Indian Heart Journal 74 (2022) 187–193

Contents lists available at ScienceDirect

Indian Heart Journal

journal homepage: www.elsevier.com/locate/ihj

Original Article

# A community-based study on electrocardiographic abnormalities of adult population from South India - Findings from a cross sectional survey

Mangalath Narayanan Krishnan [a, *, 2], Zachariah Geevar [b], Krishnan Nair Venugopal [c], Padinhare Purayil Mohanan [d], Sivadasanpillai Harikrishnan [e], Ganapathi Sanjay [e], Shanmugasundaram Devika [f], Kavumpurathu Raman Thankappan [g, 1]

[a] *Govt. Medical College, Kozhikode, Kerala, India*
[b] *Mother Hospital, Thrissur, Kerala, India*
[c] *Pushpagiri Hospital, Tiruvalla, Kottayam, Kerala, India*
[d] *Westfort High-tech Hospital, Thrissur, Kerala, India*
[e] *Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum, Kerala, India*
[f] *ICMR-National Institute of Epidemiology, Chennai, India*
[g] *Achutha Menon Centre for Health Science Studies, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum Medical College, P.O., Thiruvananthapuram, Kerala, India*

ARTICLE INFO

*Article history:*
Received 2 January 2022
Accepted 8 May 2022
Available online 13 May 2022

*Keywords:*
Prevalence
Automated ECG analysis
ECG abnormalities
Indian population

ABSTRACT

*Background:* There are no data on electrocardiographic (ECG) findings from general population of Indian subcontinent. We analyzed ECG abnormalities of in adults as part of a community survey of prevalence of coronary artery disease and risk factors from South India.

*Methods and results:* In this cross-sectional study of men and women between the ages 20 to 79 years, ECGs recorded digitally were analyzed using the Minnesota code. Electrocardiograms were analyzed for abnormalities in 4630 participants (women 59.6%). The overall prevalence of ECG abnormalities (39.9%) was higher in men (47.24% vs. 34.9% p <0.0001). QRS axis deviation, first degree AV block, fascicular blocks, incomplete right bundle branch block, sinus bradycardia and ST elevation in the anterior chest leads were markedly higher in men. Sinus tachycardia and low voltage QRS occurred more often in women. The overall prevalence of atrial fibrillation was 0.32% which was markedly lower than the western data. Brugada and early repolarisation patterns occurred in 1.06% and 1.56% respectively, equal in both age groups, but markedly higher in men. Brugada pattern occurred more often than in the west, but much less than the Far East population. Early repolarisation pattern was similar to rest of Asian population, but significantly less than the Caucasian population

*Conclusion:* In this community-based study, prevalence of major electrocardiographic abnormalities was high. Overall, men had significantly higher ECG abnormalities.



## 1. Background and objective

The electrocardiogram (ECG) is a low cost, widely available tool for detection of various cardiac abnormalities, particularly rhythm and conduction disturbances. The prevalence of various electrocardiographic abnormalities has been published from different populations.[1–5] No such data have been published from Indian subcontinent. We aimed to analyze the prevalence of abnormalities in an adult population from the state of Kerala, South India.

* Corresponding author. Department of Cardiology, Medical College, Kozhikode, Kerala, India.
*E-mail addresses:* kedaram@gmail.com (M.N. Krishnan), geevarzachariah@gmail.com (Z. Geevar), venugopalknair@gmail.com (K.N. Venugopal), drppmohanan@gmail.com (P.P. Mohanan), drharikrishnan@outlook.com (S. Harikrishnan), drsanjayganesh@yahoo.com (G. Sanjay), devika.cmc@gmail.com (S. Devika), kr.thankappan@gmail.com (K.R. Thankappan).
[1] Present address: Department of Public Health & Community Medicine, Central University Kerala, Kasaragod, Kerala, India.
[2] Present address: Consultant Cardiologist, Department of Cardiology, Ahalia Hospital, Abu Dhabi, United Arab Emirates.

https://doi.org/10.1016/j.ihj.2022.05.001
0019-4832/

## 2. Subjects and methods

This analysis was conducted on participants of the Cardiological Society of India Kerala Chapter Coronary Artery Disease and Its Risk Factors (CSIK-CRP) study that evaluated the prevalence of coronary artery disease (CAD) and its risk factors in Kerala, a southern state of India. The objectives, subjects and methods of the CSIK-CRP study have been previously described.[6] This was a community-based survey conducted from January to June 2011 in 5167 men and women between the ages 20–79 years from urban and rural sample of three regions of Kerala. We collected data using the standard interview method and responses recorded on a questionnaire. Information on basic socio-economic and demographic details, smoking, physical activity, dietary habits, and personal history of hypertension, dyslipidemia, diabetes mellitus and CAD were collected. Biochemical investigations like fasting blood sugar, total cholesterol, triglycerides and high density lipoprotein (HDL) cholesterol were measured. Low density lipoprotein (LDL) was estimated using Friedwald formula. Anthropometrics like height, weight and waist circumference were recorded in all patients. Blood pressure (BP) was recorded with electronic apparatus (Model 1A2, Omron Corporation, Shimogyo-ku, Kyoto, Japan) in sitting position, on the left arm resting on a table at heart level, after the subject having rested for at least 15 min. Three readings were taken 3 minutes apart and the mean of the last two readings was recorded as the BP.

