DOI: 10.7860/JCDR/2026/84708.22525

Original Article

Internal Medicine Section

Variation of Electrocardiographic Indices in Normal Pregnancy: A Systematic Review and Meta-analysis

PALLASEENA SEETHARAMAN SESHADRINATHAN[1], ARUNA BHOLENATH PATIL[2]

ABSTRACT

Introduction: Heart disease is a significant cause of maternal mortality. An Electrocardiogram (ECG) is the most common diagnostic modality available for its detection. ECG indices display a variety of changes during normal pregnancy.

Aim: To analyse changes in electrocardiographic indices during pregnancy compared to controls and at different trimesters in normal pregnant patients.

Materials and Methods: Data on relevant published articles in English were retrieved from PubMed using predefined search terms, including MeSH, manual searches, and references from 1932 to 2025. Normal pregnant patients without clinical heart or systemic disease were included in the study. Nineteen ECG indices were compared between pregnant and non pregnant groups. The p-value<0.05 was considered significant. Pooled estimate of the effect sizes was calculated using Hedges' g with a random-effects model to assess the variability in comparison groups. Heterogeneity was evaluated using Cochran's Q, $\tau 2$, and I2 statistics, with I2 >50% indicating substantial heterogeneity. The Newcastle–Ottawa Scale (NOS) and an adapted version (NOS-xs) were used to assess the risk of bias of the included studies

Results: After initial screening, 25 studies were included in a pregnant group (4645 patients) and a control group of non pregnant women (1191 patients) The statistical analysis was performed for values of the control compared to the 1st, 2nd, and 3rd trimesters, as well as the control versus the average value of all three trimesters for each of the ECG indices. Only the ECG indices of heart rate and Mean Corrected QT (QTc) interval showed increased statistical significance at p-value=0.0332 and p-value=0.0050, respectively, in the comparison of the control group versus the average value of all three trimesters of pregnancy. The remaining ECG indices did not show any statistically significant differences in any comparison. The magnitude of variation was found to be small by the pooled estimate of effect size. Overall, the risk of bias of the included studies was found to be low to moderate in most of the included studies.

Conclusion: A statistically significant small magnitude increase was noted only for heart rate and mean QTc in the pregnant group compared to the non pregnant control. The meta-analysis could not demonstrate statistically significant changes in any of the ECG indices between the trimesters of pregnancy.

Keywords: Heart rate, Mean QTc, Physiological adaptations Pregnancy electrocardiogram changes

INTRODUCTION

The diagnosis of heart disease in pregnant patients is crucial and challenging. Heart disease is recognised in 0.5 to 1% and accounts for 10-15% of maternal mortality [1].

ECG is commonly clinically utilised as a non invasive tool to assess cardiac electrical activity [1]. Pregnancy imposes a functional load on the heart and circulation [2]. Various physiological adaptations occur during pregnancy, including a rise in heart rate, blood volume, cardiac output, and stroke volume, as well as a decrease in peripheral vascular resistance [3].

Cardiac output begins to rise as early as the 12th week and gradually increases to 40 to 50% non pregnant value by 20 -24 weeks [1,2]. The increase in cardiac output is attributed to increases in both stroke volume and heart rate [1,2]. Stroke volume increases by 25% [3], which results from an increase in the blood volume [2] that increases by 40% at 30 weeks [4]. The increase in blood volume is attributed to an increase in both plasma and red cell volumes [2]. Plasma volume increases as early as 6 weeks, reaching about 45% above the normal by the 32nd week of pregnancy [3,5]. Total body water increases till the end of pregnancy [6]. Pregnancy also leads to a rise in oxygen consumption of around 15 to 20% [5]. There is also a significant retention of sodium and water. The work of the heart is 50% greater in pregnancy than in a non pregnant state [6]. In pregnancy, alterations in various hormones, including a rise in oestrogen, progesterone, and catecholamines, are also present [1]. Along with these, alterations, changes in the renin angiotensin system and heightened adrenoreceptor sensitivity are also additional factors that influence the cardiac output in pregnancy [1].

Blood pressure decreases in early pregnancy due to a fall in peripheral vascular resistance [1]. In the first two trimesters, there is a decrease in the systolic and diastolic Blood Pressure (BP) with wide pulse pressures [1]. Mean arterial pressure, however, remains normal. Venous pressure also increases due to a rise in blood volume [5]. As such, a hyperdynamic circulatory change occurs during pregnancy, which begins in the second month and gradually increases until 32 weeks [5].

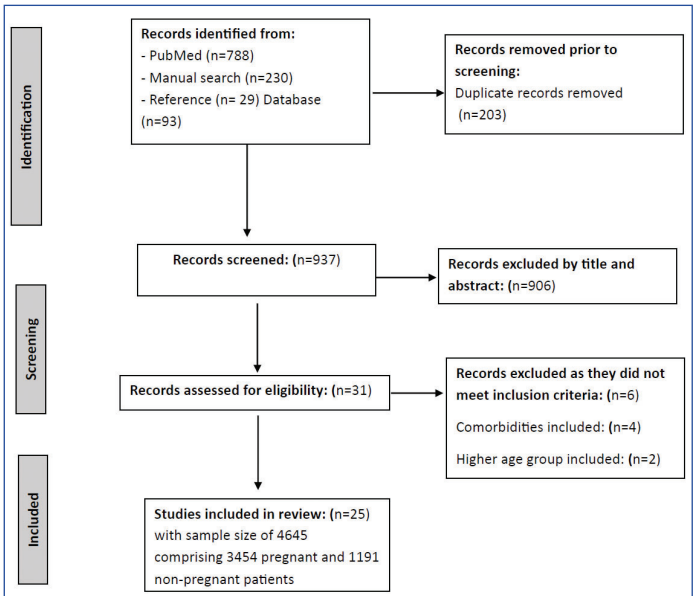
The heart rate increases early, in the first week of pregnancy, and peaks in the first half of the third trimester. Heart rate is approximately 10 to 20 beats higher than the prepregnant state [1,6].

Sinus tachycardia, increase in the QT intervals and QTc, decrease in the PR interval, Prominent Q in Lead III, T wave inversion in Lead III and V2, Q3-T3 pattern, prominent S in Lead I, T wave flattening, ST segment depression and an increase in the R/S ratio in right precordial Leads are described as some of the variations of ECG indices during normal pregnancy [7]. There is also a slight but not severe leftward shift of the QRS axis during pregnancy [1].

Knowledge of normal variation in ECG indices is essential for diagnosing various pathological abnormalities during pregnancy [7]. Hence, the present meta-analysis was performed with the intention to analyse the changes in various ECG indices during normal pregnancy to address the research question: "Are there any significant changes in ECG indices in pregnancy and across its various trimesters compared to control non pregnant patients?"

MATERIALS AND METHODS

The present systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, as shown in [Table/Fig-1].



[Table/Fig-1]: PRISMA flow diagram.

PICOTSS framework: The meta-analysis was formulated using the {P – Population, I – Intervention (or Exposure), C – Comparison, O – Outcome, T – Time, S – Setting and S – Study design (PICOTSS)} framework, to systematically analyse changes in ECG indices during the normal physiological state of pregnancy. The population included normal healthy pregnant women, with normal healthy non pregnant women serving as the control group. Comparisons were made between the pregnancy and non pregnancy groups, as well as between different pregnancy trimesters. The Intervention was defined as the physiological state of pregnancy itself, and the primary outcome was the detection of changes in ECG indices. The timing involved the measurements across different trimesters of pregnancy. The setting encompassed any clinical or hospital facility where an ECG was performed. The study design included both cross-sectional and prospective studies.

