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REVIEW ARTICLE

Diagnostic Indicators of ECG for Coronary Slow Flow Phenomenon; a Systematic Review and Meta-Analysis

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Abstract: **Introduction:** Currently, epicardial coronary angiography is still the only diagnostic tool for Coronary Slow Flow Phenomenon (CSFP). This study aimed to systematically review studies that compared Electrocardiogram (ECG) findings between patients with and without CSFP. **Methods:** Using relevant key terms, we systematically searched MEDLINE, Scopus, Embase, and Web of Science to find relevant studies up to February 5th, 2023. Effect sizes in each study were calculated as mean differences and crude odds ratio; then, random-effect models using inverse variance and Mantel-Haenszel methods were used to pool standardized mean differences (SMD) and crude odds ratios, respectively. **Results:** Thirty-two eligible articles with a total sample size of 3,937 patients (2,069 with CSFP) were included. CSFP patients had higher P-wave maximum (Pmax) (SMD: 1.02 (95% confidence interval (CI): 0.29 - 1.76); p=0.006) and P-dispersion (Pd) (SMD: 1.63 (95% CI: 0.99 - 2.27); p<0.001) compared to the control group. CSFP group also showed significantly longer QT wave maximum duration (SMD: 0.69 (95% CI: 0.33 - 1.06); p<0.001), uncorrected QTd (SMD: 1.89(95% CI: 0.67 - 3.11); p=0.002), and corrected dispersion (QTcd) (SMD: 1.63 (95% CI: 1.09 - 2.17), p<0.001). The frontal QRS-T angle was significantly higher in the CSFP group in comparison with the control group (SMD: 1.18 (95% CI: 0.31 - 2.04; p=0.007). While CSFP patients had a significantly higher T-peak to T-end (Tp-e) (SMD:1.71 (95% CI: 0.91, 2.52), p<0.001), no significant difference was noted between groups in terms of Tp-e to QT (p=0.16) and corrected QT ratios (p=0.07). **Conclusion:** Our findings suggest several ECG parameters, such as P max, Pd, QT, QTc, QTd, QTcd, Tp-e, and frontal QRS-T angle, may be prolonged in CSFP patients, and they could be employed as diagnostic indicators of CSFP before angiography.

Keywords: Coronary Artery Disease; Slow Flow Phenomenon; Electrocardiography; Systematic review

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1. Introduction

Approximately 1-7 % of patients undergoing coronary angiography exhibit delayed opacification of at least one distal artery despite the absence of a significant coronary artery lesion. This phenomenon is known as the Coronary Slow Flow Phenomenon (CSFP) (1).

Patients with CSFP often present with angina at rest or during exercise; also, some studies reported mixed-pattern angina in these patients (2, 3). Frequent relapses of chest pain and impaired exercise capacity reduce these patients' quality of life (4, 5). CSFP is linked to some levels of myocardial ischemia, which may lead to Myocardial Infarction (MI), fatal ventricular arrhythmias, and sudden cardiac death (6, 7).

Recurrent symptoms were reported in nearly 80% of patients with CSFP, and approximately 20% of them were re-hospitalized within two years of their initial diagnosis (8). Furthermore, patients with CSFP may experience long-term Major Adverse Cardiac Events (MACE) (9).

Diffuse atherosclerosis and microvascular dysfunction are proposed to play a role in CSFP pathophysiology; however, the exact mechanism remains unknown (10, 11).

Currently, epicardial coronary angiography is still the only diagnostic tool for CSFP; however, it is an invasive and costly procedure (8). Thus, expanding endeavors have aimed to find less invasive and more convenient clinical predictors/diagnostic markers of CSFP (12-15). Several laboratory markers have been introduced to help diagnose CSFP before angiography, such as neutrophil to lymphocyte ratio, platelet to lymphocyte ratio, high-sensitivity C-reactive protein (hs-CRP) level, and mean platelet volume, among others; however, their diagnostic performance has not been clear yet (16-19).

Electrocardiogram (ECG) is a readily available diagnostic tool, and recent studies have introduced distinct ECG patterns as potential predictors of CSFP.

This study aimed to systematically review and compare ECG

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findings and characteristics in patients with and without CSFP.

2. Methods

2.1. Study design and setting

The present systematic review and meta-analysis was conducted according to the Preferred Reporting Items of Systematic Reviews and Meta-analyses (PRISMA) guidelines (20). As a systematic review of published studies, no institutional ethics committee approval was required. We included observational studies that compared ECG findings between CSFP and control groups. The study protocol is registered in PROSPERO (CRD42023415242).

2.2. Search strategy

We systematically searched the online databases MEDLINE, Scopus, Embase, and Web of Science up to 5th February 2023, using relevant keywords in two domains, including "Coronary slow flow phenomenon" and "Electrocardiography."

The Boolean operator "OR" connected key terms within each domain, and domains were connected by the "AND" operator, tailored for each database.

Additionally, the first 100 pages of google scholar search results and the reference lists of similar articles were screened to identify any possible additional citations that might have been missed. We presented the detailed search strategy in Supplementary Table 1.

We imported all citations from retrieved documents into EndNote software (version X9.3.2, Captivate Analytics, California USA) and removed duplicates by automated and manual deduplication process.

2.3. Study selection

Two reviewers (PS & EJA) independently screened imported articles' titles and abstracts, followed by full texts to find eligible studies. A third senior researcher's (HR) opinion was considered in case of any disagreement.

2.4. Inclusion criteria

Studies that met all of the following eligibility criteria were included:

1) Written in English

2) Adopted an observational study design that evaluated ECG findings in CSFP patients and in a comparison group with a normal coronary flow

3) Studies that provided sufficient data to calculate the effect sizes to determine the diagnostic performance of ECG findings for CSFP

2.5. Exclusion criteria

Studies were excluded if they met any of the following criteria:

1) Animal studies

2) In-vitro studies

3) Including patients who developed coronary slow-flow phenomenon after provocative interventional maneuvers in the case group

4) Including patients with angiographic findings of significant obstructive coronary artery disease in the control group

2.6. Data extraction

Data from the full-text articles were extracted into "Data extraction form" in Microsoft Excel (Version 2016, Microsoft Corp., Redmond, WA, USA).

We extracted the following data: First author's name, country, publication year, study design and population, sample size, patients characteristics, body mass index, the prevalence of coronary risk factors (such as diabetes mellitus, hypertension, dyslipidemia, and smoking), angiographic findings comprising Thrombolysis in Myocardial Infarction (TIMI) frame count of the coronary arteries, electrocardiographic findings including P wave min duration (P min), P wave max duration (P max), P wave dispersion (Pd), heart rate, PR interval, RR interval, QRS duration, QT interval, QTc interval, QT dispersion, T-peak to T-end duration (Tp-e), fragmented QRS (fQRS), frontal QRS-T angle, and ST-T changes. Any discrepancies between researchers were resolved through discussion.

2.7. Quality assessment

The quality of the included studies was assessed independently by two of our researchers (NGH & MM) using the Joanna Briggs Institute (JBI) checklist (21). JBI critical appraisal tool adopted for use in cross-sectional studies contains eight items. According to the information provided in studies, each item is rated as either "yes," "no," "unclear," or "not applicable." The maximum score is eight points, and studies that score above six points are considered high quality. A higher score indicates a lower risk of bias and higher methodological quality.

2.8. Statistical analyses

As our primary goal, we pooled the differences in ECG parameters between CSFP and control groups using a meta-analysis standard method.

We used either random-effect or fixed-effect models according to heterogeneity, size of the standardized mean differences (SMD), and crude odds ratios; the size and significance of heterogeneity were determined using I-square statistics and Q-test, respectively. We used the random-effect model if the I-square was greater than 75% or the P-value < 0.1. SMDs and odds ratios were combined using inverse variance and Mantel-Haenszel methods, respectively.

Based on data provided by included studies, we calculated SMD for all ECG features, age, TIMI frame counts, and Body Mass Index (BMI), and crude odds ratio for sex, and coronary risk factors.

Evaluated ECG features were the mean differences of P-wave

minimum and P-wave maximum durations, P-wave dispersion, QT-interval minimum and maximum durations, QT and QTc interval dispersions, QRS duration, Tp-e and its division on QT and QTc, and frontal QRS between the CSFP and control groups.

2.9. Publication bias

Publication bias was assessed using Egger's regression asymmetry test, in which a p-value less than 0.05 indicates the presence of potential bias. Meta-analyses were conducted in R Studio software (version 4.2.2.) using the R Meta package.

3. Results

3.1. Study selection process

Our comprehensive systematic search of databases yielded 1655 documents, which were imported into EndNote software. After removing duplicates (n = 512), we screened the remaining articles based on their title and abstracts (n = 1143), followed by full texts (n = 108). Finally, 32 articles met the eligibility criteria and were included in our study. The detailed selection process is depicted in figure 1.

3.2. Features of studies

The included studies were published between 2002 and 2022, and all adopted an observational study design. All studies compared the ECG findings in patients diagnosed with CSFP with those who had normal coronary angiographic features. The diagnosis of CSFP was made based on coronary angiography and evaluations of the TIMI frame counts (TFC) in all studies. Patients underwent coronary angiography due to typical chest pain, being suspected of coronary artery disease, presence of non-ST elevation acute coronary syndrome, having a positive cardiac stress test, or stable angina. The sample size of included studies ranged between 49 to 325 patients; the pooled sample size was 3937 patients, of whom 2069 were diagnosed with CSFP, and the remaining served as the control group. Detailed characteristics and main findings of each study are presented in table 1.

