scores than Groups 2 and 3, and Groups 2 and 3 had significantly higher GS and SYNTAX scores than Group 1 (Figures 1A and B). Gensini score ($P = .519$) and SYNTAX ($P = .663$) scores did not differ significantly between Groups 2 and 3. Post hoc analysis revealed significantly more patients with GS-based severe CAD in Group 4 than in other groups and in Groups 2 and 3 than in Group 1 ($P < .001$). Similarly, there were significantly more patients with moderate and high SYNTAX score-based disease burden in Group 4 than in other groups ($P < .001$).Reflecting these findings, a significant difference was also observed in the overall diagnosis of CAD ($P < .001$). The prevalence of CAD was highest in Group 4 (95.6%), and conversely, the rate of non-CAD patients was significantly lower in this group (4.4%) compared to all others.

There were significant differences between the groups in hemoglobin ($P < .001$), glucose ($P < .001$), HbA1c ($P = .011$), creatinine ($P = .036$), calcium levels ($P = .009$), and eGFR ($P = .001$) (Table 3). The glucose level was significantly lower in Group 1 than in Groups 2 and 4 ($P = .003$ and $P < .001$, respectively). No significant differences were found between the groups in leukocyte or platelet counts, lipid profiles, triglyceride, or potassium levels (*P*-values ranged from .069 to .833).

The hierarchical regression models revealed that both ED positivity (IIEF score ≤21) and high fQRSTa (≥52.5°) were independently associated with more severe CAD, as assessed by GS and SYNTAX score (Table 4, Figure 2). Accordingly, Model 1 revealed that ED ($\beta = 16.082$, $P = .002$, 95% CI: 6.144-26.020) and high fQRSTa ($\beta = 13.642$, $P = .038$, 95% CI: 0.792-26.492) were significantly associated with higher GS-based CAD severity, and their interaction was also significant ($\beta = 16.888$, $P = .036$, 95% CI: 1.094-32.682). These correlations remained significant after adjustment for potentially confounding variables, including demographic characteristics,

Table 1. Demographic and Clinical Characteristics of Patients Stratified by Frontal QRS-T Angle and Erectile Dysfunction Status

	Group 1 (n = 63)	Group 2 (n = 57)	Group 3 (n = 25)	Group 4 (n = 91)	*P*
Age (years) †	59.0 ± 12.1	61.1 ± 9.2	61.6 ± 10.5	61.4 ± 10.7	.546***
Weight (kg) §	85.0 [53.0-114.0]	83.0 [58.0-130.0]	80.0 [67.0-122.0]	80.0 [48.0-116.0]	.323*
Height (cm) §	174.0 [160.0-185.0]	171.0 [162.0-185.0]	174.0 [160.0-188.0]	171.0 [155.0-185.0]	.052*
BMI (kg/m^2) §	27.8 [20.4-37.9]	27.7 [20.3-45.0]	27.1 [23.2-39.5]	27.3 [17.6-40.8]	.836*
Education level, n (%) ‡					
Primary	25 (39.7)^a	33 (57.9)^{a,b}	17 (68.0)^{a,b}	57 (62.6)^b	**.015****
Secondary	29 (46.0)^a	20 (35.1)^a	5 (20.0)^{a,b}	19 (20.9)^b	
University	9 (14.3)^a	4 (7.0)^a	3 (12.0)^a	15 (16.5)^a	
Marital status, n (%) ‡					
Married	51 (81.0)	53 (93.0)	24 (96.0)	82 (90.1)	.081**
Single	7 (11.1)	0 (0.0)	0 (0.0)	2 (2.2)	
Divorced/widowed	5 (7.9)	4 (7.0)	1 (4.0)	7 (7.7)	
Smoking, n (%) ‡	34 (54.0)	29 (50.9)	13 (52.0)	49 (53.8)	.983**
Alcohol consumption, n (%) ‡	16 (25.4)	10 (17.5)	6 (24.0)	10 (11.0)	.110**
Comorbidities, n (%) ‡					
Hypertension	16 (25.4)	17 (29.8)	8 (32.0)	33 (36.3)	.547**
Diabetes mellitus	14 (22.2)	22 (38.6)	7 (28.0)	37 (40.7)	.084**
Hyperlipidemia	26 (41.3)	31 (54.4)	6 (24.0)	47 (51.6)	.053**
Chronic kidney disease	1 (1.6)	3 (5.3)	0 (0.0)	9 (9.9)	.108**
Chronic obstructive pulmonary disease	8 (12.7)	4 (7.0)	3 (12.0)	10 (11.0)	.769**
Family history of coronary artery disease, n (%) ‡	32 (50.8)	23 (40.4)	9 (36.0)	35 (38.5)	.407**
Medications, n (%) ‡					
Statins	17 (27.0)	18 (31.6)	6 (24.0)	32 (35.2)	.616**
Calcium channel blockers	8 (12.7)	8 (14.0)	4 (16.0)	16 (17.6)	.855**
ACEi/ARB	10 (15.9)	15 (26.3)	6 (24.0)	26 (28.6)	.324**
Thiazide diuretics	10 (15.9)	10 (17.5)	2 (8.0)	11 (12.1)	.614**
Echocardiographic parameters §					
Heart rate (bpm)	75.0 [53.0-110.0]	74.0 [53.0-119.0]	69.0 [56.0-117.0]	76.0 [55.0-126.0]	.219*
Ejection fraction	58.0 [25.0-65.0]^a	55.0 [30.0-68.0]^a	58.0 [25.0-65.0]^{a,b}	50.0 [30.0-60.0]^b	**<.001***
End-diastolic left ventricular diameter (mm)	51.0 [45.0-63.0]	51.0 [44.0-59.0]	53.0 [45.0-65.0]	51.0 [42.0-65.0]	.875*
End-systolic left ventricular diameter (mm)	36.0 [30.0-59.0]	37.0 [28.0-52.0]	37.0 [30.0-56.0]	38.0 [27.0-57.0]	.092*
Interventricularseptal thickness (mm)	10.0 [7.0-13.0]	10.0 [7.0-13.0]	10.0 [8.0-13.0]	10.0 [7.0-16.0]	.433*
Posterior wall thickness (mm)	9.0 [7.0-12.0]	9.0 [7.0-12.0]	9.0 [7.0-13.0]	9.0 [6.0-12.0]	.475*