Data sources and search strategy: Data on relevant published articles in English were retrieved from PubMed sources using predefined search terms, including MeSH terms and free-text keywords. For the search strategy, “Electrocardiographic indices”, “ECG Changes” “Physiological adaptations”, “Heart rate”, “Mean QTc” and “Normal pregnancy” were used. Additional sources include manual searches, references, textbooks, and databases from the Tamil Nadu Dr MGR Medical University, about the research topic from 1932 to 2025. References of the included articles and related reviews were screened for additional studies.

Inclusion criteria: The inclusion criteria for the meta-analysis required studies that had normal healthy pregnant women aged 18 to 45 years without clinical evidence of heart disease. The analysis incorporated both cross-sectional and prospective study designs. Studies were required to be published in English between 1932 and 2025, with no restrictions on their geographical location, provided that the full text was available for review.

Exclusion criteria: The exclusion criteria for the meta-analysis were studies involving pregnant women with systemic diseases, including valvular heart disease, renal disease, anaemia, diabetes, thyroid disease and hypertension, as well as those involving women older than 45 years of age. Additionally, any studies presented only as an abstract or those involving animal subjects were excluded from the analysis.

Study Procedure

Data collection and extraction: The authors independently screened records, including the title, abstract, and full text. Any disagreements that occurred were resolved through discussions and, if necessary, third-party arbitration. The study design type, electrocardiographic indices (heart rate, P wave duration and amplitude, QRS duration, T wave duration and amplitude, PR interval, QT interval, Mean QTc (Bazett), QRS, P, T axes, QRS T angle, percentage of T wave inversion in Lead III and V2, and percentage of LVH by Sokolow-Lyon and Araoye criteria) were collected across the trimesters of pregnancy, and in the non pregnant control group. Patient characteristics, including mean age, geographical location, and sample size in each group, were also extracted by two authors and further reviewed for accurate analysis.

Some of the diagnostic ECG indices and their normal threshold are presented in [Table/Fig 2].

ECG indices	Definition	Normal value
Mean †QTc (Bazett)	$QT=\frac{QT}{\sqrt{RR}}$	0.35-0.43 sec
‡PR Interval	Interval from the beginning of P wave to beginning of QRS complex	0.12-0.20 sec
QRS-T angle	The frontal plane angle between QRS and T vectors	<45°
QRS axis	The mean manifest frontal plane angle of QRS vector	0-90°
QRS Duration	Interval from the onset to the end of QRS	0.05-0.11sec
P wave Duration	Duration of the P wave	0.078-0.10 sec
P wave amplitude	Height of the P wave	<2.5 mm in Lead II <1.5 mm in V1
T wave axis	The mean manifest frontal plane angle of T vector	15° -75°
Sokolow-Lyon criteria for §LVH	SV1+RV5(orRV6) ≥35mm	-
Araoye criteria for LVH	Rin Lead I>12 mm	-

[Table/Fig-2]: ECG indices characteristics.
*ECG: Electrocardiogram; †QTc: Corrected QT interval; ‡PR: Time interval from start of P wave to start of QRS complex; §LVH: Left ventricular hypertrophy

Quality Assessment

Risk of Bias Assessment of included studies: The quality and risk of bias of the included 25 studies was assessed independently by both authors using the original Newcastle-Ottawa Scale (NOS) for prospective (cohort) studies [8] and an adapted version (NOS-xs) for cross-sectional studies [9]. The NOS assigned a maximum of nine stars across three domains: Selection (maximum 4 stars), comparability (maximum 2 stars) and outcome assessment (maximum 3 stars). The adapted version (NOS-xs) assessed the quality across the domains: Sample selection (maximum 2 stars), Confounding factors (maximum 3 stars), Exposure Assessment (maximum 2 stars), and Outcome Assessment (maximum 2 stars). Any discrepancies between the authors were resolved by consensus or a third party arbitration whenever needed. Total scores were used to categorise study quality as high (0-3 stars), moderate (4-6 stars) or low (7-9) risk of bias and domain-specific information was extracted for detailed analysis and presentation.

STATISTICAL ANALYSIS

The relevant data of this study were collected and organised into a master chart using an MS Excel sheet.

The methodological quality of these cross-sectional studies was assessed in a meta-analysis. The control group represented non pregnant subjects in the study population. For each ECG index, the mean values of control and during the 1st , 2nd and 3rd trimester of pregnancy were calculated/ noted in the available studies, along

with the average value of the ECG indices for all three trimesters of pregnancy and the comparisons were done between the 1st and 2nd trimester, the 2nd and 3rd trimester, the control and 3rd trimester, and the control vs the average value of all three trimesters for each of the ECG indices. Continuous outcomes were expressed as means±SD, and effect sizes were calculated using Hedges' g with a random-effects model to account for between-study group variability, which corrects for small sample bias in standardised mean differences.

For categorical ECG outcomes, event counts were calculated Event = Proportion×n using published proportions and sample sizes, with counts rounded to the nearest integer. Zero-event arms received a continuity correction of 0.5. Meta-analysis was conducted using the DerSimonian-Laird random-effects model to pool Risk Ratios (RR) and Risk Differences (RD), accounting for both within- and between-study variance. Heterogeneity was evaluated with Cochran's Q, τ^2, and I^2statistics, considering $I^2 > 50\%$ as substantial. Pooled effect estimates are presented with 95% Confidence Intervals (CI) and p-values (α=0.05), accompanied by forest plots, including ten or more studies for analyses. Funnel plots and Egger's test were used to assess publication bias. All analyses and diagrams were performed using Python (v3.11) using libraries such as pandas, NumPy, matplotlib, scikit-learn, and stats models; descriptive tables were managed in MS Excel.

RESULTS

A total of 1,140 manuscripts were initially obtained. After removing duplicate records and those that met the exclusion criteria based on title and abstract, 31 studies remained and were assessed for eligibility. Out of these, six studies were excluded as they did not have any of the criteria mentioned above. Twenty-five studies were ultimately included in the meta-analysis, comprising a total of 4,645 patients, with 3,454 pregnant and 1,191 non pregnant control subjects aged 18 to 45 years. Out of the 25 studies [10-36], 19 studies were cross-sectional [10,11,15-20,22-26,29-32,35,36]. The remaining seven were prospective studies [12,13,17,21,27,33,34]. Fifteen studies were from India [10,11,13,14,18,20-26,28,31,32], four studies were from the USA [12,13,24,25], three from Nigeria [17,35-36], one from the UK [16], Iran [27] and Bangladesh [30] each. The baseline characteristics of the included studies are depicted in [Table/Fig-3] [10-13,15-27,29-36], which represents the study design, including sample size, mean age, year of publication, and geographical location for all the included studies. The pooled meta-analysis results are tabulated in [Table/Fig-4-13]. The pooled mean value and number of studies (n) represented by ECG indices are depicted below in [Table/Fig-4]. Heart rate was found to be 79.32±7.23 in the Control group, which progressively increased from the 1st to the 3rd trimester, reaching 95.08 at the 3rd trimester. There was a difference of 11.92 between the mean values of the pregnancy and control groups. The mean QTc was found to be 0.38882±0.01689 seconds in the control group, which increased progressively as pregnancy advanced, reaching 0.41660±0.02778 seconds at the third trimester. There was a difference of 0.02227 seconds between the mean value of pregnancy and the control group. The P-wave duration and amplitude of the control exceeded the mean value of pregnancy by 0.0051 seconds and 0.007 mm, respectively. The PR interval in the control exceeded the mean value of pregnancy by 0.011332 seconds. The QRS duration of the mean value of pregnancy exceeded the control by 0.00113 seconds. There was a leftward shift of the QRS axis mean value by 13.2o compared to the control group. The T-wave duration and amplitude were higher in the control group compared to the mean value during pregnancy by 0.0052 seconds and 0.077 mm, respectively. The ST-segment duration of the mean value in pregnancy exceeded that of the control group by 0.011 seconds. However, control ST segment was reported in only one study. There was a leftward shift of the T axis by 10.81 ° compared to the control group. There was a 60-degree increase in the QRST angle in the mean value of the pregnancy group compared to the control group. There was a leftward shift of the P axis by 11.61° compared to the control group. However, the P axis was reported in only one study. The QT interval of the mean value in pregnancy exceeded that of the control group by 0.00009 seconds. T-wave inversion in V3 and V2 exceeded that of the control group by 19.94% and 24.9%, respectively. Q in lead 3 of the mean value of pregnancy exceeded that of the control group by 7.94%. The incidence of LVH, as determined by Sokolow-Lyon voltage criteria and Araoye criteria, was higher in the pregnant group compared to the control group by 2.01% and 10.21%, respectively. The pooled Meta-Analysis Results (Hedges' g, Random Effects) are shown in [Table/Fig-5], which represents continuous outcomes of ECG indices with representation of nine or more studies in each group. The first, second, and third trimesters of pregnancy were denoted as TM1, TM2, and TM3, respectively. Comparisons were made for the non pregnant control versus TM1, TM1 versus TM2, TM2 versus TM3, and the control versus the average of the three