3.3. Quality assessment

Our quality assessment using the JBI appraisal tool revealed that all included studies scored six to eight points, indicating the high quality of all studies. Furthermore, 14 out of the 32 studies matched for confounding factors, including age, sex, and/or BMI using the frequency method (Supplementary Table 2).

3.4. Qualitative synthesis

Studies' findings regarding differences in ECG features between patients with and without CSFP were consistent in most cases. In this regard, studies all found higher values of the corrected and uncorrected P-wave dispersions (Pd), P max, QT and corrected QT interval dispersion (QTcd), Tp-e and corrected Tp-e duration, as well as frontal QRS-T angle in the CSFP group compared to the control group (table 1). 3 studies consistently found a higher frequency of fQRS in CSFP groups compared to the controls. Also, most studies reported that CSFP patients had longer QRS duration (6/7), RR interval (2/3), and QT (4/7) and QTc (7/11) intervals in comparison with the patients in the control group.

However, study findings were inconsistent regarding differences between the two groups in terms of P-wave min and PR interval durations.

Some of the included studies reported additional information regarding correlations between ECG parameters and coronary arteries' TIMI frame counts. Five studies conducted a regression model to assess the correlation between Pd and TFCs; two of them reported a significant direct correlation between Pd and the TFCs of all three coronary arteries; however, in the study by Zhuang et al. despite the presence of significant direct correlations of Pd with Left Circumflex (LCX) and mean TFCs (r = 0.291, r = 0.318, respectively), no correlation with the Left Anterior Descending Artery (LAD) and Right Cirfumferential Artery (RCA) TFCs were reported (22). Also, a significant direct correlation of Pd with LAD, LCX, and mean TFCs (r = 0.42, r = 0.4, r = 0.44, respectively) but not with RCA TFC was observed in the study by Mahmoud (23). Dogan et al. found significant correlations between Pd and P max with mean TFCs (r2 = 0.806, r2 = 0.836, respectively) (24).

QTcd and QTd were directly correlated with each of the three coronary arteries' TFCs, in one and two studies, respectively. Moreover, Mahmoud reported a significant correlation between corrected QTd and LAD, LCX, and mean TFCs, but no association was found between QTcd and RCA TFC (23).

Regarding the correlation between frontal QRS-T angle and coronary vessels TFCs, the results from studies were inconsistent; Kuyumcu et al. reported an inverse correlation between frontal QRS-T angle and mean TFC (r = - 0.496) (25), on the contrary, in the article by Isik et al. frontal QRS-T angle was directly associated with each of the three coronary arteries TFCs (6).

Furthermore, two of the three studies that evaluated correlations between fQRS and TFCs reported a significant direct correlation.

Both studies on the correlation between Tp-e and each of the three coronary arteries' TFCs found a significant direct association; also, the direct correlations of Tp-e/QT and Tpe/QTc with TFCs were observed in the study by Zehir et al. (26).

Only two studies utilized the Receiver Operating Characteristic (ROC) curve to determine the potential diagnostic value of ECG parameters in the diagnosis of CSFP. Mahfouz et al. suggested that Pd above 60 msec is associated with CSFP with 78% sensitivity and 70% specificity (13). In the Elawady et al. study, the Pd cut-off for diagnosing CSFP was 23.5 msec (sensitivity: 96.5%, specificity: 98.3%); also, they demonstrated that QTd above 46.5 msec can be a strong diagnostic factor for CSFP (area under the ROC curve (AUC): 0.99, sensitivity: 99.7%, specificity: 99.8%) (27). Further details are presented

in table 1.

3.5. Meta-analysis

We used the random-effect model to pool the effect sizes due to the presence of high heterogeneity. There was no evidence of a significant publication bias for assessed outcomes.
Study population features and ECG characteristics were pooled in each study group, separately (tables 2 & 3 and figures 2-4).

3.6. Comparison of ECG characteristics between CSFP and control groups

Based on our meta-analysis, the maximum duration of the P-wave was significantly higher in the CSFP group compared to the normal group (Pooled SMD: 1.02 (95% confidence interval (CI): 0.29, 1.76), P-value = 0.006); however, there was no difference in the minimum duration of the P-wave between two groups (P-value = 0.61). Additionally, Pd (ms) was significantly higher in the CSFP patients than in control group (Pooled SMD: 1.63 (95% CI: 0.99, 2.27), P-value: < 0.001) (Figure 2).
Similar to the P-wave, the maximum duration of the QT-interval was significantly longer in the CSFP group in comparison with the control group (Pooled SMD: 0.69 (95% CI: 0.33, 1.06), P-value = 0.0002), but its minimum duration showed no difference between groups (P-value = 0.38). Moreover, CSFP patients, compared to the control group, showed a significantly higher QT-interval dispersion (QTd) (Pooled SMD: 1.89 (95% CI: 0.67, 3.11), P-value = 0.002) and corrected QT-interval dispersion (QTcd) (Pooled SMD: 1.63 (95% CI: 1.09, 2.17), P-value ≤ 0.0001) (Figure 3).
Our meta-analysis revealed that CSFP patients had significantly higher T-wave peak to end (Tp-e) (Pooled SMD: 1.71 (95% CI: 0.91, 2.52), P-value = < 0.0001); though, there were no significant differences in the ratio of Tp-e to QT (P-value = 0.16) or QTc (P-value = 0.07) intervals between the two groups (Figure 4). Additionally, CSFP patients had significantly greater frontal QRS-T angles than control cases (Pooled SMD: 1.18 (95% CI: 0.31, 2.04), P-value = 0.007). Detailed meta-analysis results are shown in table 3.

3.7. Comparison of other potential predictors between CSFP and Control groups

Our results showed that patients with CSFP were more likely to be male (Pooled OR: 1.26 (95% CI: 1.06, 1.49), P-value = 0.006) and had a higher Body Mass Index (Pooled SMD: 0.47 (95% CI: 0.21, 0.73), P-value: 0.0004) compared to the control group (Supplementary table 3).
Furthermore, patients with CSFP, compared to normal group, were more frequently diabetics (Pooled OR: 1.32 (95% CI: 1.08, 1.6), P-value = 0.005) and current smokers (Pooled OR: 1.50 (95% CI: 1.22, 1.85), P-value = 0.0001), but there were no significant differences between groups in the prevalence of hypertension (P-value = 0.11) and dyslipidemia (P-value = 0.057).

4. Discussion

Based on our meta-analysis, patients with CSFP had significantly higher values of P max and Pd, unlike P min, compared to the control group. Regarding QT interval, corrected and uncorrected QTd, and QT max, but not QT min, were longer in CSFP patients than in the control group.
Furthermore, the frontal QRS-T angle was significantly wider in CSFP patients than in controls. Tp-e was longer in CSFP patients compared to the control group; however, no significant difference was found in Tp-e/QT and Tp-e/QTc ratios. CSFP patients were more likely to be male, diabetic, and current smokers, and they had a significantly higher BMI compared to the control group.
All included studies consistently reported higher P max, Pd, QT max, QTd, QTcd, and frontal QRS-T angel values in the CSFP group but similar P and QT min, compared to the control group.
The P wave is representative of atrial depolarization; inhomogeneous sinus impulse and atrial propagation can increase its variability (1, 13, 22-24, 27-30). A raised P dispersion (Pd), a new index defined as the difference between the maximum and minimum P wave in a 12-lead ECG, is considered an indicator of irregular atrial conduction. The included studies found that P max and Pd had a significant (direct) association with TFC, an angiographic indicator of CSFP (24, 28). Ackay et al. showed that interatrial electromechanical delay is correlated with LCX TFC but not with LAD and RCA TFC. This correlation could be due to the anatomical supply of the Left Atrium (LA) by LCX branches (28). In CSFP, atrial ischemia could prolong P max and Pd by inducing conduction disturbances such as decreased junctional conductance (28, 31).
Raised QTd indicates a heterogeneous ventricular repolarization period and ventricular electrical instability. CSFP may induce ventricular ischemia, which is supposed to explain the prolonged QT interval and increased QTd in affected patients (32). In addition, adrenalin and noradrenalin levels may increase in CSFP patients and are directly correlated with LAD and LCX TFCs (33); this autonomic imbalance (i.e., sympathetic predominance) could also explain, at least in part, the increased QTd in CSFP (34).
Evidence suggests that raised QTd is associated with fatal ventricular arrhythmias and a higher overall mortality rate (27, 34, 35); also, QTcd higher than 60 milliseconds might be a predictor of sudden cardiac death (36).
The T wave peak to end (Tp-e), representing transmural dispersion of repolarization, Tp-e/QT, and Tp-e/QTc are emerging ECG markers that could potentially predict ventricular arrhythmias (37).
Since Tp-e interval can be affected by body weight and heart rate (25), Tp-e/QT and Tp-e/QTc, which are independent of heart rate, were introduced as indices of repolarization (10, 25). The Tp-e/QT and Tp-e/QTc ratios were higher in the CSFP group compared to the control group in most studies (6, 25, 26, 36-40). Also, Karaman et al. showed that the Tp-

e/QT was an independent predictor of CSFP after adjusting for age, sex, smoking, and left ventricle volume indices (10). However, our pooled analysis failed to reach statistical significance for Tp-e/QT and Tp-e/QTc ratios. Based on available evidence, sympathovagal imbalance might also explain the changes in repolarization dispersion indices (i.e. Tp-e, Tp-e/QT, and Tp-/QTc) observed in CSFP patients (25, 40).