The participants were divided into 4 groups based on frontal QRS-T angle (fQRSTa) and erectile dysfunction (ED) status. Group 1 included patients with low fQRSTa without ED; Group 2 comprised patients with low fQRSTa with ED; Group 3 consisted of patients with high fQRSTa without ED; and Group 4 included patients with high fQRSTa with ED. Data are presented as mean ± SD (†) for age, median [minimum-maximum] (§) for weight, height, BMI, and echocardiographic parameters, and frequency with percentage (‡) for categorical variables. The a,b superscripts denote the results of post-hoc analysis; groups with different letters differ significantly from each other. Statistical comparisons were performed using Kruskal–Wallis H test (*) for non-normally distributed continuous variables, One-Way ANOVA (***) for normally distributed continuous variables, and Pearson Chi-Square or Fisher–Freeman–Halton test (**) for categorical variables. Post hoc comparisons for Kruskal–Wallis and ANOVA were conducted using Dunn's test with Bonferroni correction and Tukey's Honestly Significant Difference (HSD) test, respectively. Bold *P*-values indicate statistical significance ($P \leq .05$).

ACEi, angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blockers; BMI, body mass index; bpm, beats per minute; ED, erectile dysfunction; fQRSTa, frontal QRS-T angle; mm, millimeters.

cardiovascular risk factors, and laboratory parameters in Model 4. In the final model, ED (β = 11.927, *P* = .009, 95% CI: 2.014-21.839), high fQRSTa (β = 9.906, *P* = .012, 95% CI: 2.710-22.523), and their interaction (β = 17.233, *P* = .028, 95% CI: 1.906-32.560) remained significant predictors of higher GS. Additional significant predictors included only hemoglobin (β = −3.209, *P* = .003, 95% CI: −5.334 to −1.085).

Similarly, Model 1 revealed that ED (β = 5.524, *P* < .001, 95% CI: 2.478-8.570), high fQRSTa (β = 4.643, *P* = .021, 95% CI:

Table 2. Comparison of Angiographic Characteristics Among Patient Groups Stratified by Frontal QRS-T Angle and Erectile Dysfunction Status