### 2.1. Electrocardiography

Resting standard 12 lead ECG was recorded in all cases by trained technicians using digital recorder (Cardiart 6208, British Pharmaceutical Laboratory Ltd, Bangalore, India) with 12 lead simultaneous acquisition. The machine was calibrated at 10 mm/mV and recorded at speed of 25 mm/s. It had a frequency response of 0.05 Hz–150 Hz and sampling frequency of 1000 Hz as recommended for digital ECG acquisition.[7] Five complexes were recorded for each lead. Recorded ECGs were analyzed using Smart ECG Measurement and Interpretation Program and digitally saved into computer. Minnesota coding (MC) was performed by investigating cardiologists. Various measurements were performed as per MC criteria and methods; disagreements were resolved by consensus. One of the cardiologists (MNK) re-evaluated all ECGs. The digitally saved ECGs were zoomed in and examined visually. Wherever there was doubt regarding the automated measurements or diagnosis, manual measurements were performed using an electronic caliper with a sensitivity of 4 ms or 0.1 mm (Cardio Calipers, v4.00, ICONICO.com, Philadelphia, USA).

### 2.2. Definitions

We utilized the MC criteria 2010, Appendix A [8] for defining most of the major ECG abnormalities. We decided not to include Q, ST and T codes in this paper as these have been published in an earlier publication.[9] Likewise we have not analyzed certain other minor codes like P-wave amplitude (MC 9–3), QRS transition zone (MC 9-4-1, 9-4-2) T-wave amplitude (MC 9–5), notched and widened P wave (MC 9–6) and fragmented QRS (MC 7–10). In code 9–2, we coded only ST elevation ≥2 mm in any of V2 or V3 leads but not conforming to the diagnosis of Brugada pattern (BrP). For the diagnosis of BrP, we used the criteria laid down in the consensus conference of 2002[10] as we found this more accurate and objective than Minnesota criteria. Similarly, we used the consensus criteria of 2015[11] for analysis of prevalence of early repolarisation pattern (ERP) since this mandated the presence of a notch or slur on the QRS for diagnosis of ERP, which we thought would be more in line with the traditional definition of ERP. For T wave inversion in anterior chest leads V1 to V3, 1 mm or more inversion at the nadir of T wave in these leads was chosen.

We defined diabetes mellitus as fasting blood glucose value of ≥7 mmol/L and/or current use of medications for diabetes,[12] hypertension as blood pressure ≥140 mm of Hg systolic and/or ≥90 mm of Hg diastolic and/or currently on drugs for high blood pressure,[13] and dyslipidemia as any of: serum total cholesterol ≥5•18 mmol/L, serum LDL cholesterol ≥3•37 mmol/L, serum HDL cholesterol <1•04 mmol/L in men or <1•29 mmol/L in women, or serum triglycerides ≥1•69 mmol/L[14] Body mass index (BMI) was categorized as normal (18.0–22.9 kg/m2), overweight (23.0–24.9 kg/m2), or obesity (≥25 kg/m$^2$).[15]

### 2.3. Ethical clearance

The study was in compliance with the Helsinki Declaration and was approved by the Ethics Committee of Cardiological Society of India, Kerala Chapter. Informed written consent was obtained from all participants.

### 2.4. Statistical analysis

Data were entered in CS Pro software (US Census Bureau) version 4.0 for Windows. We used STATA (Stata Corp, Texas, USA) version 17.0 for Windows for data management and statistical analysis. Frequency distribution was done for categorical variables and continuous variables were summarized using mean with standard deviation (SD). Prevalence of ECG abnormalities with 95% confidence interval (CI) was calculated. Comparison of baseline characteristics and ECG abnormalities with respect to age and gender was done using two-tailed proportion test. The differences in the percentage with 95% CI were also provided. Age, systolic BP, diastolic BP, fasting blood glucose, total cholesterol, LDL and HDL were compared between male and female using independent sample *t*-test/modified *t*-test depending on the variance ratio test results. Statistical significance was defined at $P < 0.05$ level.

## 3. Results

Of the 5167 participants of the CSI Kerala CRP study, after excluding missing and unreadable ones we could analyze ECG of 4630 (89.6%) subjects. Table 1 outlines the basal characteristics of the study population (mean age 50.8 years). Women constituted 59.6%; the proportion was similar to the sample for the CSI CRP study (59.9%),[9] although it was higher than that in the general population of the state (52%).[16] One-fourth of the participants was <40 yrs of age and 45% was urban. There was high prevalence of obesity, hypertension, diabetes and hyperlipidemia in the population.

### 3.1. Prevalence of electrocardiographic abnormalities

The overall prevalence of ECG abnormalities in our analysis was 39.9% (men 47.2% vs. women 34.9%). The prevalence of various abnormalities by age group and gender is depicted in Tables 2 and 3 respectively. There were no cases of indeterminate axis (MC 2–5), second degree atrioventricular (AV) block (MC 6-2-1, 6-2-2, 6-2-3), intermittent left bundle branch block (LBB) or right bundle branch block (RBB) (MC 7-1-2,7-2-2), wandering pacemaker (MC 8-1-4), abnormal ventricular rhythms (MC 8-2-1, 8-2-2,8-2-3or 8-2-4), atrial flutter(MC 8-3-2,8-3-4), supraventricular tachycardia (MC 8-4-1, 8-4-2), sinus arrest (MC 8-5-1), or sino-atrial block (MC 8-5-2).