S. No.	Study names	Type of study design	Sample size ('n)	Sample size (n)	Age (in years)	Year of publication	Geographical location
			Control	Pregnant			
1	Trivedi DR et al., [10]	Cross-sectional	25	75	-	1982	India
2	Madras V et al., [11]	Cross-sectional	50	150	20-35	2015	India
3	Carr FB et al., [12]	Prospective	-	193	-	1932	USA
4	Feldman L and Hill HH [13]	Prospective	-	36		1934	USA
5	Nandini BN et al., [15]	Cross-sectional	50	150	20-35	2011	India
6	Goloba M et al., [16]	Cross-sectional	-	138	18-45	2010	United Kingdom
7	Akinwusi PO et al., [17]	Cross-sectional	70	69	20-35	2011	Nigeria
8	Nandini BN et al., [18]	Cross- sectional	50	150	20-35	2014	India
9	Sunitha M et al., [19]	Cross-sectional	50	100	20-35	2014	India
10	Lissie P et al., [20]	Cross- sectional	50	150	20-30	2017	India
11	Ananthakrishnan R et al., [21]	Prospective	-	450	21-30	2020	India
12	Kole S et al., [22]	Cross- sectional	30	193	19-35	2014	India
13	Chaudhary S et al., [23]	Cross-sectional	60	60	20-35	2015	India
14	Uma V and Syamala Devi M [24]	Cross- sectional	100	100	18-35	2016	India
15	Sumalatha B et al., [25]	Cross- sectional	-	151	23.38±3.49	2017	India
16	Nandini BN and Manjunath ML [26]	Cross sectional	50	150	20-35	2018	India
17	Omidi N et al., [27]	Prospective	-	96	18-35	2022	Iran

18	Rajani R et al., [29]	Cross- sectional	50	150	18-35	2024	India
19	Siddiqui F et al., [30]	Cross- sectional	75	150	28.09±2.77	2024	Bangladesh
20	Surin LL et al., [31]	Cross- sectional	150	150	18-45	2025	India
21	Ghodeswar KB et al., [32]	Cross- sectional	150	150	18-45	2025	India
22	Wenger NK et al., [33]	Prospective	16	24	__	1964	USA
23	Schwartz DB and Schamroth L [34]	Prospective	___	50	__	1979	USA
24	Salisu A and Karaye KM [35]	Cross- sectional	115	123	18-45	2010	Nigeria
25	Dodyi-Manuel ST and Ezennaka RC [36]	Cross- sectional	50	150	18-43	2023	Nigeria

[Table/Fig-3]: Baseline characteristics of the included studies [10-13,15-27,29-36].

S. No.	*ECG Indices	Statistics	Control	1st Mean of †TM	2nd Mean of TM	3rd Mean of TM	Average value of 3 TM
1	Heart rate	Mean	79.3273	85.452	91.4475	95.078	91.6775
		‡Std. dev.	7.2296	9.6098	10.321	10.6474	12.57
		§n	15	10	12	15	18
2	QRS duration (sec)	Mean	0.0778	0.07948	0.07724	0.0780	0.0779
		Std. dev.	0.0176	0.0117	0.0098	0.0263	0.01
		N	9	7	8	11	12
3	PR interval (sec)	Mean	0.1444	0.1353	0.1358	0.1293	0.1330
		Std. dev.	0.0257	0.0168	0.0253	0.0337	0.0254
		N	13	11	13	16	16
4	QRS Axis (degrees)	Mean	58.7789	54.466	45.4363	41.666	45.51
		Std. dev.	11.5757	12.4075	15.906	20.2614	15
		N	9	5	8	12	12
	Mean ‖QTc Bazett (secs)	Mean	0.3882	0.403611	0.41306	0.4166	0.41109
		Std. dev.	0.0169	0.0215	0.01499	0.02778	0.01
		N	11	9	11	14	14
6	P Wave duration (secs)	Mean	0.0846	0.0854	0.0826	0.0799	0.0840
		Std. dev.	0.0104	0.0461	0.0123	0.0093	0.0225
		N	7	6	6	8	9
7	P Wave amplitude(mm)	Mean	1.083	1.066	1.086	1.075	1.076
		Std. dev.	0.245	0.2866	0.32	0.2725	0.2938
		N	4	3	3	4	4
8	T Wave Duration (secs)	Mean	0.1625	0.1600	0.1530	0.159	0.1573
		Std. dev.	0.014	0.020	0.022	0.021	0.021
		N	2	2	2	2	2
9	T Wave amplitude(mm)	Mean	2.72	2.70	2.78	2.45	2.643
		Std. dev.	1.01	1.11	0.89	0.93	0.9766
		N	1	1	1	1	1
10	ST Segment Duration (secs)	Mean	0.10	0.097	0.080	0.090	0.089
		Std. dev.	–	–	–	–	–
		N	1	1	1	1	1
11	T Axis (degrees)	Mean	40.233	30	38	29.133	29.425
		Std. dev.	15	–	–	–	16
		N	3	1	1	3	4
12	QRST Angle (degrees)	Mean	15	–	–	–	21
		Std. dev.	21	–	–	–	22
		N	2	–	–	–	2
13	P Axis (degrees)	Mean	56.35	45.95	45.625	44.28	44.7465
		Std. dev.	–	22.438	22.438	22.439	22.4383
		N	1	1	2	2	2
14	QT Interval (secs)	Mean	0.34675	0.3405	0.3470	0.3525	0.3467
		Std. dev.	0.0406	0.02	0.0199	0.0207	0.02022
		N	8	4	6	8	8
15	T Wave inversion in Lead III (%)	Average percentage	15.46	18	33	35.4	24.12
		n§	5	2	3	6	7

16	T Wave Inversion in V2 (%)	Average percentage	11.1	24	24.6	36	28.2
17	Q in Lead III (%)	n§	3	2	3	4	4
		Average percentage	24.66	20	37.33	40.47	32.6
		n§	3	2	3	5	5
18	¶LVH Sokolow-Lyon (%)	Average percentage	1.34	–	–	–	3.35
		n§	2	–	–	–	2
19	LVH Araoye (%)	Average percentage	0	–	–	–	10.2
		n§	0	–	–	–	1

[Table/Fig-4]: Pooled mean value and number of studies of ECG indices.
*ECG: Electrocardiogram; †TM: Trimester; ‡Std dev: Standard deviation; §n: Number of studies; ||QTc: Corrected QT interval; ¶LVH: Left ventricular hypertrophy.