	Group 1 (n = 63)	Group 2 (n = 57)	Group 3 (n = 25)	Group 4 (n = 91)	*P*
IIEF-5 score§	24.0 [22.0-25.0]^{a}	15.0 [5.0-21.0]^{b}	23.0 [22.0-25.0]^{a}	12.0 [5.0-21.0]^{b}	<.001*
Gensini score§	6.0 [0.0-130.0]^{a}	22.0 [1.5-124.0]^{b}	20.0 [2.5-120.0]^{b}	56.0 [0.0-120.0]^{c}	<.001*
Severity grouping based on Gensini score‡					
Mild (1-20), n (%)	54 (85.7)^{a}	26 (45.6)^{b}	12 (48.0)^{b}	7 (7.7)^{c}	<.001**
Severe (≥20), n (%)	9 (14.3)^{a}	31 (54.4)^{b}	13 (52.0)^{b}	84 (92.3)^{c}	
SYNTAX score§	0.0 [0.0-27.5]^{a}	9.0 [0.0-33.0]^{b}	7.0 [0.0-26.5]^{b}	20.5 [0.0-52.0]^{c}	<.001*
Risk groups based on SYNTAX score, n (%)‡					
Low (<23)	61 (96.8)^{a}	52 (91.2)^{a}	23 (92.0)^{a}	50 (54.9)^{b}	<.001**
Moderate-high (≥23)	2 (3.2)^{a}	5 (8.8)^{a}	2 (8.0)^{a}	41 (45.1)^{b}	
CAD diagnosis, n (%)‡					
Non-CAD (<50% stenosis)	36 (57.1)^{a}	12 (21.1)^{b}	8 (32.0)^{a,b}	4 (4.4)^{c}	<.001**
CAD presence	27 (42.9)^{a}	45 (78.9)^{b}	17 (68.0)^{a,b}	87 (95.6)^{c}	

Table 2 displays coronary artery disease presence andseverity across the 4 patient groups stratified by frontal QRS-T angle (fQRSTa) and erectile dysfunction (ED) status. Group 1 included patients with low fQRSTa without ED; Group 2 comprised patients with low fQRSTa with ED; Group 3 consisted of patients with high fQRSTa without ED; and Group 4 included patients with high fQRSTa with ED. Data are presented as median [minimum-maximum] (§) for continuous variables and frequency with percentage (‡) for categorical variables. Statistical analyses were performed using Kruskal-Wallis H test (*) for continuous variables and Pearson Chi-Square or Fisher–Freeman–Halton test (**) for categorical variables.The different superscript letters (a, b, c) indicate statistically significant differences between groups based on post-hoc analysis using Dunn's test with Bonferroni correction. Groups sharing the same superscript letter do not differ significantly from each other, while groups with different letters represent statistically significant differences ($P \leq .05$). Bold *P*-values indicate statistical significance ($P \leq .05$).
CAD, coronary artery disease; ED, erectile dysfunction; fQRSTa, frontal QRS-T angle; Gensini, Gensini coronary artery disease severity scoring system; SYNTAX, SYNergy between percutaneous coronary intervention with TAXus and cardiac surgery scoring system.

0.705-8.582), and their interaction (β = 5.645, *P* = .022, 95% CI: 0.804-10.485) were significantly associated with higher SYNTAX score-based CAD severity. These correlations remained significant across Models 2 to 4, with the interaction term maintaining significance in the model fully adjusted for potentially confounding variables (β = 5.864, *P* = .015, 95% CI: 1.167-10.561). In the final model, only hemoglobin (β = −1.216, *P* < .001, 95% CI: −1.867 to −0.565) was additionally found to be associated with SYNTAX score-based CAD severity.

The addition of each block of variables resulted in significant improvements in the explained variance for both GS ($\Delta R^2 = 0.038$, *P* = .031) and the SYNTAX score ($\Delta R^2 = 0.041$, *P* = .011) in the final model.

The Spearman's correlation analysis revealed statistically significant relationships among the assessed parameters (Table 5). A moderate negative correlation was detected between the IIEF-5 score and fQRSTa ($r = -0.436$, $P < .001$). Furthermore, the fQRSTa was found to have a moderate positive correlation with both the Gensini score ($r = 0.495$, $P < .001$) and the SYNTAX score ($r = 0.484$, $P < .001$). Similarly, the IIEF-5 score was observed to have a moderate negative relationship with both the Gensini score ($r = -0.597$, $P < .001$) and the SYNTAX score ($r = -0.579$, $P < .001$).

DISCUSSION

Our study's findings indicated that the coexistence of ED-positivity and high fQRSTa was independently and

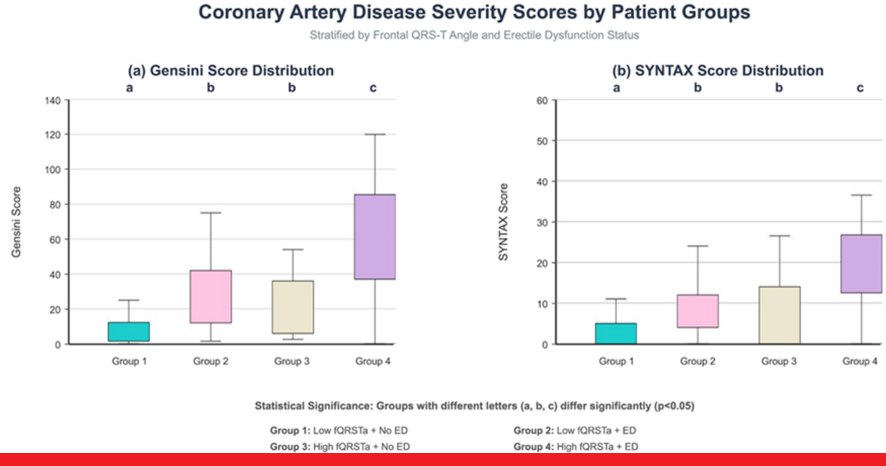

Figure 1. Schematic representation of a) the Gensini and b) SYNTAX scores among the groups.