The QRS-T angle, defined as the angle between the electrical direction of ventricular depolarization (QRS) and repolarization (T wave), is an index of myocardial depolarization and repolarization heterogeneity (6, 25). All studies consistently found a higher QRS-T angle in CSFP patients compared to controls (6, 25, 41). The frontal QRS-T angle showed a direct correlation with TFC in studies by Isik et al. and Ozbek et al. (6, 41).

5. Limitations

Most of the included studies were conducted in the middle-east, and there were no studies from North America and Europe. Additionally, evidence was insufficient regarding some of the indices, such as the frontal QRS-T angle. The populations of the included studies were heterogeneous in terms of demographic characteristics, thus producing a high heterogeneity in our meta-analysis. Although all included studies compared the ECG parameters between the CSFP and control groups, no study compared these ECG indices between CSFP and ischemic heart disease (IHD) patients; therefore, we suggest additional studies that evaluate these indices between these two groups.

6. Conclusions

Our study suggests that several ECG parameters, such as P max, Pd, QT, QTc, QTd, QTcd, Tp-e, and frontal QRS-T angle, may be prolonged in CSFP patients compared to normal coronary flow patients. A number of these parameters were also directly correlated with TFC. So, these ECG parameters could be employed as diagnostic factors of CSFP before coronary angiography.

7. Declarations

7.1. Acknowledgments

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7.2. Conflict of interest

Authors declare no conflict of interest.

7.3. Funding

None.

7.4. Authors' contribution

[MM and HR] Came up with the idea and designed the study. [MM, PS, and AM] searched databases and screened retrieved records. [PS, EJ, and NGh] extracted the data from included studies. [MM, PS, and HR] conducted the meta-analyses. [MM, PS, NGh, and EJ] prepared the tables and [PS, EJ] conducted the quality assessment. [ShY and HR] Supervised the conduction of the study and provided specialized consultation. All authors took part in the preparation of the draft. All authors critically revised the draft and approved the final manuscript.

7.5. data availability

Data is available on request.

7.6. Impact on daily practice

The ECG findings, especially Pd, QTd, Tp-e, and frontal QRS-T angle, are valuable findings and should be measured and considered in patients suspected of CSFP.

7.7. Using artificial intelligence chatbots

We acknowledge the use of ChatGPT [https://chat.openai.com] and Grammarly [https://grammarly.com] to grammar-check our writing at the final stage of preparation.

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Table 1: Characteristics and main findings of included studies

Author	Country	Group	N	Male, n(%)	Age, year Mean (SD)	Cardiovascular risk factors, n (%)	TFC, Frame/second Mean (SD)			ECG findings†	More findings
							LAD	LCX	RCA		
Akcay et al. 2009	Turkey	Control	40	62.5 (25)	47.5 (7.4)	DM: 15 (6) Smoking: 57.5 (23)	19.9 (1.2)*	19.4 (1.7)*	17.9 (1.5)*	↑ P max ↔ $Pmin$ ↑ Pd	Interatrial electromechanical delay was directly correlated with LCX TFC (r = 0.457)* Pd was directly correlated with: LAD TFC (r = 0.575)*; LCX TFC (r = 0.429)*; RCA TFC (r = 0.382)* Pmax was directly correlated with: LAD TFC (r = 0.473)* & LCX TFC (r = 0.406)* & RCA TFC (r = 0.326)*
		Case	34	61.1 (21)	51.2 (13.2)	DM: 14.7 (5) Smoking: 58.8 (20)	40.5 (13.3)*	31.2 (10.9)*	26.1 (9.9)*		
Askin & Tanriverdi 2021	Turkey	Control	100	65 (65)	51.7 (1.4)	Smoking: 32 (32)*	41.3 (3.9)*	38.4 (2.4)*	28.4 (2.1)*	↓ RR interval ↔ $PRinterval$ ↔ $QRSduration$ ↑ QT interval ↑ QTc interval ↔ $Tp-e$ ↑ Tp-e/QTc ↑ iCEB‡ ↑ iCEBc	
		Case	100	67 (67)	52.2 (2.6)	Smoking: 48 (48)*	24.9 (2.8)*	22.2 (1.4)*	18.5 (1.4)*		
Atak et al. 2003	Turkey	Control	71	66.2 (47)	50 (8)	DM: 12.6 (9) HTN: 35.2 (25) Smoking: 35.2 (25)* Positive stress test: 22 (16)*	24 (4)*	23 (4)*	22 (3)*	↓ QTc min ↔ $QTcmax$ ↑ QTcd	QTcd was directly correlated with: LAD TFC (r = 0.686)* & LCX TFC (r = 0.527)* & RCA TFC (r = 0.558)*
		Case	49	67.3 (33)	48 (9)	DM: 12.2 (6) HTN: 36.7(18) Smoking: 53 (26)* Positive stress test: 55 (27)*	48 (16)*	51 (15)*	53 (14)*		
Cakmak et al. 2015	Turkey	Control	53	50.9 (27)	53.67 (2.88)	DM: 18.8 (10) HTN: 43.3 (23) Dlp: 37.7 (20) Smoking: 43.3 (23) Family history: 16.9 (9)	NR	NR	NR	↑ fQRS	LAD, LCX, and RCA TFCs were significantly higher in patients with fQRS compared to patients without fQRS fQRS as directly correlated with: LAD TFC (r = 0.416)* & LCX TFC (r = 0.233)* & RCA TFC (r = 0.188)* & mean TFC (r = 0.383)* fQRS is an independent predictor of CSFP (adjusted OR[95%CI] 2.66 [1.07,6.62])

Table 1: Characteristics and main findings of included studies (continue)

Author	Country	Group	N	Male, n(%)	Age, year Mean (SD)	Cardiovascular risk factors, n (%)	TFC, Frame/ second Mean (SD)			ECG findings†	More findings
							LAD	LCX	RCA		
		Case	112	65.2 (73)	53.33 (3)	DM: 20.5 (23) HTN: 56.2 (63) Dlp: 41 (46) Smoking: 27.6 (31) Family history: 30.3 (34)	NR	NR	NR		
Cutri et al. 2010	Australia	Control	20	45 (9)*	54.8 (13.5)*	DM: 5 (1) HTN: 0 (0)* Dlp: 30 (6)* Smoking: 25 (5)	NR	NR	NR	↑ Resting ST changes ↑ Inferior ST elevation ↔ *AnteriorSTelevation* ↔ *RestingTwavechange* ↔ *InferiorTwavechange* ↔ *AnteriorTwavechange* ↔ *QTcInterval* ↔ *STsegmentchange* ↑ T wave change ↑ Max ST deviation ↑ Max T wave deviation	
		Case	37	72.9 (27)*	49 (14.6)*	DM: 24.3 (9) HTN: 51.3 (19)* Dlp: 54 (20)* Smoking: 51.3 (19)	NR	NR	NR		
Dogan et al. 2008	Turkey	Control	32	24 (75)	75 (24)	DM: 12.5 (4) HTN: 37.5 (12) Smoking: 50 (16)	13.8 (3.7)*	14.7 (3)*	15 (2.4)*	↔ *Pmin* ↑ P max ↑ Pd	Mean TFC in CSFP vs. Control: 42.9 (9.2) vs. 17.3 (9.2)* P max was directly correlated with mean TFC (r2 = 0.836)* Pd was directly correlated with mean TFC (r2 = 0.806)*
		Case	48	36 (75)	75 (36)	DM: 10.4 (5) HTN: 35.4 (17) Smoking: 47.9 (23)	34.7 (7.2)*	34.4 (8.5)*	35.2 (7.8)*		
Elawady et al. 2022	Egypt	Control	100	52 (52)	51.5 (8.73)	DM: 32 (32) HTN: 50 (50) Dlp: 20 (20) Smoking: 36 (36) CAD: 34 (34) Family history: 26 (26)	14.5 (2.3)*	11.7 (1.4)*	11.4 (1.4)*	↑ QTd ↑ Pd	Mean TFC in CSFP vs. Control: 20.8 (2.71) vs. 1106 (1.05)* QTd was directly correlated with Pd (r = 0.862)* QTd was directly correlated with: LAD TFC (r = 0.58)* & LCX TFC (r = 0.716)* & RCA TFC (r = 0.7)* ROC curve Analysis Results:

Table 1: Characteristics and main findings of included studies (continue)