Comparison groups	†n (no. of studies)	‡Hedges' g (§RE=Random Effect)	95% ||CI (lower–upper)	p-value	¶τ^2	**I^2 (%)
Control vs ††TM1	9	-0.1100	-0.4296 – 0.2097	0.5001	0.0000	0.0
TM1 vs ‡‡TM2	9	-0.0915	-0.4153 – 0.2323	0.5796	0.0000	0.0
TM2 vs §§TM3	10	-0.0272	-0.3111 – 0.2568	0.8513	0.0000	0.0
Control vs ||||Avg of 3TM	11	-0.0998	-0.5773 – 0.3776	0.6819	0.4127	64.94

[Table/Fig-5]: Pooled meta-analysis results for continuous outcomes of *ECG indices.
*ECG: Electrocardiogram; †n: Number of studies; ‡Hedges' g: Standardised mean difference; §RE: Random effects model; ||CI: Confidence interval; ¶τ^2: Between-study variance (tau-squared); **I^2: Percentage of variation across studies due to heterogeneity; ††TM1: First trimester; ‡‡TM2: Second trimester; §§TM3: Third trimester; ||||Avg of 3TM: Average of all three trimesters; All pooled effects are minimal (|g| < 0.2) and non-significant. Heterogeneity was negligible for the first three comparisons (I^2=0%), but moderate to high for the control vs. Avg of 3TM comparison ($I^2 \approx 65\%$), indicating variability among ECG indices-specific effects.

trimesters (3TM). The pooled effect sizes ranged between -0.0272 and -0.1100. The p-values ranged between 0.5001 and 0.8513, indicating non significance. I^2 (%) was 0.0 in all groups except for the control, when compared to the average of the 3TM value, where it was observed to be 64.94%. The τ^2 value, however, was found to be only 0.4127 in the above group. The meta-analysis results of individual ECG indices (heart rate, QRS duration, PR interval, mean QTc, P-wave duration and amplitude, QT interval, and T-wave axis) across various groups in the study population are depicted in the following [Table/Fig-6-9]. In Control vs TM1 and TM1 vs TM2, TM2 vs TM3, the p-value was not significant for any of the ECG indices

ECG indices	‡n1	§n2	||Hedges' g	¶SE (Standard Error)	95% **CI	p-value
Heart rate	15	10	-0.7110	0.4417	-1.5781 – 0.1561	0.1086
QRS duration	9	7	-0.1146	0.4593	-1.0147 – 0.7855	0.8023
PR interval	13	11	0.3942	0.3665	-0.3246 – 1.1130	0.2776
QRS Axis	9	5	0.3479	0.5180	-0.6670 – 1.3628	0.5026
Mean ††QTc Bazett	11	9	-0.7609	0.4464	-1.6362 – 0.1144	0.0885
P Wave duration	7	6	-0.0244	0.5119	-1.0286 – 0.9798	0.9620
P Wave amplitude	4	3	0.0617	0.7060	-1.3218 – 1.4452	0.9309
QT Interval	8	4	0.1800	0.7008	-1.1930 – 1.5530	0.7976
T Axis	3	1	0.6568	0.9013	-1.1086 – 2.4222	0.4655

[Table/Fig-6]: Comparison of ECG* indices between Control and TM1†
*ECG: Electrocardiogram; †TM1: First trimester; ‡n1: Number of studies in control group; §n2: Number of studies in first trimester group; ||Hedges' g: Standardised mean difference; ¶SE: Standard error; **CI: Confidence interval; ††QTc: Corrected QT interval; (Other ECG indices where n<=1 in either group were excluded)

ECG indices	§n1	||n2	¶Hedges' g	**SE	95% ††CI	p-value
Heart Rate	10	12	-0.6112	0.4117	-1.4183 – 0.1959	0.1399
QRS Duration	7	8	0.2051	0.4767	-0.7299 – 1.1401	0.6679
PR Interval	11	13	-0.0167	0.3597	-0.7206 – 0.6873	0.9633
QRS Axis	5	8	0.5714	0.5178	-0.4436 – 1.5864	0.2707
Mean ‡‡QTc Bazett	9	11	-0.5078	0.4209	-1.3338 – 0.3182	0.2272
P Wave duration	6	6	0.1489	0.5266	-0.8835 – 1.1813	0.7769
P Wave amplitude	3	3	-0.0641	0.7254	-1.4851 – 1.3569	0.9303
QT Interval	4	6	-0.3708	0.5673	-1.4823 – 0.7406	0.5116
T Axis	1	1	-0.5157	1.0926	-2.6575 – 1.6261	0.6389

[Table/Fig-7]: Comparison of *ECG indices between †TM1 and ‡TM2.
*ECG: Electrocardiogram; †TM1: First trimester; ‡TM2: Second trimester; §n1: Number of studies in first trimester group; ||n2: Number of studies in second trimester group; ¶Hedges' g: Standardised mean difference; **SE: Standard error; ††CI: Confidence interval; ‡‡QTc: Corrected QT interval

ECG indices	§n1	||n2	¶Hedges' g	**SE	95% ††CI	p-value
Heart rate	12	15	-0.3588	0.3657	-1.0761 – 0.3585	0.3276
QRS duration	8	11	-0.0421	0.4512	-0.9276 – 0.8434	0.9264
PR interval	13	16	0.2259	0.3339	-0.4289 – 0.8807	0.4969
QRS axis	8	12	0.2197	0.4471	-0.6572 – 1.0966	0.6246
Mean ‡‡QTc Bazett	11	14	-0.1440	0.3424	-0.8151 – 0.5271	0.6716
P wave duration	6	8	0.3486	0.5318	-0.6930 – 1.3902	0.5097
P wave amplitude	3	4	0.0356	0.6683	-1.2747 – 1.3459	0.9575
QT interval	6	8	-0.2337	0.5235	-1.2609 – 0.7934	0.6561
T axis	1	3	0.2582	1.0187	-1.7398 – 2.2561	0.7997

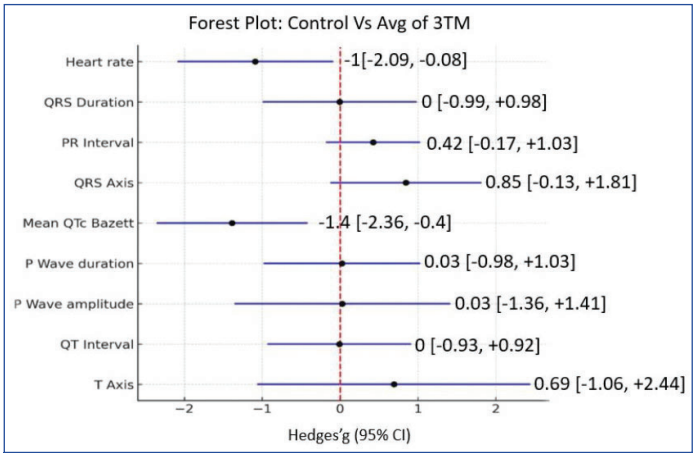
[Table/Fig-8]: Comparison of *ECG indices between †TM2 and ‡TM3.
*ECG: Electrocardiogram; †TM2: Second trimester; ‡TM3: Third trimester; §n1: Number of studies in second trimester group; ||n2: Number of studies in third trimester group; ¶Hedges' g: Standardised mean difference; **SE: Standard error; ††CI: Confidence interval; ‡‡QTc: Corrected QT interval