Table 3. Laboratory Parameters of Patient Groups Classified According to Frontal QRS-T Angle and Erectile Dysfunction Status

	Group 1 (n = 63)	Group 2 (n = 57)	Group 3 (n = 25)	Group 4 (n = 91)	*P**
Hemoglobin (g/dL) §	15.1 [12.2-17.0]^{a}	14.0 [9.1-16.4]^{b}	14.2 [8.8-16.2]^{a,b}	13.6 [7.9-17.8]^{b}	**<.001***
Low hemoglobin (<10.9 g/dL) ‡	0 (0.0)^{a}	3 (5.3)^{a,b}	3 (12.0)^{b}	11 (12.1)^{b}	**.008****
Leukocyte count (/μL) §	8.2 [4.4-15.2]	9.2 [4.7-16.3]	9.0 [4.7-17.9]	9.0 [1.8-19.0]	.769*
Platelet count (/μL) §	278.0 [136.0-703.0]	234.0 [150.0-435.0]	262.0 [132.0-508.0]	249.0 [68.0-890.0]	.069*
Glucose (mg/dL) §	96.0 [74.0-302.0]^{a}	118.0 [67.0-317.0]^{b}	99.0 [73.0-403.0]^{a,b}	118.0 [73.0-372.0]^{b}	**<.001***
High glucose (>106 mg/dL) ‡	20 (31.7)^{a}	37 (64.9)^{b}	11 (44.0)^{a,b}	53 (58.2)^{b}	**.001****
HbA1c §	5.6 [4.2-10.4]^{a}	5.8 [4.3-12.4]^{a,b}	5.4 [4.4-11.2]^{a,b}	5.9 [4.2-11.0]^{b}	**.011***
High HbA1c (>5.6) ‡	25 (39.7)^{a}	31 (54.4)^{a,b}	12 (48.0)^{a,b}	58 (63.7)^{b}	**.029****
Creatinine (mg/dL) §	0.8 [0.5-1.4]^{a,b}	0.8 [0.5-2.4]^{a}	0.9 [0.7-1.3]^{a,b}	0.9 [0.5-2.4]^{b}	**.036***
High creatinine (>0.95 mg/dL) ‡	15 (23.8)^{a}	12 (21.1)^{a}	5 (20.0)^{a}	34 (37.4)^{b}	**.042****
eGFR (mL/dk/1.73m^2) §	102.0 [46.0-144.0]^{a}	95.0 [32.0-129.0]^{a,b}	93.0 [56.0-115.0]^{a,b}	89.0 [27.0-122.0]^{b}	**.001***
High eGFR (>90 mL/min/1.73 m^2) ‡	47 (74.6)^{a}	39 (68.4)^{a}	14 (56.0)^{a,b}	41 (45.1)^{b}	**.001****
Total cholesterol (mg/dL) §	194.0 [101.0-309.0]	175.0 [92.0-357.0]	195.0 [114.0-300.0]	179.0 [91.0-325.0]	.284*
HDL cholesterol (mg/dL) §	41.0 [26.0-74.0]	44.0 [24.0-62.0]	42.0 [30.0-65.0]	39.0 [22.0-80.0]	.266*
LDL-cholesterol (mg/dL) §	131.0 [57.0-212.0]	119.0 [54.0-246.0]	126.0 [73.0-207.0]	124.0 [50.0-220.0]	.221*
Triglyceride (mg/dL) §	165.0 [61.0-765.0]	165.0 [37.0-849.0]	137.0 [61.0-330.0]	142.0 [40.0-1652.0]	.583*
Calcium (mg/dL) §	9.2 [8.5-10.3]^{a}	9.1 [7.9-10.2]^{a,b}	9.3 [8.3-10.5]^{a,b}	9.1 [7.3-10.5]^{b}	**.009***
Low calcium (<8.8 mg/dL) ‡	3 (4.8)^{a}	13 (22.8)^{b}	2 (8.0)^{a,b}	26 (28.6)^{b}	**<.001****
Potassium (mEq/L) §	4.2 [3.7-5.0]	4.2 [3.4-5.6]	4.2 [3.6-5.1]	4.3 [3.1-5.4]	.833*