Author	Country	Group	N	Male, n(%)	Age, year Mean (SD)	Cardiovascular risk factors, n (%)	TFC, Frame/second Mean (SD)			ECG findings†	More findings
							LAD	LCX	RCA		
											- QTd: AUC: 0.996 [0.986,1]*, Cutoff : >46.5 ms, Sensitivity: 99.75%, Specificity: 99.8% - Pd: AUC: 0.99 [0.977,1]*, Cutoff : >23.5 ms, Sensitivity: 96.55%, Specificity: 98.3%
		Case	100	64 (64)	47.78 (12)	DM: 32 (32) HTN: 58 (58) Dlp: 16 (16) Smoking: 46 (46) CAD: 24 (24) Family history:34 (34)	23.6 (5.3)*	20.2 (4.8)*	20 (4.8)*		
Eshraghi et al. 2018	Iran	Control	40	NR	53.8 (9.7)	DM: 15 (6) HTN: 37.5 (15) Smoking: 25 (10) Dlp: 32.5 (13)	17.5 (2.5)*	12.7 (2.5)*	12 (2.6)*	↑ QTd ↑ Pd	Pd was directly correlated with: LAD TFC (r = 0.444)* only in CSFP group & LCX TFC (r = 0.556)* only in CSFP group & RCA TFC (r = 0.613)* only in CSFP group QTd was directly correlated with: LAD TFC (r = 0.489)* only in CSFP group & LCX TFC (r = 0.668)* only in CSFP group & RCA TFC (r = 0.508)* only in CSFP group None of above correlations were statistically significant in control group
		Case	47	NR	51.6 (7.3)	DM: 19.1 (9) HTN: 36.1 (17) Smoking: 29.8 (14) Dlp:31.9 (15)	29.5 (8.2)*	21.9 (6.6)*	21 (9.5)*		
Isık et al. 2021	Turkey	Control	103	45.6 (47)	49.8 (9.3)	DM: 6.8 (7) HTN: 4.9 (5) Smoking: 24.3 (25)	21.9 (1)	18 (0.6)	17 (1)	↑ Tp-e ↑ Tp-ec ↔ $QTInterval$ ↔ QTc ↑ Tp-e/QT ↑ Tp-e/QTc ↑ Tp-ec/QT ↑ Tp-ec/QTc ↑ Frontal QRS-T angle	Frontal QRS-T angle was directly correlated with: LAD TFC (r = 0.34)* & LCX TFC (r = 0.262)* & RCA TFC (r = 0.247)* Frontal QRS-T angle was significantly higher in multi-vessel CSFP compared to single-vessel CSFP (p = 0.039)* Tp-e, Tp-ec, QT Interval, QTc, Tp-e/QT, Tp-e/QTc, Tp-ec/QT were similar between multi- and single-vessel CSFP patients
		Case	97	52.5 (51)	51.6 (9.7)	DM:9.3 (9) HTN: 8.2 (8) Smoking: 30.9 (30)	36.2 (0.8)	26.1 (0.8)	26.9 (0.6)		

Table 1: Characteristics and main findings of included studies (continue)

Author	Country	Group	N	Male, n(%)	Age, year Mean (SD)	Cardiovascular risk factors, n (%)	TFC, Frame/second Mean (SD)			ECG findings†	More findings
							LAD	LCX	RCA		
Karamanet al. 2014	Turkey	Control	51	47 (24)	52.8 (9.1)	DM: 11.7 (6) HTN: 29.4 (15) Dlp: 33.3 (17) Smoking: 25.4 (13) 35 (2.2)*	22 (2.2)*	21.9 (1.4)*	↑ QT Interval ↑ QTD ↑ QTc ↑ QTcd ↑ Tp-e ↑ Tp-e/QT ↑ Tp-e/QTc	Multivariate Logistic Regression: (Adjusted for age, sex, smoking, and left ventricle volume indices) - Tp-e	Tp-e/QT were independent predictors of CSFP (Adjusted OR [95%CI] 1.21 [1.11,1.32], 1.13 [1.04,1.19], respectively)*
		Case	50	56 (28)	52.9 (10.3)	DM: 20 (10) HTN: 42 (21) Dlp: 38 (19) Smoking: 22 (11)	50.8 (5.8)*	29 (3.1)*	30.3 (2.4)*		
Zhuang et al. 2016	China	Control	66	65 (43)	55.9 (10)	DM: 16.6 (11) HTN: 37.8 (25) Dlp: 24.4 (16) Smoking: 18.1 (12) Family history: 16.7 (11)	20.6 (3.90*	19.9 (4.1)*	20.7 (4)*	↔ $Pmin$ ↑ P max ↑ Pd	Mean TFC in CSFP vs. Control: 36.4 (7.5) vs. 20.4 (3)* CV of TFC was significantly higher in CSFP patients compared to control group P max was directly correlated with: LCX TFC (r = 0.244)* & Mean TFC (r = 0.318)* & CV of TFC (r = 0.506)* Pd was directly correlated with: LCX TFC (r = 0.291)* & Mean TFC (r = 0.307)* & CV of TFC (r = 0.579)* P min was not correlated with TFCs P max and Pd were not correlated with LAD and RCA TFCs
		Case	72	66.6 (48)	56.7 (10.2)	DM: 20.8 (15) HTN: 41.6 (30) Dlp: 19.4 (14) Smoking: 20.8 (15) Family history: 12.5 (9)	36.6 (10.1)*	35.2 (12.8)*	37.5 (11.2)*		
Zehir et al. 2015	Turkey	Control	33	57.5 (19)	49.8 (5)	DM: 21.2 (7) Smoking: 45.4 (15)	23.6 (2.4)	23.2 (2.2)	24.9 (2)	↑ Tp-e ↔ $QTInterval$ ↔ QTc ↑ Tp-e/QT ↑ Tp-e/QTc	Tp-e was directly correlated with: LAD TFC (r = 0.63)* & LCX TFC (r = 0.64)* & RCA TFC (r = 0.58)* Tp-e/QT was directly correlated with: LAD TFC (r = 0.59)* & LCX TFC (r = 0.62)* & RCA TFC (r = 0.59)* Tp-e/QTc was directly correlated with: LAD TFC (r = 0.51)* & LCX TFC (r = 0.46)* & RCA TFC (r = 0.45)*
		Case	33	54.5 (18)	51.6 (4.2)	DM: 27.2 (9) Smoking: 48.5 (16)	47.4 (8)	47.1 (8.6)	50.3 (8.9)		

Table 1: Characteristics and main findings of included studies (continue)

Author	Country	Group	N	Male, n(%)	Age, year Mean (SD)	Cardiovascular risk factors, n (%)	TFC, Frame/second Mean (SD)			ECG findings†	More findings
							LAD	LCX	RCA		
Tenekecioglu et al. 2015	Turkey	Control	40	57.5 (23)	47.8 (12.5)	DM: 7.5 (3) Dlp: 15 (6) Smoking: 35 (14)	17 (1.5)*	20 (2.4)*	19 (1.7)*	↔ $QTInterval$ ↔ QTc ↑ Tp-e ↑ Tp-e/QT ↑ Tp-e/QTc	Mean TFC in CSFP vs. Control: 23 (5) vs. 19 (1.7)*
		Case	50	80 (40)	48.6 (12.5)	DM: 6 (3) Dlp: 38 (19) Smoking: 44 (22)	20 (5.4)*	24 (7.8)*	26 (8.7)*		
Suner & Cetin. 2016	Turkey	Control	30	70 (21)	51.5 (4.5)	DM: 30 (9) HTN: 23.3 (7) Smoking: 33.3 (10)	29.9 (5.1)	20.5 (2.7)	19.7 (1.7)	↑ Pdc ↑ QTcd ↑ Tp-ec ↑ Tp-e/QT	Mean TFC in CSFP vs. Control: 37.7 (7.4) vs. 22.8 (2.1)*
		Case	30	63.3 (19)	51.3 (8.9)	DM: 33.3 (10) HTN: 30 (9) Smoking: 46.6 (14)	49.8 (13.5)	31.6 (10.7)	39.9 (8.2)		
Sucu et al. 2018	Turkey	Control	45	71 (32)	50.8 (10.8)*	NR	NR	NR	NR	↑ RR Interval ↑ PR Interval ↑ QRS Duration ↑ T Wave Duration ↑ inferior ERP , ↑ lateral ERP ↑ inferolateral ERP ↔ $SlurringPattern$ ↑ Notching Pattern ↑ Ascendant ST Segment ↔ $Horizontal/non-ascendantST$ ↑ Horizontal/non-ascendant ST and notching ↑ Negative T Wave ↑ J-point elevation 2mm ↔ $J-pointelevation2mm$ ↔ $fQRS$	
		Case	115	71.3 (82)	51.9 (11.5)*	NR	NR	NR	NR		
Kuyumcu et al. 2019	Turkey	Control	60	60 (36)	54.9 (9.5)	DM: 15 (9) HTN: 33.3 (20) Dlp: 31.6 (19) Smoking: 36.6 (22)* Family history:11.7 (7)	39 (10)	28 (7)	29 (7)	↔ QT ↔ QTc ↑ Tp-e ↓ Tp-e/QT ↓ Tp-e/QTc ↑ fQRS	Mean TFC in CSFP vs. Control: 32 (6) vs. 14 (4)* Frontal QRS-T angle was inversely correlated with mean TFC (r = - 0.496)*
		Case	60	58.3 (35)	55.8 (8.9)	DM: 16.6 (10) HTN: 31.6 (19) Dlp: 36.6 (22) Smoking: 55 (33)* Family history: 18.3 (11)	17 (4)	12 (5)	12 (4)		

Table 1: Characteristics and main findings of included studies (continue)