ECG indices	‡n1	§n2	||Hedges' g	¶SE	95% **CI	p-value
Heart rate	15	18	-1.0883	0.5108	-2.0895 – -0.0870	0.0332
QRS duration	9	12	-0.0056	0.5043	-0.9930 – 0.9818	0.9903
PR interval	13	16	0.4266	0.3088	-0.1788 – 1.0319	0.1658
QRS axis	9	12	0.8460	0.4955	-0.1251 – 1.8171	0.0885
Mean ††QTc Bazett	11	14	-1.3860	0.4949	-2.3550 – -0.4171	0.0050
P wave duration	7	9	0.0252	0.5134	-0.9806 – 1.0311	0.9610

P wave amplitude	4	4	0.0302	0.7078	-1.3559 – 1.4163	0.9660
QT Interval	8	8	-0.0090	0.4723	-0.9336 – 0.9156	0.9848
T Axis	3	4	0.6906	0.8949	-1.0616 – 2.4428	0.4418

[Table/Fig-9]: Comparison of ˆECG indices between Control and the average value of †3TM.
ˆECG: Electrocardiogram; †3TM: All three trimesters; ‡n1: Number of studies in control group; §n2: Number of studies in pregnancy groups; ||Hedges' g: Standardised mean difference; ¶SE: Standard error; ¨CI: Confidence interval; ††QTc: Corrected QT interval

compared to the control group. In the control vs Avg 3TM group, only heart rate and mean QTC had significant p-values of 0.0332 and 0.0050, respectively. The Forest plot for the ECG indices (heart rate, QRS duration, PR interval, QRS axis, Mean QTC, P-wave duration and amplitude, QT interval, and T axis) is shown in [Table/Fig-10]. It is noted that, except for heart rate and mean QTc, the CIs for the remaining ECG indices cross the null effect line and are therefore



[Table/Fig-10]: Forest plot for control versus the average of three trimesters.
Effect sizes and CIs are shown on the right of each error bar for clarity; The red dashed line at zero represents the null effect.

not statistically significant. The Meta-analysis for categorical outcomes of ECG indices, namely, T-wave inversion in Leads III, V2, and QRST angle, is shown in [Table/Fig-11-14]. Comparisons were made for the non-pregnant control versus TM1, TM1 versus

†ECG Indices	Control ‡k/N	TM1 k/N	Risk Ratio (§RR) (95% CI)	p-value	Risk Difference (RD) (95% ||CI)	p-value
T wave inversion (Lead III)	1/5	0/2	0.56 (0.03-9.44)	0.68	-0.08 (-0.53-0.37)	0.71
T wave inversion (Lead V2)	0/3	0/2	1.00 (0.07-14.4)	0.99	0.00 (-0.40-0.40)	1
Q in Lead III	1/3	0/2	0.67 (0.05-9.12)	0.76	-0.17 (-0.72-0.38)	0.54

[Table/Fig-11]: Meta-Analysis results of T wave inversion and Q in lead III between Control and ˆTM1.
TM1: First trimester; †ECG: Electrocardiogram; ‡k/N: Number of events/total sample size; §RR: Risk ratio; ||CI: Confidence interval; ¶RD: Risk difference; Pooled RR=0.74 (95% CI: 0.25–2.20, p=0.59); Pooled RD=-0.08 (95% CI: -0.36–0.20, p=0.57)

‡ECG Indices	TM1 §k/N	TM2 k/N	||RR (95% ¶CI)	p-value	RD (95% ¨CI)	p-value
T wave inversion (Lead III)	0/2	1/3	1.67 (0.11–25.1)	0.71	0.17 (-0.37–0.71)	0.53
T wave inversion (Lead V2)	0/2	1/3	1.67 (0.11–25.1)	0.71	0.17 (-0.37–0.71)	0.53
Q in Lead III	0/2	11/3	1.67 (0.11–25.1)	0.71	0.17 (-0.37–0.71)	0.53

[Table/Fig-12]: Meta-Analysis results of T wave inversion and Q in lead III between ˆTM1 and †TM2.
ˆTM1: First trimester; †TM2: Second trimester; ‡ECG: Electrocardiogram; §k/N: Number of events/total sample size; ||RR: Risk ratio; ¶CI: Confidence interval; ¨RD: Risk difference; Pooled RR=1.67 (95% CI: 0.37–7.56, p=0.50); Pooled RD=0.17 (95% CI: -0.20–0.55, p=0.38)

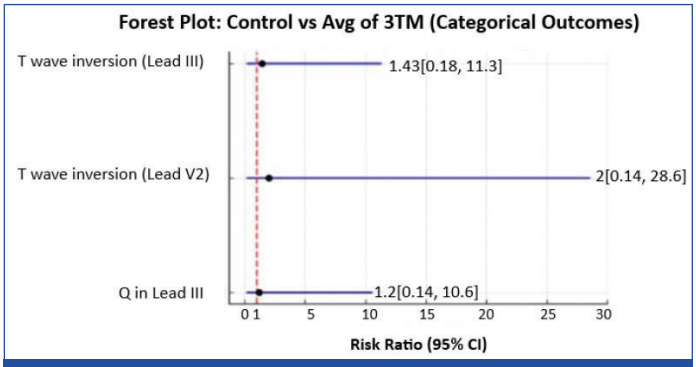
‡ECG Indices	TM2 §k/N	TM3 k/N	||RR (95% ¶CI)	p-value	¨RD (95% CI)	p-value
T wave inversion (Lead III)	1/3	2/6	1.00 (0.13-7.70)	1	0.00 (-0.55-0.55)	1
T wave inversion (Lead V2)	1/3	¼	0.75 (0.06-9.59)	0.82	-0.08 (-0.66-0.50)	0.77
Q in Lead III	1/3	2/5	1.20 (0.14-10.6)	0.87	0.07 (-0.54-0.68)	0.81

[Table/Fig-13]: Meta-Analysis results of T wave inversion and Q in lead III between *TM2 and †TM3.
ˆTM2: Second trimester; †TM3: Third trimester; ‡ECG: Electrocardiogram; §k/N: Number of events/total sample size; ||RR: Risk ratio; ¶CI: Confidence interval; ¨RD: Risk difference. Pooled RR=0.98 (95% CI: 0.29–3.29, p=0.97); Pooled RD=-0.01 (95% CI: -0.33–0.31, p=0.95)

ˆECG Indices	Control† k/N	§Avg value of 3 TM k/N	||RR (95%¶CI)	p-value	¨RD (95% CI)	p-value
T wave inversion (Lead III)	01/5	2/7	1.43 (0.18–11.3)	0.74	0.09 (-0.44–0.62)	0.72
T wave inversion (Lead V2)	0/3	¼	2.00 (0.14–28.6)	0.59	0.25 (-0.35–0.85)	0.41
Q in Lead III	0/3	2/5	1.20 (0.14–10.6)	0.87	0.07 (-0.54–0.68)	0.81

[Table/Fig-14]: Meta-analysis results of T wave inversion and Q in lead III between Control and Average of TM.
ˆECG: Electrocardiogram; † k/N: Number of events/total sample size; ‡k/N: Number of events/total sample size; §Avg value of 3 TM: Average value of all three trimesters; ||RR: Risk ratio; ¶CI: Confidence interval; ¨ RD: Risk difference. Pooled RR=1.45 (95% CI: 0.47–4.46, p=0.52); Pooled RD=0.14 (95% CI: -0.20–0.48, p=0.42)

TM2, TM2 versus TM3, and the control versus the average of the three trimesters (3TM). It is noted that the pooled RR ranged from 0.74 to 1.67. The pooled RR and RD had wide CIs that included the null value. The p-value ranged between 0.41 and 1.0, indicating that the result was not statistically significant. For the comparison of control vs avg 3TM, the Forest plot for the ECG indices T-wave inversion in Lead III, Lead V2, and Q in Lead III is depicted in [Table/Fig-15], which shows that the CIs for all three indices crossed the null line and are therefore not significant.The meta-analysis results regarding the QRST angle (in degrees) are shown in [Table/Fig-16]. The comparison between control vs avg of 3TM value showed a p-value of 0.89 with a wide CI, which included 0, hence not found to be significant. The ECG indices, including T-wave duration and amplitude, ST duration, P-axis,



[Table/Fig-15]: Forest plot with RR, CI values annotated for categorical ECG outcomes (Control vs Avg 3TM).
The red dashed line at RR=1 represents no difference between groups; Each outcome point displays its RR and confidence interval directly on the plot.