Table 3 presents laboratory parameters across the 4 patient groups stratified by frontal QRS-T angle (fQRSTa) and erectile dysfunction (ED) status. Group 1 included patients with low fQRSTa without ED; Group 2 comprised patients with low fQRSTa with ED; Group 3 consisted of patients with high fQRSTa without ED; and Group 4 included patients with high fQRSTa with ED. Data are presented as median [minimum-maximum] (§) for continuous variables and frequency with percentage (‡) for categorical variables. Statistical analyses were performed using Kruskal–Wallis H test (*) for continuous variables and Pearson Chi-Square or Fisher–Freeman–Halton test (**) for categorical variables. The different superscript letters (a, b) indicate statistically significant differences between groups based on post-hoc analysis using Dunn's test with Bonferroni correction. Groups sharing the same superscript letter do not differ significantly from each other, while groups with different letters represent statistically significant differences ($P \leq .05$). Bold *P*-values indicate statistical significance ($P \leq .05$).
ED, erectile dysfunction; eGFR, estimated glomerular filtration rate; fQRSTa, frontal QRS-T angle; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

synergistically associated with increased CAD severity, as assessed by both GS and SYNTAX score. Among the 4 study groups, Group 4, which included patients with ED and high fQRSTa, had the most adverse ECHO and angiography profiles. The median EF was significantly lower in Group 4 than in other groups.

Erectile dysfunction is a common condition, particularly in elderly, obese, or diabetic males with CAD.[6,16,21] Although some studies have questioned the relationship between ED severity and the extent of coronary involvement,[6] accumulating evidence supports ED as a reliable marker of CAD severity.[1,22] The Second Princeton Consensus Guidelines recommend that men with ED should be regarded as cardiac or vascular patients, even in the absence of overt cardiac symptoms.[23] Memon et al[4] found ED to be significantly associated with age, diabetes, hypertension, and positive exercise stress test results, reinforcing the notion that ED may be a surrogate marker for systemic atherosclerosis. Similarly, other authors have emphasized that the presence of organic ED in asymptomatic men should prompt cardiovascular risk stratification.[2] In parallel, it was found that ED independently predicts coronary atherosclerotic burden when assessed in conjunction with fQRSTa.

Öncel and Akkoç[3] reported prolonged P-wave dispersion in ED patients and a significant negative correlation between IIEF score and P-wave dispersion. They also found that fragmented QRS complexes, an established marker of myocardial scarring and ischemia, were correlated with ED.[7,24] These findings suggest that ED may signal underlying cardiac electrical instability. Atrial fibrillation, another arrhythmogenic condition, has also been associated with ED.[3,25-27] Similarly, it was found that fQRSTa, a marker of repolarization heterogeneity, is negatively correlated with erectile function, suggesting the interplay between cardiovascular electrical instability and ED.

It is important to note that there is no universally accepted cutoff value for fQRSTa, and this has been a subject of discussion in the literature. Tanriverdi et al[28] highlighted the challenges of using fixed, predefined thresholds across different patient populations. In line with this, rather than adopting a pre-existing value, we determined the optimal fQRSTa cutoff for predicting the presence of CAD in this specific patient cohort through ROC curve analysis. This approach ensures that the cutoff value of 52.5° is empirically derived and most relevant to the clinical question of this study, thereby strengthening its validity.

While prior studies have shown that ED and fQRSTa can independently predict severe CAD in separate populations,[9-11,29] this study is the first to propose using their combination as a composite screening tool for CAD. By demonstrating

Table 4. Hierarchical Regression Analysis of Erectile Dysfunction and Frontal QRS-T Angle on Coronary Artery Disease Severity