Author	Country	Group	N	Male, n(%)	Age, year Mean (SD)	Cardiovascular risk factors, n (%)	TFC, Frame/second Mean (SD)			ECG findings†	More findings
							LAD	LCX	RCA		
Mahfouz et al. 2014	Egypt	Control	50	52 (26)	52.3 (7.9)	DM: 48 (24)* HTN: 58 (29) Smoking: 22 (11)*	NR	NR	NR	↔ $Pmin$ ↑ Pmax ↑ Pd ↔ $QTcmax$ ↓ QTcmin ↑ QTcd	ROC curve: - Pd: AUC: 0.74 [0.64,0.84]*, Cutoff: > 60 ms, Sensitivity: 78%, Specificity: 70%
		Case	50	68 (34)	49.6 (7.8)	DM: 70 (35)* HTN: 42 (21) Smoking: 60 (30)*	NR	NR	NR		
Mahmoud 2013	Egypt	Control	30	40 (12)	60.5 (5.5)	Smoking: 30 (9)	16.6 (1.2)*	15.6 (1.2)*	14 (1.2)*	↔ $Pmin$ ↑ Pmax ↑ Pd ↑ QTc ↑ QTD ↑ QTcd	Pd was directly correlated with: LAD TFC (r = 0.42)* & LCX TFC (r = 0.4)* & Mean TFC (r = 0.44)* Pd was not significantly correlated with RCA QTcd was directly correlated with: LAD TFC (r = 0.54)* & LCX TFC (r = 0.7)* & Mean TFC (r = 0.5)* QTcd was not significantly correlated with RCA
		Case	35	37.1 (13)	58.4 (6.7)	Smoking: 28.6 (10)	42.4 (2.4)*	32.9 (1.8)*	29.4 (5.4)*		
Nough et al. 2018	Iran	Control	43	58.1 (25)	52.8 (8.5)	DM: 32.5 (14) HTN: 44.2 (19) Smoking: 34.9 (15) Positive stress test: 44.2 (19)	29.8 (6.6)*	20.3 (1.9)*	21 (2)*	↑ Total filtered QRS duration114ms ↔ $Voltageinthelast40ms <$ 20mcv ↑ Late potential duration below 40 mcv>38 ms	Mean TFC in CSFP vs. Control: 42.8 (13.4) vs. 23.7 (2.8)*
		Case	43	62.8 (27)	53.7 (8.3)	DM: 37.2 (16) HTN: 51.1 (22) Smoking: 41.9 (18) Positive stress test: 44.2 (19)	55.8 (14.1)*	32.4 (10.9)*	38.2 (15.1)*		
Özbek 2021	Turkey	Control	50	86 (43)	56.5 (10.1)	DM: 18 (9) HTN: 74 (37) Dlp: 52 (26) Smoking: 32 (16) Family history: 28 (14)	20.5 (4.4)*	19.3 (4.9)*	20.2 (4.7)*	↔ $PRInterval$ ↔ $QRSDuration$ ↑ QTc ↔ $QRSAxis$ ↔ $TwaveAxis$ ↑ Frontal QRS-T angle	Mean TFC in CSFP vs. Control: 43.93 (9.56) vs. 20 (4.1)* fQRS was directly correlated with Mean TFC (r = 0.618)* Multivariate logistic Regression: Frontal QRS-T angle (Adjusted OR [95%CI] 1.04 [1.01,1.06])
		Case	76	85.5 (65)	58.4 (9.2)	DM: 28.9 (22) HTN: 76.3 (58) Dlp: 64.5 (49) Smoking: 34.2 (26) Family history: 27.6 (21)	44.7 (11.3)*	42.1 (9.4)*	40.8 (8.5)*		

Table 1: Characteristics and main findings of included studies (continue)

Author	Country	Group	N	Male, n(%)	Age, year Mean (SD)	Cardiovascular risk factors, n (%)	TFC, Frame/second Mean (SD)			ECG findings†	More findings
							LAD	LCX	RCA		
Rashidinejad et al. 2017	Iran	Control	57	42.1 (24)	54.4 (6.7)	DM: 26.3 (15) HTN: 43.8 (25) Dlp: 17.5 (10) Smoking: 10.5 (6)	NR	NR	NR	↔ *Rhythm* ↔ *Axis* ↔ *PRInterval* ↔ *QRSDuration* ↓ Old MI ↔ *RBBB* ↔ *LBBB* ↔ *Pchange* ↔ *LongPR* ↔ *WideQRS* ↔ *STchange* ↔ *Tchange*	
		Case	105	54.3 (57)	51.8 (9.9)	DM: 17.1 (18) HTN: 40.9 (43) Dlp: 14.3 (15) Smoking: 19 (20)	NR	NR	NR		
Sen et al. 2016	Turkey	Control	100	53 (53)	52.4 (8.6)	DM: 25 (25)* HTN: 48 (48) Dlp: 17 (17) Smoking: 51 (51)* Family history: 39 (39)*	22.9 (5)*	19.6 (5)*	22.9 (5)*	↑ Tp-e tail ↑ Tp-e tangent ↔ *QRSDuration* ↔ *QTInterval* ↔ *QTc* ↑ Tp-e tail / QT ↑ Tp-e tangent / QT	Tp-e tail was directly correlated with: LAD TFC (r = 0.62)* & LCX TFC (r = 0.58)* & RCA TFC (r = 0.64)* 24 hour ECG Holter: ↑ Ventricular Extra Systole ↑ Episodes of non-sustained VT
		Case	100	51 (51)	53.4 (10)	DM: 38 (38)* HTN: 62 (62) Dlp: 18 (18) Smoking: 80 (80)* Family history: 56 (56)*	48.1 (11)*	34.4 (10)*	26.4 (9)*		
Sezgin et al. 2007	Turkey	Control	25	64 (16)	47 (7)	NR	36 (3)*	19 (2)*	21 (3)*	↔ *QRSDuration* ↑ QTc ↑ QTd ↑ QTcd	
		Case	24	66.6 (16)	47 (8)	NR	58 (10)*	40 (9)*	38 (9)*		
Sucu et al. 2016	Turkey	Control	45	71.1 (32)*	50.8 (11.7)*	NR	NR	NR	NR	↔ *Pwaveamplitude* ↔ *PRInterval* ↔ *QTInterval* ↑ RR Interval ↑ QRS Duration ↑ T Wave Duration ↑ Tp-e ↔ *QTmax* ↔ *QTmin* ↔ *QTc* ↑ QTd ↔ *QTI* ↔ *QTcI* ↔ *JTmax* ↔ *JTmin* ↔ *JTd* ↑ JTc ↔ *JTI* ↑ JTcI ↑ Tp-e/QT ↑ Tp-e/QTc	

Table 1: Characteristics and main findings of included studies (continue)

Author	Country	Group	N	Male, n(%)	Age, year Mean (SD)	Cardiovascular risk factors, n (%)	TFC, Frame/second Mean (SD)			ECG findings†	More findings
							LAD	LCX	RCA		
		Case	115	71.3 (82)*	51.9 (11.5)*	NR	NR	NR	NR		
Amirzadegan et al. 2017	Iran	Control	244	38.5 (94)*	55 (9.5)	DM: 19.3 (47) HTN: 41.8 (102) Dlp: 69.7 (170) Smoking: 15.6 (38) Family history: 19.3 (47)	NR	NR	NR	↔ *PathologicS/Change*	
		Case	81	63 (51)*	53.3 (10.7)	DM: 18.5 (15) HTN: 35.8 (29) Dlp: 72.8 (59) Smoking: 21 (17) Family history: 23.5 (19)	NR	NR	NR		
Beltrame et al. 2002	Australia	Control	47	44.7 (21)*	55 (11)*	DM: 6.3 (3) HTN: 46.8 (22) Dlp: 17 (8) Smoking: 8.5 (4)* Family history: 41 (19) Positive stress test: 39 (11)	35 (10)*	25 (8)*	27 (11)*	↑ ST/T Changes	
		Case	47	68.1 (32)[8]	50 (10)*	DM: 10.6 (5) HTN: 38.3 (18) Dlp: 31.9 (15) Smoking: 31.9 (15)* Family history: 41 (19) Positive stress test: 19 (6)	92 (47)*	50 (24)*	58 (30)*		
Guntekin et al. 2011	Turkey	Control	25	56 (14)	53.9 (9.3)	DM: 12 (3) HTN: 32 (8) Smoking: 20 (5)	29.6 (1.5)*	24.7 (1.4)*	22.8 (1.7)*	↔ *QTcmin* ↑ QTcmax ↑ QTcd	
		Case	32	62.5 (20)	56.5 (12.2)	DM: 25 (8) HTN: 43.7 (14) Smoking: 28.1 (9)	38.5 (13.3)*	41.7 (11.6)*	49 (28.5)*		
Seyiz 2018	Turkey	Control	110	56.4 (62)	56.6 (6.7)	Smoking: 28.1 (31)	16.7 (1.1)*	15 (0.8)*	14.1 (0.8)*	↑ RWPT V1 ↑ RWPT V6 ↑ Pd	Mean TFC in CSFP vs. Control: 36 (5.3) vs. 15.2 (0.6)* RWPT V1 was directly correlated with: LAD TFC (r = 0.8)* & LCX TFC (r = 0.89)* & RCA TFC (r = 0.84)* & Mean TFC (r = 0.91)* RWPT V6 was directly correlated with: LAD TFC (r = 0.91)* & LCX TFC (r = 0.93)* & RCA TFC (r = 0.8)* & Mean TFC (r = 0.93)*
		Case	110	52.7 (58)	56.3 (7.5)	Smoking: 34.5 (38)	42.2 (8.6)*	34.9 (5.1)*	31 (2.8)*		

Table 1: Characteristics and main findings of included studies (continue)