ˆECG Index	Control (Mean±†SD, ‡n)	§Avg value of 3 TM (Mean ±SD, n)	||Hedges'g	95% ¶CI	p-value
QRST Angle (°)	15±21 (n=2)	21±22 (n=2)	0.16	-2.18,2.50	0.89

[Table/Fig-16]: Meta-analysis result of QRST angle (in degrees).
ˆECG: Electrocardiogram; †SD: Standard deviation; ‡n: Number of studies; §Avg value of 3 TM: Average value of all three trimesters; ||Hedges' g: Standardised mean difference; ¶CI: Confidence interval

and Voltage Criteria for Sokolow-Lyon and Araoye, had a low sample size, with control subjects fewer than 115. Hence, it is not tabulated in the results.

Risk of bias: The results of the risk of bias assessment are detailed in [Table/Fig-17,18][10-13,15-20,21-27,29-32,33-36].

(5.3%) rated as having a moderate risk of bias. Common issues identified across the included studies related to insufficient information and lack of adequate adjustment for Body Mass Index (BMI), smoking, respiratory rate and electrolyte status as some of the confounding factors. Additionally, the manual interpretation

S. No.	Study names/ year	Study sample selection	Assessment of exposure	Assessment of the outcome	Confounding factors	Score points	Overall Risk of Bias (ROB)
1	Trivedi DR et al., [10], 1982	**	**	*	*	6	Moderate
2	Madras V et al., [11], 2015	**	**	**	**	8	Low
3	Nandini BN et al., [15], 2011	**	**	**	**	8	Low
4	Goloba M et al., [16], 1995	**	**	**	***	9	Low
5	Nandini BN et al., , 2014 [18]	**	**	**	***	9	Low
6	Sunitha M et al., [19] 2014	**	**	**	**	8	Low
7	Lissie P et al., [20] 2017	**	**	**	**	8	Low
8	Kole S et al., 2014 [22]	**	**	**	**	8	Low
9	Uma V and Syamala Devi M 2016 [24]	**	**	**	***	9	Low
10	Sumalatha B et Al., [25], 2017	**	**	**	**	8	Low
11	Nandini BN and Manjunath ML [26], 2018	**	**	**	**	8	Low
12	Rajani R et al., [29], 2024	**	**	**	**	8	Low
13	Siddiqui F et al., [30], 2024	**	**	**	***	9	Low
14	Surin LL et al., [31], 2025	**	**	**	**	8	Low
15	Godeswar KB et al., [32], 2025	**	**	**	**	8	Low
16	Salisu A and Karaye KM [35], 2010	**	**	**	***	9	Low
17	Dodyi-Manuel ST and Ezennaka RC [36], 2023	**	**	**	***	9	Low
18	Chaudhary S et al., [23]	**	**	**	**	8	Low
19	Akinwusi PO et al., [17]	**	**	**	**	8	Low

[Table/Fig-17]: The Risk of Bias (ROB) for included cross-sectional studies using adapted version NewCastle-Ottawa Scale (NOS-xs) [10,11,15-20,22-26,29-32,35,36].

S. No.	Study names/year	Selection	Comparability	Outcome	Score Points	Overall risk of bias (ROB)
1	Carr FB et al.,1932 [12]	****	*	**	7	Low
2	Feldman L and Hill HH 1934 [13]	***	*	**	6	Moderate
3	Ananthakrishnan R et al., [21], 2020	****	*	**	7	Low
4	Omidi N et al., [27], 2022	****	*	***	8	Low
5	Wenger NK et al., [33],1964	****	*	***	8	Low
6	Schwartz DB and Schamroth L [34], 1979	****	*	**	7	Low

[Table/Fig-18]: The risk of bias (ROB) for included prospective studies using the NewCastle-Ottawa scale (NOS) [12,13,21,27,33,34].

The domain-specific scores, including separate columns for outcome and exposure assessment in NOS-xs studies, are presented for clarity. Overall, the included studies were assessed as having a low risk of bias, with only one [11] of the six prospective studies (16.7%) and one [10] of the 19 cross-sectional studies utilising older ECG models in historical prospective studies [12,13] and details regarding adequacy of follow-up affected the risk of bias assessment. However, the low overall risk of bias across the majority of the included studies supported the validity of the meta-analysis findings.

Publication bias: The assessment of publication bias across the 25 included studies revealed no significant concerns. The funnel plot appeared largely symmetrical, indicating a balanced spread of effect sizes without clustering of smaller studies toward favourable outcomes. Both Egger's regression and Begg's rank correlation tests were non significant (p-value >0.05), confirming a lack of statistically detectable small-study effects. Although one pooled comparison (Control vs average of three TM interventions) exhibited substantial heterogeneity (I^2=64.9%; τ^2=0.4127), this is more likely attributable to variations in study design, measurement approaches, and population characteristics rather than selective reporting. Overall, the findings suggest no strong evidence of publication bias, supporting the reliability of the synthesised effect estimates.

DISCUSSION

The ECG changes are known to occur in pregnant women due to physiological adaptive changes and the consequent haemodynamic burden on the cardiovascular system [21,27]. ECG is a commonly employed non invasive tool for diagnosing heart disease [21,36]. As knowledge of ECG variations is crucial, this meta-analysis aimed to analyse ECG changes during pregnancy.

In the meta-analysis, the mean heart rate was found to be higher in the pregnancy group compared to the control group, a Statistically significant difference. However, the pooled estimate of the effect size was small, indicating only a small magnitude of this variation. This correlated with the observations of Friedberg CK et al., who noted only a slight acceleration of heart rate during pregnancy [6]. The meta-analysis noted an increase in heart rate of only 12 beats/min during pregnancy compared to the control. This correlated with the observations of Friedberg CK et al., and Braunwald E et al., [6,7]. It was also noted that there is a progressive increase in the heart rate from the 1st to the 3rd trimester. This was consistent with observations by Landt H and Benjamin JE [14]. However, there were no statistically significant differences in the variation of heart rate across various trimesters of pregnancy. Some of the individual studies demonstrated a statistically significant increase in heart rate across the different trimesters of pregnancy [11,15,20-22,26,29], while others { Salisu A and Karaye KM [35] and Battioni L et al., [28]} could not demonstrate a statistically significant difference. The meta-analysis, being a pooled estimate, effectively accounted for the discrepancies observed across the individual studies. Furthermore, while the included studies generally relied solely on p-values to determine statistical significance, the meta-analysis also focused on the actual magnitude of change or effect size to provide a more precise quantitative result.