Some abnormality of QRS axis occurred in 3.8% of participants, left axis deviation being by far the commonest. Both left and right

**Table 1**
Baseline characteristics of the study population.

| Characteristic | Total (n = 4630) | Men (n = 1871) | Women (n = 2759) | P value |
|---|---|---|---|---|
| Age, years, Mean (SD) | 50.82 (13.99) | 51.81 (14.17) | 50.16 (13.82) | 0.0001 |
| Age group, N(%) | | | | |
| 20–29 | 299 (6.46) | 129 (6.89) | 170 (6.16) | <0.001 |
| 30–39 | 803 (17.34) | 276 (14.75) | 527 (19.10) | |
| 40–49 | 1059 (22.87) | 417 (22.29) | 642 (23.27) | |
| 50–59 | 925 (19.98) | 355 (18.97) | 570 (20.66) | |
| 60–69 | 1092 (23.59) | 489 (26.14) | 603 (21.86) | |
| 70–79 | 452 (9.76) | 205 (10.96) | 247 (8.95) | |
| Region, N (%) | | | | |
| Urban | 2093 (45.21) | 915 (48.90) | 1178 (42.70) | <0.001 |
| Rural | 2537 (54.79) | 956 (51.10) | 1581 (57.30) | |
| BMI, N (%) | | | | |
| Low | 307 (6.64) | 129 (6.91) | 178 (6.46) | <0.001 |
| Normal | 1546 (33.44) | 733 (39.24) | 813 (29.51) | |
| Overweight | 894 (19.34) | 408 (21.84) | 486 (17.64) | |
| Obese | 1876 (40.58) | 598 (32.01) | 1278 (46.39) | |
| Smoking, N (%) | | | | |
| Never | 3501 (79.79) | 880 (50.09) | 2621 (99.62) | <0.001 |
| Past | 306 (6.97) | 302 (17.19) | 4 (0.15) | |
| Current | 581 (13.24) | 575 (32.73) | 6 (0.23) | |
| Hypertension, N (%) | | | | |
| Normal | 2808 (60.79) | 1082 (58.08) | 1726 (62.63) | 0.002 |
| Hypertensive | 1811 (39.21) | 781 (41.92) | 1030 (37.37) | |
| Diabetes mellitus, N(%) | | | | |
| Non-Diabetics | 3648 (79.22) | 1428 (76.73) | 2220 (80.90) | 0.001 |
| Diabetics | 957 (20.78) | 433 (23.27) | 524 (19.10) | |
| High cholesterol, N (%) | | | | |
| Normal | 1926 (41.94) | 846 (45.61) | 1080 (39.46) | <0.001 |
| High | 2666 (58.06) | 1009 (54.39) | 1657 (60.54) | |
| Systolic BP, Mean (SD) | 130.32 (20.74) | 133.05 (19.81) | 128.48 (21.16) | <0.001 |
| Diastolic BP, Mean (SD) | 76.28 (11.12) | 77.45 (11.32) | 75.49 (10.92) | <0.001 |
| Fasting blood glucose, Mean (SD) | 100.87 (33.99) | 101.90 (33.46) | 100.17 (34.33) | 0.0906 |
| Total cholesterol, Mean (SD) | 209.99 (42.60) | 204.51 (41.40) | 213.71 (43.01) | <0.001 |
| LDL, Mean (SD) | 134.77 (37.54) | 128.96 (36.86) | 138.70 (37.50) | <0.001 |
| HDL, Mean (SD) | 50.03 (12.12) | 47.40 (11.99) | 51.81 (11.88) | <0.001 |

BMI = body mass index; LDL = low density lipoproteins; HDL = high density lipoproteins; SD = standard deviation.

axis deviations were more often encountered in men and older age group.

Among conduction abnormalities (11.4%), incomplete LBB constituted the maximum; left anterior fascicular block (LAFB), LBBB and RBBB (both complete and incomplete) and first degree AV block were more often present in ≥40-year age group. The prevalence of first degree AV block, incomplete RBB, and sinus bradycardia were markedly higher in men while sinus tachycardia occurred much more often in women. Ventricular pre-excitation was rare. We did not encounter any AV blocks higher than first degree barring an isolated case of third-degree AV block.

Some form of rate or rhythm abnormality was present in 325 (7%) participants. The overall prevalence of atrial fibrillation (AF) was 0.32%. We observed AF in the older age group only.

Brugada pattern occurred in 49 cases (1.06%) in our sample (Type I in 0.04% and Type II/III in 1.02%); it was markedly higher in men while did not differ between age groups. There were 72 cases of ERP in the sample (1.56%); again, the prevalence was markedly higher in men, but similar between younger and older participants. Low voltage QRS complex or isolated ST elevation in V2 or V3 occurred equally in both age groups. Low voltage QRS was significantly more often seen in women while anterior chest lead ST elevation occurred much more often in men. The prevalence of T inversion in V1 was expectedly more in the younger age group. T wave inversion in V1 alone occurred equally in men and women, while combined T wave inversion in V1 to V3 occurred much more often in women.

## 4. Discussion

In a population survey of urban and rural communities of Kerala, we studied ECG abnormalities in men and women aged between 20 and 79 years. In this study, the prevalence of abnormalities was high.