Author	Country	Group	N	Male, n(%)	Age, year Mean (SD)	Cardiovascular risk factors, n (%)	TFC, Frame/second Mean (SD)			ECG findings†	More findings
							LAD	LCX	RCA		
Simsek et al. 2016	Turkey	Control	38	86.8 (33)	49.9 (8.8)	DM: 0 (0) HTN: 21 (8) Smoking: 28.9 (11)	23.8 (4.7)	22.2 (3.3)	21.6 (3.4)	$\leftrightarrow QTcmin$ ↑ QTcmax ↑ QTcd	QTcd was directly correlated with CSFP (r = 0.496)*
		Case	67	56.7 (38)	53.3 (9.9)	DM: 5.9 (4) HTN: 13.4 (9) Smoking: 40.3 (27)	49.9 (18.9)	50.7 (19.7)	53.7 (25.4)		
Turkmen et al. 2007	Turkey	Control	36	61.1 (22)	47 (7)	NR	NR	NR	NR	$\leftrightarrow Pmin$ ↑ Pmax ↑ Pd	
		Case	40	65 (26)	50 (8)	NR	NR	NR	NR		
Gumrokcuoglu et al. 2011	Turkey	Control	40	NR	NR	NR	NR	NR	NR	↑ Pmax ↑ Pd ↑ QTc ↑ QTcd	
		Case	50	NR	NR	NR	NR	NR	NR		
Yilmaz et al. 2014	Turkey	Control	44	50 (22)	53.2 (8.5)	DM: 13.6 (6) HTN: 31.8 (14)* Smoking: 27.3 (12) Family history: 27.3 (12)	19.8 (2)	20.7 (3.5)	19.2 (2.3)	↑ fQRS	fQRS presence was not correlated with LAD, LCX, or RCA TFC Multivariate logistic Regression: CSFP was an independent predictor of fQRS (Adjusted OR [95%CI] 1085 [2.38,49.35])
		Case	60	56.6 (34)	55.7 (10.7)	DM: 25 (15) HTN: 68.3 (41)* Smoking: 18.3 (11) Family history: 26.7 (16)	28.4 (9.3)	29.9 (9.3)	30.3 (9.8)		

* shows statistical significance (P value < 0.05). † The arrow direction shows significant differences in electrocardiography (ECG) findings between CSFP patients and controls, with upward arrows indicating higher values in CSFP patients and downward arrows indicating lower values. ‡ iCEB = QT/QRS, iCEBc = QTc/QRS. AUC: Area Under the Curve, 95%CI: 95% Confidence Interval, CSFP: Coronary slow flow phenomenon; CV: Coefficient of Variation; Dlp: Dyslipidemia; DM: Diabetes mellitus; ERP: Early repolarization pattern; fQRS: Fragmented QRS;HTN: Hypertension; CAD: coronary artery disease; iCEB: Index of cardiac electrophysiological balance; JTI: JT interval index; JTc: Corrected JT interval; JTcI: Corrected JT interval index; JTd: JT interval dispersion; LAD: Left anterior descending; LBBB: Left bundle branch block; LCX: Left circumflex; MI: Myocardial infarction; N: Number; NR: Not reported; OR: Odds Ratio; P max: P-wave maximum duration; P min: P-wave minimum duration; Pdc: Corrected P-wave dispersion; Pd: P-wave dispersion; QTc: Corrected QT interval; QTcI: Corrected QT interval index; QTcd: Corrected QT interval dispersion; QTI: QT interval index; QTd: QT interval dispersion;RBBB: Right bundle branch block; RCA: Right coronary artery; ROC curve: Receiver Operating Characteristic curve; RWPT: R-wave peak time; SD: Standard deviation; TFC: TIMI frame count; Tp-e: T-wave peak to end; Tp-ec: Corrected T peak to end.

Table 2: Characteristics, coronary risk factors prevalence, and angiography findings of patients with and without coronary slow flow phenomenon (CSFP)

Characteristics	N	CSFP		No-CSFP		P value
		Cases (n)	Findings	Cases (n)	Findings	
Mean age (years)	31	2019	52.5 (51.5, 53.6)	1828	52.4 (51.3, 53.5)	0.897
Male (%)	30	1972	62 (57.6, 66.2)	1788	56.9 (51.9, 61.7)	0.006
Mean BMI, (m/kg^2)	18	1030	27.6 (26.8, 28.3)	908	26.7 (25.9, 27.5)	< 0.001
Diabetes mellitus	23	1383	21.3 (16.6, 27)	1334	17 (13.2, 21.5)	0.01
Hypertension	23	1531	31.4 (19.3, 46.7)	1406	26.9 (16.6, 40.4)	0.118
Dyslipidemia	12	890	35.1 (24.8, 46.9)	888	29 (20.7, 39.1)	0.07
Smoking	28	1749	37.1 (30.8, 43.8)	1702	28.5 (23.8, 33.6)	< 0.001
Mean LAD TFC	23	1364	41.2 (35.2, 47.2)	1278	24.6 (21.3, 28)	0.004
Mean LCX TFC	23	1364	33.5 (29.3, 37.7)	1278	20.5 (18.2, 22.8)	0.003
Mean RCA TFC	23	1364	34.1 (29.1, 39)	1278	19.6 (17.6, 21.6)	0.001

Data are presented with 95% confidence interval. N: Number of available studies; LAD: Left anterior descending; LCX: Left circumflex; n: Number; RCA: Right coronary artery; TFC: TIMI frame count; BMI: Body mass index. Analyses were done using random-effect model.

Table 3: Electrocardiography (ECG) characteristics of patients with and without coronary slow flow phenomenon (CSFP)

ECG parameters	N	CSFP		No-CSFP		P value
		Cases (n)	Findings	Cases (n)	Findings	
HR (/minute)	19	1246	74.2 (72, 76.4)	1032	73.7 (71.5,76)	0.266
P-wave max (ms)	7	309	112.7 (101.4, 123.9)	284	101.5 (93.2, 109.8)	0.006
P-wave min (ms)	7	309	80.1 (64.9, 95.2)	284	78.4 (67.5, 89.3)	0.616
P-wave dispersion (ms)	11	616	41.5 (36.5, 46.6)	574	26.5 (21.2, 31.7)	< 0.001
QT interval min (ms)	3	214	376.2 (356.9, 395.6)	108	368.5 (361, 376)	0.388
QT interval max (ms)	4	264	429.3 (402, 456.5)	148	402.9 (386.7, 419)	< 0.001
QT dispersion (ms)	7	401	52 (33.3, 70.7)	321	30.3 (23.9, 36.7)	0.002
QTc dispersion (ms)	9	387	56.2 (44.1, 68.2)	360	38.7 (30.7, 46.6)	< 0.001
QRS duration (ms)	7	695	94.1 (91.2, 96.9)	466	88.8 (83.5, 94)	0.023
T wave peak/end (ms)	9	635	93.4 (83.7, 103)	562	81.7 (74.9, 88.5)	< 0.001
T wave peak to /end/QT	8	535	0.24 (0.21, 0.27)	462	0.21 (0.19, 0.24)	0.163
T wave peak to/end/ QTc	7	505	0.2 (0.18, 0.23)	432	0.18 (0.15, 0.20)	0.075
Frontal QRS-T angle	3	233	55.3 (44.3, 66.4)	213	37.1 (29.4, 44.7)	0.008

Data are presented with 95% confidence interval. N: Number of available studies; LAD: Left anterior descending; LCX: Left circumflex; n: Number; RCA: Right coronary artery; TFC: TIMI frame count; BMI: Body mass index. Analyses were done using random-effect model.