	Model 1			Model 2			Model 3			Model 4		
Variables	β	***P***	**95% CI**	β	***P***	**95% CI**	β	***P***	**95% CI**	β	***P***	**95% CI**
Gensini Score as Dependent Variable												
Main Effects												
ED presence (0 = absent, 1 = present)	16.082	**.002**	6.144-26.020	16.259	**.001**	6.429-26.090	15.663	**.002**	5.731-25.594	11.927	**.009**	2.014-21.839
High fQRSTa (0 = low <52.5°, 1 = high ≥52.5°)	13.642	**.038**	0.792-26.492	13.623	**.036**	0.917-26.329	13.279	**.042**	0.480-26.078	9.906	**.012**	2.710-22.523
ED × fQRSTa interaction	16.888	**.036**	1.094-32.682	16.338	**.040**	0.731-31.946	16.546	**.038**	0.885-32.206	17.233	**.028**	1.906-32.560
Demographic variables												
Age (years)	–			0.032	.848	−0.364 to 0.299	0.056	.758	−0.304 to 0.417	0.166	.425	−0.243 to 0.574
BMI (kg/m^2)	–			1.267	.438	−0.400 to 2.134	1.114	.149	−0.219 to 2.009	0.854	.059	−0.034 to 1.743
Cardiovascular risk factors												
Diabetes mellitus (0 = absent, 1 = present)	–			–			4.390	.264	−3.328 to 12.108	0.869	.881	−10.535 to 12.273
Hypertension (0 = absent, 1 = present)	–			–			1.523	.700	−6.257 to 9.303	3.542	.364	−4.128 to 11.212
Hyperlipidemia (0 = absent, 1 = present)	–			–			0.535	.886	−6.835 to 7.906	0.255	.944	−6.942 to 7.453
Smoking (0 = absent, 1 = present)	–			–			5.896	.135	−1.854 to 13.646	7.356	.060	−0.318 to 15.030
Laboratory parameters												
HbA1c (%)	–			–			–			1.907	.264	−1.448 to 5.261
eGFR (mL/min/1.73m^2)	–			–			–			−0.160	.168	−0.387 to 0.068
Hemoglobin (g/dL)	–			–			–			−3.209	**.003**	−5.334 to −1.085
Model statistics												
R^2		0.335			0.358			0.369			0.407	
Adjusted R^2		0.326			0.344			0.343			0.375	
ΔR^2		–			**0.023***			**0.010***			**0.038***	
F-statistic		38.95***			25.68***			14.66***			12.74***	
SYNTAX score as dependent variable												
Main effects												
ED presence (0 = absent, 1 = present)	5.524	**<.001**	2.478-8.570	5.458	**<.001**	2.421-8.495	5.005	**.001**	1.947-8.063	3.724	**.002**	0.687-6.762
High fQRSTa (0 = low <52.5°, 1 = high ≥52.5°)	4.643	**.021**	0.705-8.582	4.515	**.024**	0.589-8.440	4.645	**.021**	0.704-8.585	3.529	**.017**	0.338-7.395

(*Continued*)

Table 4. Hierarchical Regression Analysis of Erectile Dysfunction and Frontal QRS-T Angle on Coronary Artery Disease Severity (*Continued*)

	Model 1			Model 2			Model 3			Model 4		
Variables	β	***P***	**95% CI**	β	***P***	**95% CI**	β	***P***	**95% CI**	β	***P***	**95% CI**
ED × fQRSTa interaction	5.645	**.022**	0.804-10.485	5.647	**.022**	0.826-10.469	5.488	**.026**	0.667-10.310	5.864	**.015**	1.167-10.561
Demographic variables												
Age (years)	–			0.042	.415	−0.060 to 0.145	0.056	.319	−0.055 to 0.167	0.008	.899	−0.117 to 0.133
BMI (kg/m^2)	–			0.250	.067	−0.018 to 0.518	0.230	.102	−0.046 to 0.505	0.134	.332	−0.138 to 0.407
Cardiovascular risk factors												
Diabetes mellitus (0 = absent, 1 = present)	–			–			1.799	.137	−0.577 to 4.175	0.378	.831	−3.116 to 3.873
Hypertension (0 = absent, 1 = present)	–			–			0.117	.923	−2.278 to 2.512	0.741	.535	−1.609 to 3.091
Hyperlipidemia (0 = absent, 1 = present)	–			–			1.345	.244	−0.924 to 3.614	1.443	.198	−0.762 to 3.649
Smoking (0 = absent, 1 = present)	–			–			1.405	.247	−0.981 to 3.791	1.764	.141	−0.587 to 4.116
Laboratory parameters												
HbA1c (%)	–			–			–			0.528	.313	−0.500 to 1.556
eGFR (mL/min/1.73 m^2)	–			–			–			−0.023	.513	−0.093 to 0.046
Hemoglobin (g/dL)	–			–			–			−1.216	**<.001**	−1.867 to −0.565
Model statistics												
R^2		0.381			0.393			0.407			0.448	
Adjusted R^2		0.373			0.380			0.383			0.418	
ΔR^2		–			**0.012***			**0.014***			**0.041***	
F-statistic		47.61***			29.81***			17.24***			15.08***	

Model 1: Main effects and interaction only; Model 2: Model 1 + demographic variables; Model 3: Model 2 + cardiovascular risk factors; Model 4: Model 3 + laboratory parameters.
Values are presented as unstandardized regression coefficients (β) with confidence intervals (95% CI). ΔR^2 represents the change in explained variance from the previous model.
Bold *P*-values indicate statistical significance ($P \leq .05$).
BMI, body mass index; ED, erectile dysfunction; eGFR, estimated glomerular filtration rate; fQRSTa, frontal QRS-T angle; HbA1c, glycated hemoglobin; SE, standard error.
*$P < .05$.
**$P < .01$.
***$P < .001$.