The major drivers of high prevalence of ECG findings were incomplete LBB, sinus tachycardia, ST elevation V2 and/or V3, low voltage QRS and T inversion in the precordial leads (V1 to V3). Of these, precordial T inversion is not part of Minnesota criteria; ST elevation in V2 and/or V3 may not be considered an abnormality (a normal variation), and not according to the MC 9–2. However, we thought these findings might be of interest to the readers. If the ST elevation in V2 and/or V3 and precordial T inversion are discounted, the prevalence of abnormalities becomes 1285 (27.7%).

Overall, men had significantly higher ECG abnormalities. The higher overall prevalence of ECG abnormalities in men was driven primarily by LAD, first degree AV block, sinus bradycardia, incomplete RBB and LBB, precordial ST elevation, BrP and ERP. In older participants there was high prevalence of LAD, RAD, LBB, RBB, first degree AV block, IVCD, LAFB and right precordial T wave inversion.

In an Indian study of 3798 healthy volunteers who participated in phase I clinical trials (age, mean 31 years; 80% < 45years of age) Hingorani et al[17] found morphological abnormalities in 25.5%. Rhythm abnormalities (11.5%) were higher in their study while conduction abnormalities (5.4%) were lower. First degree AV block occurred more often in their study (2.2% vs. 1.24%) probably due to the difference in the criteria for diagnosis (>200 ms vs. ≥ 220 ms);

**Table 2**
Prevalence of electrocardiographic abnormalities by age.

| | Minnesota code | Total (n = 4630) (%) | <40 Yrs (n = 1102) (%) | ≥40 Yrs (n = 3528) (%) | Difference (95% CI) | P value |
|---|---|---|---|---|---|---|
| Overall ECG abnormalities | | 1847 (39.9) | 425 (38.57) | 1422 (40.3) | - 1.73 (1.59,4.99) | 0.3 |
| I . Axis deviation | | | | | | |
| *LAD | 2–1 | 105 (2.27) | 9 (0.82) | 96 (2.72) | 1.9 (−1.02, −2.6) | <0.001 |
| RAD | 2-2 or 2-3 | 68 (1.47) | 26 (2.36) | 42 (1.19) | 1.17 (0.20, 2.13) | 0.005 |
| Extreme axis | 2–4 | 4(0.09) | 0 | 4 (0.11) | −0.11(-0.22,-0.0023) | 0.263 |
| II . Conduction abnormalities | | | | | | |
| 3° AV block | 6–1 | 1 (0.02) | 0 | 1 (0.03) | −0.03(-0.08, 0.03) | 0.576 |
| 1° AVB | 6–3 | 54 (1.17) | 2 (0.18) | 52 (1.47) | −1.29 (−1.76, −0.82) | <0.001 |
| Pre-excitation | 6-4-1 or 6-4-2 | 2 (0.04) | 0 | 2 (0.06) | −0.06 (-0.14,0.02) | 0.429 |
| Short PR interval | 6–5 | 65 (1.40) | 18 (1.63) | 47 (1.33) | 0.30 (−0.54, 1.14) | 0.458 |
| Pacemaker | 6–8 | 1 (0.02) | 0 | 1 (0.03) | −0.03 (-0.08,0.03) | 0.576 |
| LBB | 7-1-1 | 28 (0.60) | 0 | 28 (0.79) | −0.79 (−1.09, −0.50) | 0.003 |
| RBB | 7-2-1 | 41 (0.89) | 3 (0.27) | 38 (1.08) | −0.81 (−1.26, −0.35) | 0.013 |
| Incomplete RBB | 7–3 | 29 (0.63) | 3 (0.27) | 26 (0.74) | −0.47 (−0.88, −0.05) | 0.088 |
| nonspecific IVCD | 7–4 | 12(0.26) | 1 (0.09) | 11(0.99) | −0.9 (-0.4,-1.3) | <0.003 |
| Incomplete LBB | 7–6 | 163 (3.52) | 37(3.36) | 126 (3.57) | −0.21 (−1.44, 1.01) | 0.737 |
| LAFB | 7–7 | 53 (1.14) | 1 (0.09) | 52 (1.47) | −1.38 (−1.82, −0.95) | <0.001 |
| Bifascicular Block | 7–8 | 7 (0.15) | 0 | 7 (0.20) | −0.20 (-0.35,-0.05) | 0.139 |
| III . Rate and rhythm abnormalities | | | | | | |
| Sinus tachycardia | 8–7 | 168 (3.63) | 48 (4.36) | 120 (3.40) | 0.95 (−0.39, 2.30) | 0.139 |
| Sinus bradycardia | 8–8 | 69 (1.49) | 15 (1.36) | 54 (1.53) | −0.17 (−0.96, 0.63) | 0.685 |
| Atrial fibrillation | 8-3-1, or 8-3-3 | 15 (0.32) | 0 | 15 (0.43) | −0.43 (−0.64, −0.21) | 0.030 |
| SVPB | | 30 (0.65) | 5(0.45) | 25 (0.71) | −0.25 (-0.74,0.23) | 0.357 |
| VPB | | 43 (0.93) | 6 (0.55) | 37(1.05) | −0.50 (-1.05,0.05) | 0.128 |
| IV . Miscellaneous abnormalities | | | | | | |
| Brugada pattern | Consensus 2002[12] | 49 (1.06) | 9 (0.82) | 40 (1.13) | −0.32 (−0.95, 0.32) | 0.3692 |
| ERP | Consensus 2016[13] | 72 (1.56) | 19 (1.72) | 53 (1.50) | 0.22 (−0.65, 1.09) | 0.6033 |
| Low voltage QRS | 9–1 | 160 (3.46) | 39 (3.54) | 121 (3.43) | 0.11 (−1.14, 1.35) | 0.8623 |
| ST elevation in V2 or V3 | 9–2 | 138 (2.98) | 41 (3.72) | 97 (2.75) | 0.97 (−0.27, 2.21) | 0.0980 |
| T inversion V1, V2 or V3 | | | | | | |
| V1 | | 340 (7.34) | 113 (10.25) | 227 (6.43) | 3.82 (1.85, 5.79) | <0.001 |
| V1+V2 | | 86 (1.86) | 23 (2.09) | 63 (1.79) | 0.30 (−0.65, 1.25) | 0.518 |
| V1+ V2+V3 | | 44 (0.95) | 7 (0.64) | 37(1.05) | −0.41 (−0.99, 0.16) | 0.217 |