The increase in heart rate during pregnancy has been attributed to the autonomic and hormonal changes that occur during pregnancy, as well as a compensatory mechanism to increase stroke volume [20,36]. A decrease in the parasympathetic tone during pregnancy was also attributed to the increase in the heart rate [11]

It also observed that there was a statistically significant increase in the mean QTc in the pregnant group compared to the control group, and a progressive increase in mean QTc from the 1st to the 3rd trimesters of pregnancy, which was similar to the observations of Nandini BN et al., [18]. However, there was no statistically significant variation of mean QTc across the different trimesters of pregnancy, which aligned with the observations of Dodyi-Manuel ST and Ezennaka RC, [36]. It was also observed that the absolute value of mean QTc was within the normal range in the pregnancy group, which correlated with the observations of Battioni L et al., and Zamani M et al., [28,37]. It was also noted in the meta-analysis that there was an increase in the mean QTc of 0.0154 seconds in the 1st trimester compared to the non pregnant control, which is similar to the meta-analysis results of Aboshady OA et al., who observed a QTc interval increase by 0.01 seconds during the 1st trimester compared to the non pregnant group [38].

The increase in the QTc in pregnancy has been variably attributed to hormonal changes involving estrogen and progesterone, autonomic changes and cardiac remodelling leading to eccentric hypertrophy in pregnancy [38].

There were no statistically significant changes observed for the P-wave duration and Amplitude. These results aligned with observations of Nandini BN and Manjunath ML, Dodyi-Manuel ST and Ezennaka RC and Singh S et al., [26,36,39].

There was a progressive shortening of the PR interval from the first to the third trimesters of pregnancy, but this change was not statistically significant. This is in correlation with the observations of Dodyi-Manuel ST and Ezennaka RC [36]. There was no statistically significant difference in the PR interval between the pregnant and non pregnant groups, which correlated with the observations of Singh S et al., [39]. The shortening of the PR interval is attributed to accelerated AV conduction resulting from increased sympathetic tone and increased blood volume [15].

A progressive leftward shift of both QRS and T axis was noted from the 1st trimester to the 3rd trimester, although this shift was not statistically significant. It was also observed that the absolute values of the QRS axis and T axis were within the normal range at the 3rd trimester, and this correlated with observations of Schwartz DB and Schamroth L, who cautioned that a leftward shift of QRS, even 0 to - 30° at full term, reflects early left anterior hemiblock [34]. These results also correlated with the studies of Oakley GDG, Akinwusi PO et al., and Battioni L et al., [4,17,28]. The QRS axis represents the direction of the depolarisation of the ventricles. The leftward shift of the QRS axis is attributed to the elevation of the diaphragm due to the enlarged uterus [36], rotation of the heart and increased blood volume [18].

It was observed that there was a progressive increase in T-wave inversion in Leads III and V2 from the 1st to the 3rd trimesters of pregnancy; however, these changes, when compared to the non pregnant control, did not achieve statistical significance.

The Q wave in lead III was higher in the 3rd trimester compared to the control group, which progressively increased from the 1st trimester to the 3rd trimester. This correlated with observations by Nandini BN et al., and Battioni L et al., [18,28]. However, meta-analysis could not demonstrate the above changes to be statistically significant. The prominent Q wave in lead III in pregnancy was attributed to the transverse position of the heart due to elevation of the diaphragm [13]. And as an expression of left axis shift of QRS [14,19].

The Left Ventricular Hypertrophy (LVH), which was detected by the Sokolow-Lyon's Voltage criteria, was attributed to an increase in the LV mass due to physiological hypertrophy in pregnancy [31]. Prevalence of LVH according to these criteria was found to be higher in the pregnant group compared to the control group. However, the sample size was small. The LVH, which was detected by Araoye criteria, was attributed to left ventricular chamber dilatation and hypertrophy due to haemodynamic changes in pregnancy [17]. This criterion yielded a higher prevalence of LVH in the pregnant group when used among the Nigerian population in a study [17]. However, this finding was based on data from only one study with a small sample size [17].

Meta-analysis could not demonstrate statistically significant variations for ST-segment duration, which correlated with observations of Singh S et al., [39]. There was also no statistically significant difference in the QT interval between pregnant and non pregnant groups.

The pooled estimate of effect size was found to be small for the ECG indices, including heart rate, QRS duration, PR interval, mean QTc, P-wave duration and amplitude, QRS and T-axis, T-wave inversion in leads III and V2, and QRS-T angle. This indicated that there were only small changes in ECG indices between the pregnant and non pregnant

groups. This correlates with observations reported in standard cardiology textbooks, which indicate that who stipulated that, except for a slight leftward shift of the QRS axis, there are no characteristic electrocardiographic changes that occur during pregnancy [1,4].

In the group comparing the pregnancy and control, the meta-analysis found a small but statistically significant increase in the heart rate and mean QTc interval. The pooled estimate of the effect size was small for all the indices. A high degree of heterogeneity (I^2=64.94%, τ^2=0.41) was noted for overall ECG indices between the pregnancy and control, even though this variation was not statistically significant (p-value=0.68) [40]. In contrast, when comparing different trimesters of pregnancy, no significant average changes were detected across the trimesters for any of the ECG indices, with high consistency across the studies (I2=0%, τ^2=0.00). Hence, pregnancy, even though it was associated with a small and specific increase only in the heart rate and mean QTc, the overall average effect is limited, and the consistency depends on the comparisons being made [41].

The changes in the ECG indices could still be significant for individual patients even if overall pooled results suggest inconsistent effects. Therefore, the clinician must meticulously analyse the ECG changes for each patient in a unique context. The above knowledge should be of clinical value in aiding the diagnosis of pathological ECG patterns during pregnancy.

Limitation(s)

The meta-analysis had several limitations. Out of the total 25 studies, 15 were from India and cannot be confidently generalised to the global population. Variations in body build across study populations and inconsistent physiological conditions, as well as at the time of ECG measurement, could alter the ECG indices. Additionally, various designs, including both prospective and retrospective studies, were included. Furthermore, meta-analysis combined older studies that used older ECG machine models with subjective manual interpretation and newer studies that utilised computerised models that could result in technological and interpretation differences in ECG indices. These limitations could affect the final pooled results.

CONCLUSION(S)

The meta-analysis has revealed a statistically significant, yet small in magnitude, increase in only heart rate and mean QTc interval during pregnancy. There were no statistically significant changes in any of the ECG indices across the various trimesters of pregnancy. Future larger studies are needed to apply novel ECG indices and computerized artifical intelligence-based algorithms, which could precisely shed light on their variations during different trimesters of pregnancy.