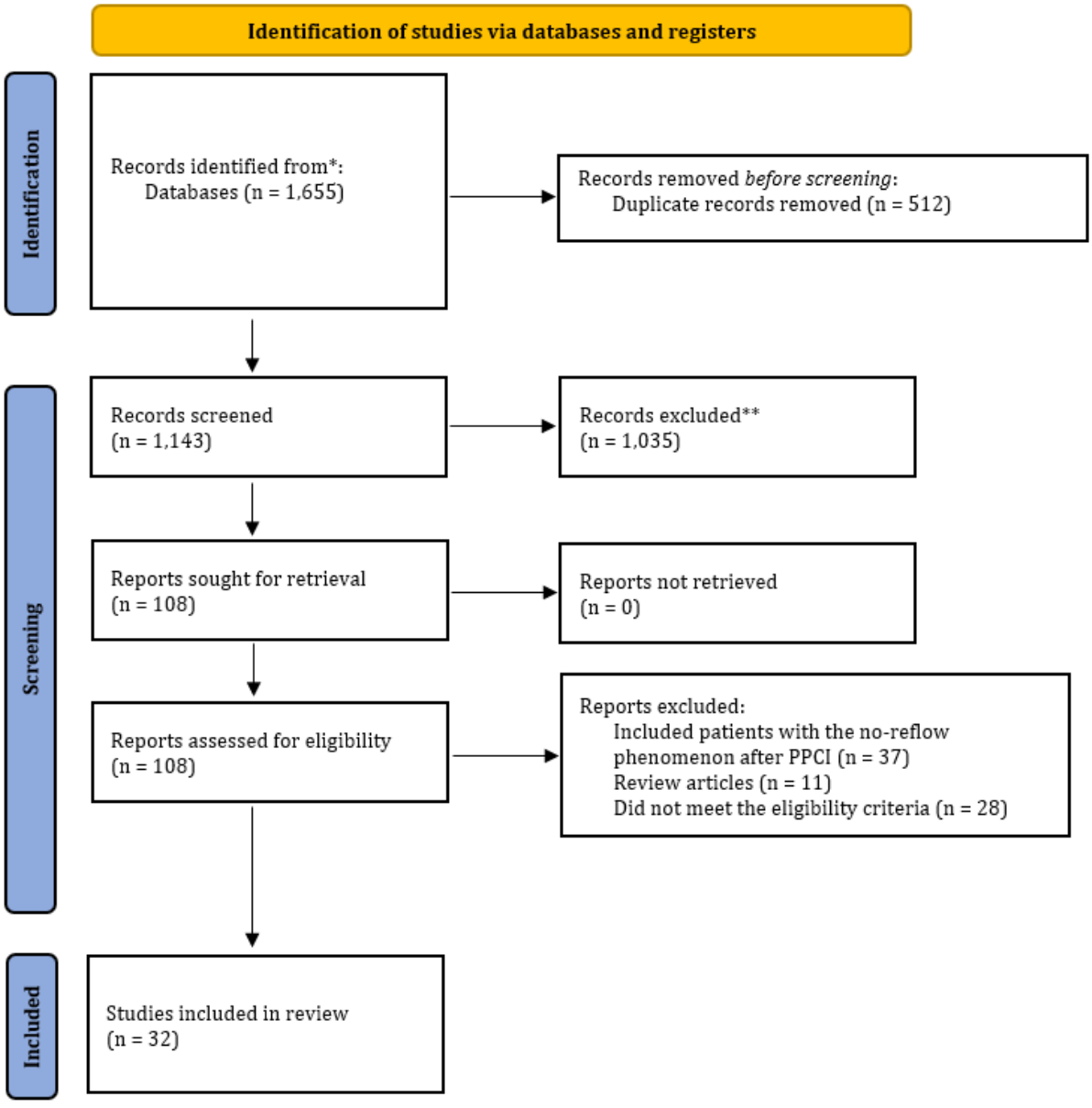

Figure 1: PRISMA 2020 flow diagram for new systematic reviews, which included searches of databases and registers only. PPCI: Primary Percutaneous Coronary Intervention.

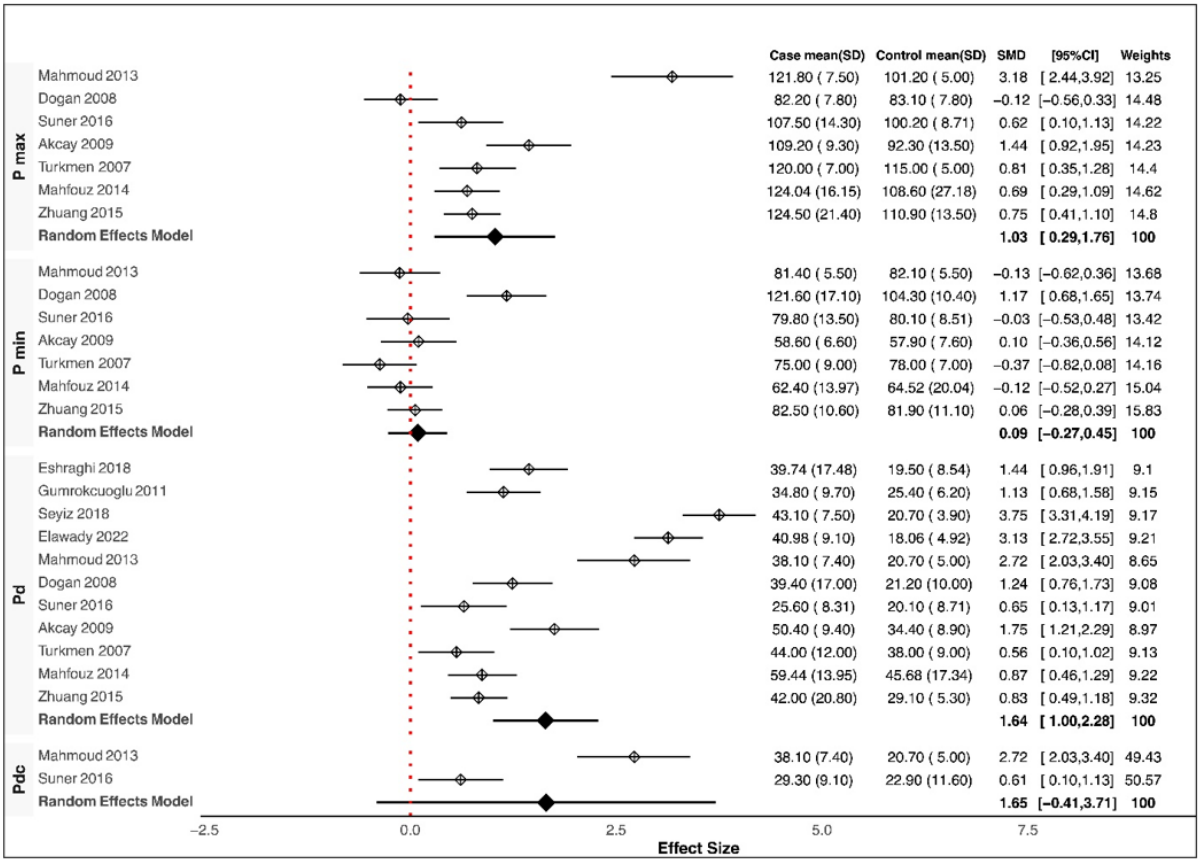

Figure 2: Forest plots showing the standardized mean differences (SMDs) of P-wave-related parameters using the random-effect model between Coronary Slow Flow Phenomenon (CSFP) and control groups. Heterogeneity (I^2): P wave max duration (P max): 90.41%, P wave min duration (P min): 76.13%, P-dispersion (Pd): 95.54%, Corrected P-wave dispersion (Pdc): 95.68%. CI: confidence interval; SD: standard deviation.

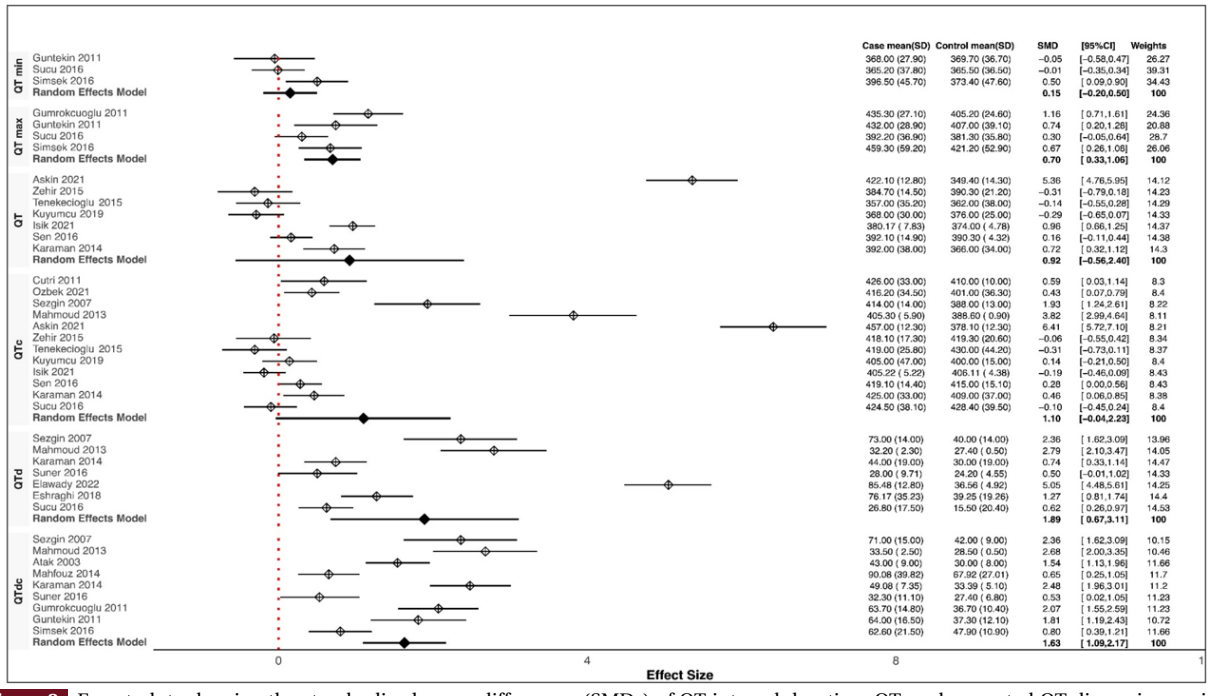

Figure 3: Forest plots showing the standardized mean differences (SMDs) of QT interval duration, QT, and corrected QT dispersions using the random-effect model between Coronary Slow Flow Phenomenon (CSFP) and control groups. Heterogeneity (I^2): QT min: 52.8%, QT max: 66.56%, QT: 98.06%, Corrected QT interval (QTc): 97.38%, QT interval dispersion (QTd): 97.28%, Corrected QT interval dispersion (QTcd): 89.68. CI: confidence interval; SD: standard deviation.