LAD = left axis deviation; RAD = right axis deviation; AVB = atrioventricular block; LBB = left bundle branch block; RBB = right bundle branch block; IVCD = intraventricular conduction defect; LAFB = left anterior fascicular block; SVPB = supraventricular premature beats; VPB = ventricular premature beats; ERP = early repolarisation pattern. *LAD excluding LAFB. ** Excluding complete LBB and RBB.

complete or incomplete RBB, LBBB or LAFB occurred more often in our study presumably due to higher age distribution.

In a large Finnish study, Haataja et al[18] found that complete RBB, complete LBB, LAFB, incomplete LBB, incomplete RBB and nonspecific IVCD occurred in 1.1%, 0.9%, 0.1%, 1%, 1%, and 0.6% of general population respectively while they were mostly lower in our study; however, LAFB occurred much more frequently. Saggu and associates[19] published the prevalence of atrial fibrillation from Indian urban sample; they found AF in about 0.2%, similar to our data. The reported prevalence of AF varied among Asian countries from 0.6% to 1.6%[20–22] while in Caucasian population it was 1.4%–4%.[23–25] Our AF prevalence was less than other Asian countries and markedly less than the western prevalence. Notably, AF occurred only in the older age group of our sample.

We also compared our data on ECG abnormalities with the data published on a sample of 14,424 civil servants (aged 35 to 74) from 6 cities of Brazil[26] and another recent Chinese population-based study of 47,325 men and women (age >20 years) of urban and rural China[27] (Table 6). These studies were comparable with our study in terms of age range of the sample. QRS axis deviation was more prevalent in the Chinese study. First degree AV block was higher in our data; higher degrees of atrioventricular blocks were rare in all studies. Left bundle branch block occurred more often in our study; RBB was higher in the Brazilian study. Atrial fibrillation/atrial flutter occurred similarly in all these studies.

In this survey, we chose the criteria proposed by the Consensus 2002 for defining BrP as it was explicit and unambiguous, unlike the MC which had some inconsistencies. Likewise, we decided not to use the more recent Consensus criteria of 2012,[28] because this again failed to clearly define several issues for making diagnosis, although it had incorporated stricter criteria to eliminate non-Brugada conditions. Moreover most major studies on prevalence of BrP based their diagnosis on the Consensus 2002 criteria (or Consensus 2005,[29] which is a minor modification of Consensus 2002) and we thought using the same criteria will allow meaningful comparison.[30–32] Worldwide pooled prevalence of spontaneous Type I, Type II/III Brugada ECG pattern is 0.03%–0.05% and 0.42%, respectively.[33,34] The prevalence of Type I BrP is 0.08% in Asian countries and 0.02% in Caucasian population. Our study showed Type I Brugada pattern in 0.04% and Type II/III pattern in 1.02%. The prevalence of BrP in our study was 1.06%, similar to overall Asian data (1.8%), although it was much lower than certain far-east countries like Thailand and the Philippines.[34] Brugada pattern in our study was significantly more often seen in men, but was not different between age groups.

There were 72 cases of ERP in our sample (1.56%). The overall prevalence was much lower than reported from western studies (14–18%),[35,36] probably due to differences in the criteria for diagnosis. Recently, a large study from Argentina,[37] published the prevalence of ERP using criteria identical to our study found a prevalence of 8.1% which was much higher than our data. In a recent survey of comparable general population from China, Sun et al showed 1.3% prevalence for ERP, similar to our data.[38] There were significantly more men with ERP in our study; however, unlike other reports, the prevalence was not higher in the young.