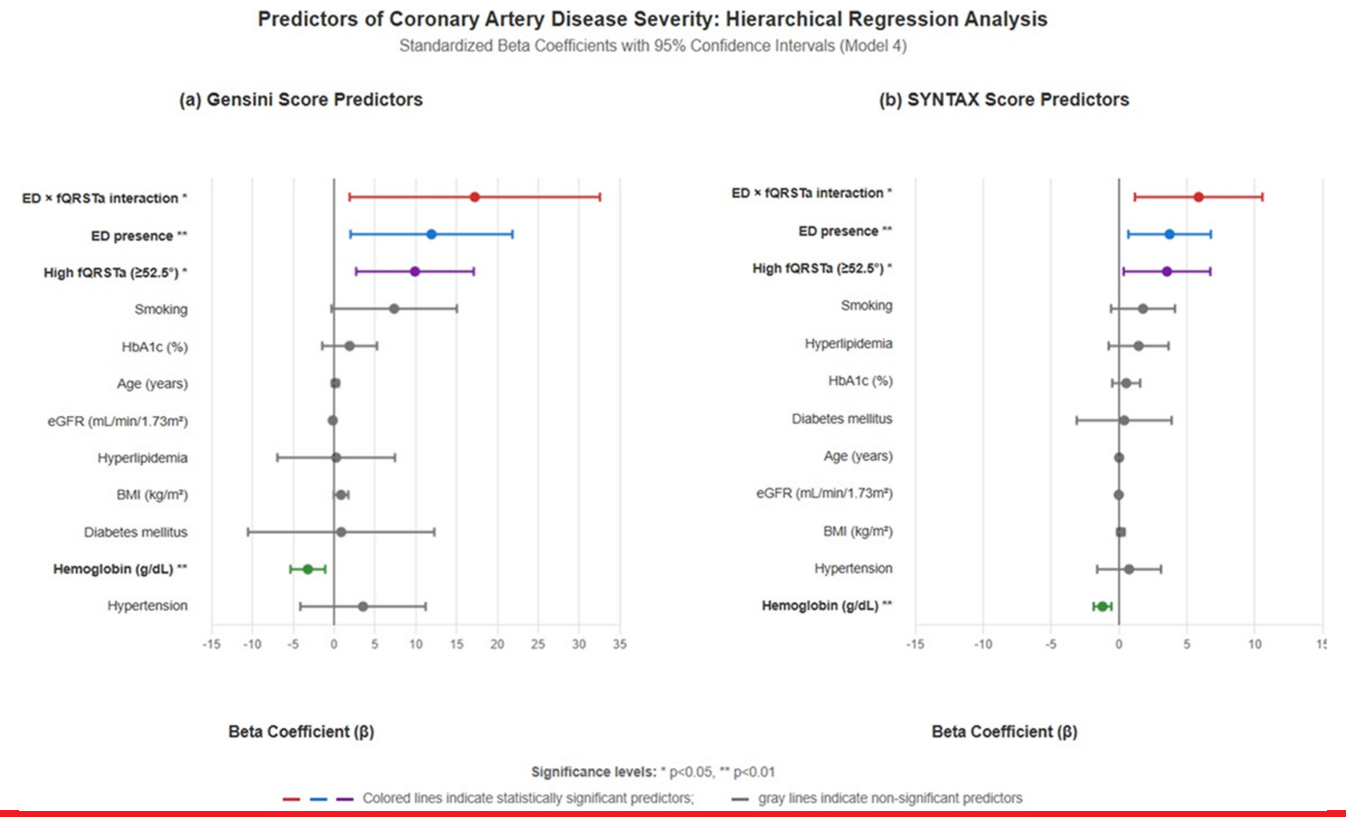

Figure 2. The hierarchical regression analysis for Model 4 shows a significant association of both erectile dysfunction and a high frontal QRS-T angle with a) Gensini score-based and b) SYNTAX score-based coronary artery disease severity.

their additive and synergistic value, a novel and practical approach is presented for enhancing CAD risk stratification. This is conceptually similar to the work of Colluoglu et al,[30] who found that the combined use of fQRSTa and platelet-to-lymphocyte ratio predicted ischemic cardiomyopathy more accurately than either parameter alone in patients with ST-elevation myocardial infarction.