REFERENCES

[1] Camm AJ, Luscher TF, Serruys PW. The ESC Textbook of Cardiovascular Medicine. 2nd ed. Oxford: Oxford University Press; 2010. p. 1240-41.
[2] Oram S. Clinical heart disease. 2nd ed. London: William Heinemann Medical Books Ltd; 1981. p. 701.
[3] Fuster V, Walsh RA, Harrington RA. Hurst's The Heart. 13th ed. New York: McGraw-Hill Companies, Inc.; 2011. p. 2149.
[4] Julian DG, Camm AJ, Fox KM, Hall RJC, Poole-Wilson PA. Diseases of The Heart. London: Bailliere Tindall; 1989. p. 1363-64.
[5] Wood P. Diseases of the Heart and Circulation. 3rd ed. London: Asia Publishing House; 1968. p. 1036-38.
[6] Friedberg CK. Diseases of The Heart. 3rd ed. Philadelphia: WB Saunders Company; 1966. p. 1731-33.
[7] Zipes DP, Libby P, Bonow RO, Mann DL, Tomaselli GF, Braunwald E. Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine. 12th ed. Philadelphia: Elsevier Inc.; 2022. p. 1723-24.
[8] Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses [Internet]. Available from: http://www.ohri.ca/programs/clinical_epidemiology/oxford.htm. [cited 2009 Oct 19].
[9] Carra MC, Romandini P, Romandini M. Risk of bias evaluation of cross-sectional studies: adaptation of the Newcastle-ottawa scale. J Periodontal Res. 2025;0:01-10.
[10] Trivedi DR, Desai CA, Chandwani S. Study of electrocardiographic changes in normal non-pregnant and pregnant women. J Obstet Gynaecol India. 1982;32:808-11.
[11] Madras V, Challa N. Electrocardiographic variations during three trimesters of normal pregnancy. Int J Res Med Sci. 2015;3(9):2218-22.
[12] Carr FB, Palmer RS. Observations on electrocardiography in heart disease associated with pregnancy with especial reference to axis deviation. Am Heart J. 1932;8(2):238-41.
[13] Feldman L, Hill HH. Electrocardiographic changes in toxaemia of pregnancy. Am Heart J. 1934;10(1):110-17.
[14] Landt H, Benjamin JE. Cardiodynamic and electrocardiographic changes in normal pregnancy. Am Heart J. 1936;12(5):592-607.
[15] Nandini BN, Shiva Kumar DG, Manjunath ML, Girish Babu M. Shortening of PR interval in different trimesters of pregnancy: A cross-sectional study. Int J Biomed Adv Res. 2011;2(11):421-26.
[16] Goloba M, Nelson S, Macfarlane P. The electrocardiogram in pregnancy. Comput Cardiol. 2010;37:693-96.
[17] Akinwusi PO, Oboro VO, Adebayo RA, Akintunde AA, Adeniji AO, Isawumi IA, et al. Cardiovascular and electrocardiographic changes in Nigerians with a normal pregnancy. Cardiovasc J Afr. 2011;22(2):71-75.
[18] Nandini BN, Shivakumar DG, Aithal M, Sreepadma S. Occurrence of Q wave, QTc interval and QRS frontal axis during different trimesters of pregnancy: A cross-sectional study. Int J Curr Res Acad Rev. 2014;2(7):79-88.
[19] Sunitha M, Chandrasekharappa S, Brid SV. Electrocardiographic QRS axis, Q wave and T-wave changes in 2nd and 3rd trimester of normal pregnancy. J Clin Diagn Res. 2014;8(9):BC17-BC21.
[20] Lissie P, Vadapalli K, David MA, Sherke BA, Karthik J. A study of changes in heart rate and ECG during second and third trimester of pregnancy: A comparative study. Indian J Clin Anat Physiol. 2017;4(4):524-28.
[21] Ananthakrishnan R, Sharma S, Joshi S, Karunakaran S, Mohanty S. Electrocardiographic changes in normal pregnancy. J Mar Med Soc. 2020;22(2):187-92.
[22] Kole S, Shenoy J, Shivakumar J, Suvarna P, Prasannakumar J. Electrocardiographic changes during different trimesters of pregnancy. Natl J Physiol Pharm Pharmacol. 2014;4(3):187-90.
[23] Chaudhary S, Saha CG, Sarkar D. Electrocardiographic changes during pregnancy at third trimester: a comparative study. Med J Shree Birendra Hosp. 2015;14(2):12-16.
[24] Uma V, Syamala Devi M. Electrocardiographic changes during the third trimester of pregnancy: a cross-sectional study. Sch J Appl Med Sci. 2016;4(8E):3054-57.
[25] Sumalatha B, Jyotsna M, Indrani G. Electrocardiographic changes during normal pregnancy. Indian J Cardiovasc Dis Women. 2017;2(3):35-38.
[26] Nandini BN, Manjunath ML. A comparative study of electrocardiographic changes during different trimesters of pregnancy with nonpregnant controls. Int J Physiol. 2018;6(1):5-11.
[27] Omidi N, Khorgami MR, Khatami F, Mahalleh M. Electrocardiographic indices and pregnancy: a focus on changes between first and third trimesters. Iran J Obstet Gynecol Infertil. 2022;25(4):01-08.
[28] Battioni L, Eidelman G, Enriquezi B, Herscovich N, Arismendi L. Electrocardiography during the third trimester of pregnancy: description of its characteristics. Argent J Cardiol. 2021;89(2):131-35.
[29] Rajani R, Shaik P, Subash Babu P, Venkata Siva J, Vijaya Jyothi A, Vijaya Nirmala M, et al. Electrocardiographic changes in normal pregnancy across trimesters. Eur J Cardiovasc Med. 2024;14(3):1186-94.
[30] Siddiqui F, Alam MF, Rahman A, Baby SA. Electrocardiographic changes in second and third trimesters in Bangladesh: A comparative study. Sch Int J Obstet Gynecol. 2024;7(10):522-26.
[31] Surin LL, Ghodeswar KB, Mokal S. Study on ECG and cardiovascular changes in pregnant and non-pregnant women. Int J Curr Pharm Rev Res. 2025;17(3):604-08.
[32] Ghodeswar KB, Surin LL, Abraham AK, Mokal S. Comparative study on ECG and cardiovascular pattern in different trimesters among pregnant women. Int J Life Sci Biotechnol Pharma Res. 2025;14(3):45-52.
[33] Wenger NK, Hurst JW, Strozier VN. Electrocardiographic changes in pregnancy. Am J Cardiol. 1964;13(6):774-78.
[34] Schwartz DB, Schamroth L. The effect of pregnancy on the frontal plane QRS axis. J Electrocardiol. 1979;12(3):279-81.
[35] Salisu A, Karaye KM. Electrocardiographic indices in a rural pregnant Nigerian women population. Sahel Med J. 2010;13(3):147-52.
[36] Dodyi-Manuel ST, Ezennaka RC. Electrocardiographic changes during normal pregnancy in Southern Nigeria. J Med Dent Sci Res. 2023;10(3):28-33.
[37] Zamani M, Esmailian M, Yoosefian Z. QT interval in pregnant and non-pregnant women. Emerg (Tehran). 2014;2(1):22-25.
[38] Aboshady OA, Raffa JZ, Quinney SK, Tisdale JE, Overholser BR. QTc interval changes in preeclampsia vs. normal pregnancy: A systematic review and meta-analysis. Clin Pharmacol Ther. 2025;117(6):01-11.
[39] Singh S, Mohan U, Shukla N, Pandey S, Singh SS, Pandey US, et al. Case control study of electrocardiographic changes in pregnant women. Indian J Community Med. 1995;8(2-3):24-27.
[40] Rücker G, Schwarzer G, Carpenter JR, Schumacher M. Undue reliance on I2 in assessing heterogeneity may mislead. BMC Med Res Methodol. 2008;8:79.
[41] Sanderson S, Tatt ID, Higgins JP. Tools for assessing quality and susceptibility to bias in observational studies in epidemiology: A systematic review and annotated bibliography. Int J Epidemiol. 2007;36(3):666-76.

PARTICULARS OF CONTRIBUTORS:
1. Senior Cardiologist, Department of Cardiology, ESIC Medical College and Hospital, Chennai, Tamil Nadu, India.
2. Associate Professor, Department of Community Medicine, ESIC Medical College and Hospital, Chennai, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Pallaseena Seetharaman Seshadrinathan,
A16 Ceebros, 6 PCO Road, Egmore, Chennai-600008, Tamil Nadu, India.
E-mail: srisupri@hotmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Oct 13, 2025
- Manual Googling: Dec 18, 2025
- iThenticate Software: Dec 20, 2025 (9%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Oct 04, 2025**
Date of Peer Review: **Oct 14, 2025**
Date of Acceptance: **Dec 23, 2025**
Date of Publishing: **Mar 01, 2026**