In a recent survey of 10,783 apparently healthy subjects of 6 different ethnicities, Ter Haar et al.[39] found right precordial ST elevation in 3.4% with strong age and sex predilections, being much

**Table 3**
Prevalence of electrocardiographic abnormalities by gender.

| | Minnesota code | Total (n = 4630) (%) | Men (n = 1871) (%) | Women (n = 2759) (%) | Difference (95% CI) | P value |
|---|---|---|---|---|---|---|
| Overall ECG abnormalities | | 1847 (39.9) | 884 (47.24) | 963 (34.9) | 12.34 (9.46, 15.21) | <0.0001 |
| I. QRS Axis | | | | | | |
| LAD* | 2–1 | 105 (2.27) | 54 (2.89) | 51 (1.85) | 1.04(0.16, 2.00) | 0.002 |
| RAD | 2-2 or 2-3 | 68 (1.47) | 38 (2.03) | 30 (1.09) | 0.94 (0.20,1.69) | 0.009 |
| Extreme axis | 2–4 | 4(0.09) | 4 (0.21) | 0 (0) | 0.21 (0.0045,0.42) | 0.015 |
| II. Conduction abnormalities | | | | | | |
| 3° AV block | 6–1 | 1 (0.02) | 0 (0.00) | 1 (0.04) | −0.04(-0.11,0.03) | 0.410 |
| 1° AVB | 6–3 | 54 (1.17) | 36 (1.92) | 18 (0.65) | 1.27 (0.58,1.96) | <0.001 |
| Pre-excitation | 6-4-1 or 6-4-2 | 2 (0.04) | 1 (0.05) | 1 (0.04) | 0.02(-0.11,0.14) | 0.782 |
| Short PR interval | 6–5 | 65 (1.40) | 20 (1.07) | 45 (1.63) | −0.56 (−1.23,0.10) | 0.111 |
| Pacemaker | 6–8 | 1 (0.02) | 0 (0.00) | 1 (0.04) | −0.04(-0.11,0.03) | 0.410 |
| LBB | 7-1-1 | 28 (0.60) | 9 (0.48) | 19 (0.69) | −0.21 (−0.65,0.23) | 0.371 |
| RBB | 7-2-1 | 41 (0.89) | 21 (1.12) | 20 (0.73) | 0.40 (−0.18,0.97) | 0.157 |
| Incomplete RBB | 7–3 | 29 (0.63) | 25 (1.34) | 4 (0.15) | 1.19 (0.65,1.73) | <0.001 |
| **Nonspecific IVCD | 7–4 | 12(0.26) | 6 (0.32) | 6 (0.22) | 0.1(-0.21, 0.5) | 0.512 |
| Incomplete LBB | 7–6 | 163 (3.52) | 81 (4.33) | 82 (2.97) | 1.36 (0.24,2.48) | 0.014 |
| LAFB (LAHB) | 7–7 | 53 (1.14) | 32 (1.71) | 21 (0.76) | 0.95 (0.28,1.62) | 0.003 |
| Bifascicular Block | 7–8 | 7 (0.15) | 4 (0.21) | 3 (0.11) | 0.11(-0.14,0.35) | 0.367 |
| III. Rate and rhythm abnormalities | | | | | | |
| Sinus tachycardia | 8–7 | 168 (3.63) | 30 (1.6) | 138 (5) | −3.40 (−4.39,-2.41) | <0.001 |
| Sinus bradycardia | 8–8 | 69 (1.49) | 50 (2.67) | 19 (0.69) | 1.98 (1.19,2.78) | <0.001 |
| Atrial fibrillation | 8-3-1 or 8-3-3 | 15 (0.32) | 7 (0.37) | 8 (0.29) | 0.08 (−0.26,0.43) | 0.621 |
| SVPB | | 30(0.65) | 14 (0.75) | 16 (0.58) | 0.17 (−0.31,0.65) | 0.484 |
| VPB | | 43(0.93) | 19 (1.02) | 24 (0.87) | 0.15 (−0.43,0.72) | 0.612 |
| IV. Miscellaneous abnormalities | | | | | | |
| Brugada Pattern | Consensus[12] | 49 (1.06) | 44 (2.35) | 5 (0.18) | 2.17 (1.47, 2.88) | <0.001 |
| ERP | Consensus[13] | 72 (1.56) | 66(3.53) | 6 (0.22) | 3.31 (2.46, 4.16) | <0.001 |
| Low voltage QRS | 9–1 | 160 (3.46) | 39 (2.08) | 121 (4.39) | −2.30 (−3.30,-1.30) | <0.001 |
| ST elevation in V2 or V3 | 9–2 | 138 (2.98) | 131 (7.00) | 7 (0.25) | 6.75 (5.58,7.92) | <0.001 |
| T inversion V1,V2, or V3 | | | | | | |
| V1 alone | | 340 (7.34) | 135 (7.22) | 205 (7.43) | −0.22 (−1.74,1.31) | 0.783 |
| V1+V2 | | 86 (1.86) | 14 (0.75) | 72 (2.61) | −1.86 (−2.57,-1.15) | <0.001 |
| V1+ V2+V3 | | 44 (0.95) | 4 (0.21) | 40 (1.45) | −1.24 (−1.73,-0.74) | <0.001 |

LAD = left axis deviation; RAD = right axis deviation; AVB = atrioventricular block; LBB = left bundle branch block; RBB = right bundle branch block; IVCD = intraventricular conduction defect; LAFB = left anterior fascicular block; SVPB = supraventricular premature beats; VPB = ventricular premature beats; ERP = early repolarisation pattern. *LAD excluding LAFB. ** Excluding complete LBB and RBB.