Table 5. Spearman's Rank Correlations Between Frontal QRS-T Angle, IIEF-5 Score, SYNTAX Score, and Gensini Score

Correlation	n	Spearman's rho	95% CI	*P*
fQRSTa and IIEF-5 score	236	−0.436	−0.537 to −0.324	**<.001**
fQRSTa and SYNTAX score	236	0.484	0.377 to 0.579	**<.001**
fQRSTa and Gensini score	236	0.495	0.389 to 0.588	**<.001**
IIEF-5 score and SYNTAX score	236	−0.579	−0.660 to −0.485	**<.001**
IIEF-5 score and Gensini score	236	−0.597	−0.675 to −0.505	**<.001**

Interpretation of Spearman's rho values: Values range from −1 to +1, where negative values indicate inverse correlation and positive values indicate direct correlation. The magnitude indicates strength of association: 0.00-0.19 = very weak; 0.20-0.39 = weak; 0.40-0.59 = moderate; 0.60-0.79 = strong; 0.80-1.00 = very strong.
Bold *P*-values indicate statistical significance ($P \leq .05$).
fQRSTa, frontal QRS-T angle; IIEF-5, International Index of Erectile Function-5; n, number of participants.

Hierarchical regression models provided compelling evidence that the combination of high fQRSTa and ED confers a more substantial predictive value for CAD severity than either variable alone. Notably, Group 4, which comprised patients with both high fQRSTa and ED, consistently had the highest GS and SYNTAX score, even after adjustment for potentially confounding conventional cardiovascular risk factors and laboratory markers. In the final model, the interaction between ED-positivity and high fQRSTa remained significant, suggesting a synergistic effect that amplifies the likelihood of advanced coronary atherosclerosis. Group 2 and Group 3 had significantly higher CAD burden compared to Group 1, whereas Group 4 had significantly higher CAD burden than all other groups, indicating that these ED-positivity and high fQRSTa interact multiplicatively rather than additively. These findings support the clinical utility of using ED and fQRSTa in tandem, particularly for identifying high-risk patients in whom conventional risk factors may underestimate the severity of CAD. The co-occurrence of ventricular repolarization abnormalities and ED likely reflects a shared underlying pathophysiological substrate, potentially involving endothelial dysfunction, microvascular disease, or autonomic imbalance. Thus, a combined approach may enhance early detection and risk stratification in asymptomatic or minimally symptomatic male patients.

Study Limitations

This study had several limitations. First, its cross-sectional design limits the ability to make causal inferences between fQRSTa, ED, and CAD severity. Longitudinal studies are

warranted to determine whether these parameters can predict future cardiovascular events. Secondly, this study has several limitations regarding the diagnosis and prevalence of ED. The prevalence of ED in this sample (62.7%) may seem high; however, this is an expected finding within a high-risk population of male patients with suspected CAD, who share numerous common risk factors for both conditions. It is important to note that the diagnosis of ED was based solely on the IIEF-5 questionnaire. While this is a validated and widely used tool, it is subject to self-reporting bias. No additional confirmatory evaluations, such as a detailed urological examination, Doppler ultrasonography, or hormonal assessments, were performed to differentiate between organic and psychogenic causes of ED. This lack of a comprehensive diagnostic workup is a key limitation. Consequently, these results reflect the prevalence and associations within this specific study cohort, namely patients undergoing coronary angiography for suspected CAD, and should not be generalized to the broader male population, which would likely exhibit a lower prevalence and different risk profile. Thirdly, although the results were adjusted for a wide range of potentially confounding cardiovascular risk factors and laboratory markers, residual confounding from unmeasured variables such as testosterone levels, physical activity, or psychosocial stress cannot be entirely excluded. Fourthly, fQRSTa, which reflects ventricular repolarization heterogeneity, may have been influenced by unmeasured factors such as medication use, electrolyte disturbances, and autonomic tone. Lastly, the relatively small number of patients in Group 3 (n=25) may have reduced the statistical power of the relevant subgroup analyses.

CONCLUSION

These findings demonstrated that both ED and high fQRSTa are independently and synergistically associated with increased CAD severity. The combination of ED-positivity and high fQRSTa, 2 easily accessible noninvasive markers, provides incremental predictive value beyond traditional cardiovascular risk factors. Hence, simultaneous assessment of ED and fQRSTa may serve as a practical and efficient tool for identifying patients at elevated risk of severe coronary atherosclerosis, particularly in settings where early and cost-effective risk stratification is essential.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Health Sciences University, Adana City Training and Research Hospital (Approval No.: 12/458; Date: April 10, 2025).

Informed Consent: Written informed consent was obtained from all participants who agreed to take part in the study.

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