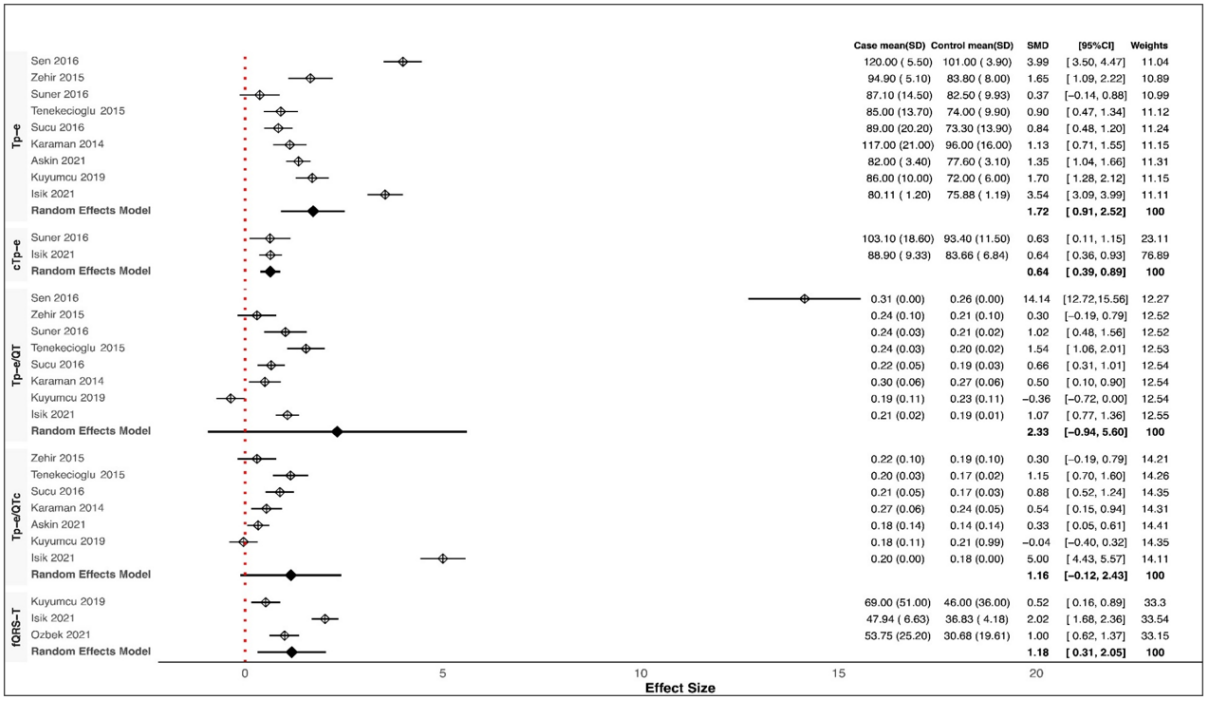

Figure 4: Forest plots showing the standardized mean differences (SMDs) of T-peak to T-end (Tp-e)and its division on QT and corrected QT intervals and fronal QRS-T angle using the random-effect model between Coronary Slow Flow Phenomenon (CSFP) and control groups. Heterogeneity (I^2): Tp-e: 96.43%, cT-e: 0%, Tp-e/QT: 98.24%, Tp-e/QTc: 97.62%, fragmented QRS (fQRS)-T: 94.52%. CI: confidence interval; SD: standard deviation; QTc: Corrected QT interval.

Supplementary table 1: Detailed systematic search strategy (searched on February 5^{Th})

Question	**What are the electrocardiography (ECG) characteristics of patients with coronary slow flow phenomenon (CSFP)?**
Research title	ECG characteristics of patients with the coronary slow flow phenomenon: A systematic review and meta-analysis
PICOT	P: Patients who were diagnosed with CSFP E: ECG characteristics/findings C: Patients with normal coronary angiography O: Differences in ECG patterns between the CSFP and control group T: Observational studies
Keywords	Coronary slow flow phenomenon, CSFP, Angiographic slow flow, Electrocardiography, ECG, Systematic review, Meta-analysis, TFC
Strategy	Scopus: (TITLE-ABS-KEY("Coronary slow flow") OR TITLE-ABS-KEY("CSFP") OR TITLE-ABS-KEY("Thrombolysis in Myocardial Infarction frame count") OR TITLE-ABS-KEY("angiographic slow flow") OR TITLE-ABS-KEY("TIMI frame count") OR TITLE-ABS-KEY("Slow Coronary Flow") OR TITLE-ABS-KEY("No-reflow") OR TITLE-ABS-KEY("No reflow")) AND (TITLE-ABS-KEY("ECG") OR TITLE-ABS-KEY("Electrocardiography") OR TITLE-ABS-KEY("Electrocardiographic") OR TITLE-ABS-KEY("Electrocardiogram") OR TITLE-ABS-KEY("Tpe") OR TITLE-ABS-KEY("Tp-e") OR TITLE-ABS-KEY("cardio-electrophysiological balance") OR TITLE-ABS-KEY("EKG") OR TITLE-ABS-KEY("Electrocardiograph")) (N = 649)
	PubMed: ((Coronary slow flow[Title/Abstract]) OR (CSFP[Title/Abstract]) OR (Thrombolysis in Myocardial Infarction frame count[Title/Abstract]) OR (angiographic slow flow[Title/Abstract]) OR (TIMI frame count[Title/Abstract]) OR (Slow Coronary Flow[Title/Abstract]) OR (No-reflow[Title/Abstract]) OR (No reflow[Title/Abstract])) AND ((ECG[Title/Abstract]) OR (Electrocardiography[Title/Abstract]) OR (Electrocardiographic[Title/Abstract]) OR (Electrocardiogram[Title/Abstract]) OR (Tpe[Title/Abstract]) OR (Tp-e[Title/Abstract]) OR (cardio-electrophysiological balance[Title/Abstract]) OR (EKG[Title/Abstract]) OR (Electrocardiograph[Title/Abstract])) (N = 205)
	Web Of Science: (TS=(Coronary slow flow) OR TS=(CSFP) OR TS=(Thrombolysis in Myocardial Infarction frame count) OR TS=(angiographic slow flow) OR TS=(TIMI frame count) OR TS=(Slow Coronary Flow) OR TS=(No-reflow) OR TS=(No reflow)) AND (TS=(ECG) OR TS=(Electrocardiography) OR TS=(Electrocardiographic) OR TS=(Electrocardiogram) OR TS=(Tpe) OR TS=(Tp-e) OR TS=(cardio-electrophysiological balance) OR TS=(EKG) OR TS=(Electrocardiograph)) (N = 353)
	EMBASE: ('Coronary slow flow':ab,ti OR 'CSFP':ab,ti OR 'Thrombolysis in Myocardial Infarction frame count':ab,ti OR 'TIMI frame count':ab,ti OR 'Slow Coronary Flow':ab,ti OR 'No-reflow':ab,ti OR 'No reflow':ab,ti) AND ('ECG':ab,ti OR 'Electrocardiography':ab,ti OR 'Electrocardiographic':ab,ti OR 'Electrocardiogram':ab,ti OR 'Tpe':ab,ti OR 'Tp-e':ab,ti OR 'cardio-electrophysiological balance':ab,ti OR 'EKG':ab,ti OR 'Electrocardiograph':ab,ti) (N = 448)

Supplementary table 2: Quality and risk of bias assessment of included studies according to Joanna Briggs Institute (JBI) critical appraisal tool

Included Studies	JBI quality assessment criteria								Total Score
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	
Ackay et al., 2009	Y	Y	Y	Y	Y	Y	N	Y	8/8 (100%)
Askin et al., 2021	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Atak et al., 2003	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Cakmak et al., 2015	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Cutri et al., 2011	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Dogan et al., 2008	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Elawady et al., 2022	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Eshraghi et al., 2018	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Isik et al., 2021	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Karaman et al., 2014	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Zhuang et al., 2015	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Zehir et al., 2015	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Tenekecioglu et al., 2015	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Suner et al., 2016	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Sucu et al., 2018	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Kuyumcu et al., 2019	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Mahfouz et al., 2014	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Mahmoud Khaled et al., 2013	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Nough et al., 2018	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Ozbek et al., 2021	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Rashidinezhad et al., 2017	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Sen et al., 2016	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Sezgin et al., 2007	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Sucu et al., 2016	Y	Y	Y	Y	Y	N	Y	Y	7/8 (78%)
Amirzadegan et al., 2017	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Beltrame et al., 2002	Y	Y	Y	Y	Y	N	Y	Y	7/8 (78%)
Guntekin et al., 2011	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Seyiz et al., 2018	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Simsek et al., 2016	Y	Y	Y	Y	Y	N	Y	Y	7/8 (87%)
Turkmen et al., 2007	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)
Gumrokcuoglu et al., 2011	Y	N	Y	Y	Y	N	Y	Y	6/8 (75%)
Yilmaz et al., 2014	Y	Y	Y	Y	Y	Y	Y	Y	8/8 (100%)

Note: Y: Yes; N: No; U: Unclear. Q1= Were the criteria for inclusion in the sample clearly defined? Q2= Were the study subjects and the setting described in detail? Q3= Was the exposure measured in a valid and reliable way? Q4= Were objective, standard criteria used for measurement of the condition? Q5= Were confounding factors identified? Q6= Were strategies to deal with confounding factors stated? Q7= Were the outcomes measured in a valid and reliable way? Q8= Was appropriate statistical analysis used?

Supplementary table 3: Meta-analysis of predictors associated with Coronary Slow Flow Phenomenon

Predictors	N	Pooled SMD/OR (95% CI)	P-value	Heterogeneity		
				I^2 (%)	Q test	P-value
Age (years)	31	0.0056 (-0.0786 - 0.0897)	0.89	37.3	47.8	0.02
BMI (kg/m^2)	18	0.47 (0.21, 0.73)	0.0004	88.7	150.2	< 0.0001
Male	30	1.26 (1.06, 1.49)	0.006	31.0	42	0.06
Smoking	27	1.50 (1.22, 1.85)	< 0.0001	41.4	44.4	0.01
Hypertension	20	1.18 (0.95, 1.47)	0.11	41.5	32.5	0.02
Diabetes mellitus	23	1.32 (1.08, 1.60)	0.005	0.0	16.7	0.77
Dyslipidemia	12	1.24 (0.99, 1.54)	0.057	10.1	12.24	0.34

N: Number of studies; BMI: Body Mass Index; CI: confidence interval; SMD: standardized mean deiffrence; OR: Odds ratio.