**Table 4**
Comparison with other studies of electrocardiographic abnormalities.

| ECG abnormality | Current study (n = 4630) N (%) | ELSA–Brazil Study[33] (n = 14,424) N (%) | Liping Yu[34] (n = 34,965) N (%) |
|---|---|---|---|
| LAD | 105(2.27) | NR | 698 (2.13) |
| RAD | 68 (1.47) | NR | 254 (0.67) |
| Extreme axis | 4 (0.09) | NR | NR |
| 3° AVB | 1 (0.02) | 0 | 16 (0.04) |
| 2 ∘AVB | | | |
| Mobitz Type II | 0 | 0 | |
| Mobitz Type I | 0 | NR | |
| 1° AVB | 54 (1.24) | NR | 141 (0.47) |
| Pre-excitation | 2 (0.04) | 43(0.3) | 44 (0.09) |
| Short PR | 65(1.4) | NR | 241 (0.7) |
| Intermittent aberrancy | 0 | NR | NR |
| Pacemaker | 1 (0.02) | 8 (0.036) | 9 (0.03) |
| LBB | 28 (0.60) | 69 (0.48) | 28 (0.12) |
| RBB | 45 (0.97) | 237(1.64) | 289 (0.85) |
| Nonspecific IVCD | 12(0.26) | 29 (0.2) | 59 (0.2) |
| LAFB | 53 (1.14) | NR | NR |
| Bifascicular Block | 7 (0.15) | NR | NR |
| Incomplete LBB | 163(3.5) | NR | NR |
| Incomplete RBB | 29 (0.63) | NR | 285(0.97) |
| Sinus tachycardia | 168 (3.62) | NR | 540 (1.68) |
| Sinus bradycardia | 69(1.49) | NR | 703 (2.81) |
| Supraventricular/Ventricular tachycardia | 0 | 0 | 28 (0.09%) |
| Atrial fibrillation | 15(0.32) | 48 (0.33) | 77 (0.28) |
| Atrial flutter | 0 | | |
| Ventricular ectopics | 43(0.93) | NR | 544 (1.57) |
| Supraventricular ectopics | 30(0.65) | NR | |

NR- = not reported; LAD = left axis deviation; RAD = right axis deviation; AVB = atrioventricular block; LBB = left bundle branch block; RBB = right bundle branch block; IVCD = intraventricular conduction defect; LAFB = left anterior fascicular block.
Note: Brugada pattern, early repolarisation pattern or other miscellaneous abnormalities were not reported in either of the comparison studies.

more common in men and young (<40 yrs) individuals. Our study too showed ST segment elevation in V2 or V3 in 2.98% of ECGs with a highly significant predilection for men.

### *4.1. Strengths and limitations of the study*

This study is the only large community-based survey of electrocardiographic abnormalities from Indian subcontinent. The study had a wide age range of participants and was representative of the population in the region. The electrocardiograms were properly recorded, stored and read electronically; measurements were meticulously rechecked by experienced cardiologists. However, there are some limitations for the study: the sample size was modest; the age range was 20–79 years, and subjects age 80 years or more were not included in the study; there was some imbalance in the gender distribution of the sample, skewed towards women. Consequently, these should be factored while assessing the data presented in this study.

## 5. Conclusion

In this population survey, prevalence of major electrocardiographic abnormalities was high. Overall, men had significantly higher ECG abnormalities. Compared to similar surveys from Brazil and China, QRS axis deviation, first degree AV block, IVCD and sinus tachycardia appeared to be more prevalent in our study. The prevalence of AF was similar to Asian data, but much less compared to Caucasian population. The prevalences of BrP and ERP were similar to other Asian population, but that of BrP higher and ERP much lower compared to western data. Both occurred more in men, but contrary to other surveys occurred equally between age groups.

## Funding

The study was funded exclusively by the Cardiological Society of India, Kerala Chapter, a professional organization of cardiologists in India. The funding source had no role in the design, data collection, analysis or interpretation or writing up of the article.

## Authors' contributions

The conception and design of the study was by ZG, MNK, SH, and KRT, acquisition of data by ZG, MNK, KV, PPM, SH and GS, analysis and interpretation of data by SD and KRT. Drafting the article was done by MNK; revising it for critically important intellectual content and final approval of the version to be submitted was by all authors.

## Declaration of competing interest

None.

## References

1. Khurshid S, Choi SH, Weng L, et al. Frequency of cardiac rhythm abnormalities in a half million adults. *Circ Arrhythm Electrophysiol*. 2018;11(7), e006273. https://doi.org/10.1161/CIRCEP.118.006273.
2. Li J, Wang H, Cao C, Xiao C. Analysis of 12-leads electrocardiogram of 8970 cases from community natural population. *Heart*. 2011;97(21). https://doi.org/10.1136/heartjnl-2011-300867.279. Suppl 3: A 94.
3. Ostrander Jr LD, Brandt RL, Kjelsberg MO, Epstein FH. Electrocardiographic findings among the adult population of a total natural community, Tecumseh, Michigan. *Circulation*. 1965;31:888–898. https://doi.org/10.1161/01.cir.31.6.888.
4. De Bacquer D, De Backer G, Kornitzer M. Prevalences of ECG findings in large population-based samples of men and women. *Heart*. 2000;84:625–633. https://doi: 10.1136/heart.84.6.625.
5. Denes P, Garside DB, Lloyd-Jones D, et al. Major and minor electrocardiographic abnormalities and their association with underlying cardiovascular disease and risk factors in Hispanics/Latinos (from the Hispanic community health study/study of Latinos). *Am J Cardiol*. 2013;112(10):1667–1675. https://doi: 10.1016/j.amjcard.2013.08.004.
6. Zachariah G, Harikrishnan S, Krishnan MN, et al. Prevalence of coronary artery disease and coronary risk factors in Kerala, South India: a population survey-design and methods. *Indian Heart J*. 2013;65:243–249. https://doi.org/10.1016/j.ihj.2013.04.008.
7. Kligfield P, Gettes LS, Bailey JJ, et al. Recommendations for the standardization and interpretation of the electrocardiogram. Part I: the electrocardiogram and its Technology: a scientific statement from the American heart association electrocardiography and arrhythmias committee, council on clinical Cardiology; the American college of Cardiology foundation; and the heart rhythm society. *Circulation*. 2007;115(10):1306–1324. https://doi.org/10.1161/CIRCULATIONAHA.106.180200.
8. Prineas RJ, Crow RS, Zhang Z. *The Minnesota Code Manual of Electrocardiographic Findings*. 2nd ed. Springer; 2010.
9. Krishnan MN, Zachariah G, Venugopal K, et al. Prevalence of coronary artery disease and its risk factors in Kerala, South India: a community-based cross-sectional study. *BMC Cardiovasc Disord*. 2016;16:12.
10. Wilde AAM, Antzelevitch C, Borggrefe M, et al. Proposed diagnostic criteria for the Brugada syndrome. Consensus report. *Circulation*. 2002;106:2514–2519. https://doi.org/10.1161/01.CIR.0000034169.45752.4A.
11. Macfarlane PW, Antzelevitch C, Haissaguerre M, et al. The early repolarization pattern. A consensus paper. *J Am Coll Cardiol*. 2015;66:470–477. https://doi.org/10.1016/j.jacc.2015.05.033.
12. American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care*. 2010;33(1):S62–S69. https://doi.org/10.2337/dc10-S062.
13. Chobanian AV, Bakris GL, Black HR, et al. The Seventh report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 Report. *JAMA*. 2003;289:2560–2572. https://doi.org/10.1001/jama.289.19.2560.
14. Third report of the national cholesterol education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III) final report. *Circulation*. 2002;106:3143. https://doi.org/10.1161/circ.106.25.3143.
15. Misra A, Chowbey P, Makkar BM, et al. For consensus group. Consensus statement for diagnosis of obesity, abdominal obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management. *J Assoc Phys India*. 2009;57:163–170. PMID: 19582986.
16. *Census*; 2011. https://censusindia.gov.in/2011census/population_enumeration.html.
17. Hingorani P, Natekar M, Deshmukh S, et al. Morphological abnormalities in baseline ECGs in healthy normal volunteers participating in phase I studies. *Indian J Med Res*. 2012;135(3):322–330. PMID: 22561618.
18. Haataja P, Nikus K, Kähönen M, et al. Prevalence of ventricular conduction blocks in the resting electrocardiogram in a general population: the Health 2000 Survey. *Int J Cardiol*. 2013;167:1953–1960. https://doi.org/10.1016/j.ijcard.2012.05.024.
19. Saggu DK, Sundar G, Nair SG, et al. Prevalence of atrial fibrillation in an urban population in India: the Nagpur pilot study. *Heart Asia*. 2016;8:56–59. https://doi.org/10.1136/heartasia-2015-010674.
20. Iguchi Y, Kimura K, Aoki J, et al. Prevalence of atrial fibrillation in community-dwelling Japanese aged 40 years or older in Japan: analysis of 41,436 non-employee residents in Kurashiki-city. *Circ J*. 2008;72(6):909–913. https://doi.org/10.1253/circj.72.909.
21. Zhou Z, Hu D. An epidemiological study on the prevalence of atrial fibrillation in the Chinese population of mainland China. *J Epidemiol*. 2008;18(5):209–216. https://doi.org/10.2188/jea.je2008021.
22. Kiatchoosakun S, Pachirat O, Chirawatkul A, Choprapawan C, Tatsanavivat P. Prevalence of cardiac arrhythmias in Thai community. *J Med Assoc Thai*. 1999;82(7):727–733. PMID: 10511776.
23. Naccarelli GV, Varker H, Lin J, Schulman KL. Increasing prevalence of atrial fibrillation and flutter in the United States. *Am J Cardiol*. 2009;104:1534–1539. https://doi.org/10.1016/j.amjcard.2009.07.022.
24. DeWilde S, Carey IM, Emmas C, Richards N, Cook DG. Trends in the prevalence of diagnosed atrial fibrillation, its treatment with anticoagulation and predictors of such treatment in UK primary care. *Heart*. 2006;92:1064–1070. https://doi.org/10.1136/hrt.2005.069492.
25. Sturm JW, Davis SM, O'Sullivan JG, Vedadhaghi ME, Donnan GA. The Avoid Stroke as Soon as Possible (ASAP) general practice stroke audit. *Med J Aust*. 2002;176:312–316. https://doi.org/10.5694/j.1326-5377. 2002. Tb04430. x.
26. Pinto – Philho MM, Brant LCC, Foppa M, et al. Major electrocardiographic abnormalities according to the Minnesota coding system among Brazilian adults (from the ELSA-Brazil Cohort Study). *Am J Cardiol*. 2017;119:2081–2087. https://doi.org/10.1016/j.amjcard.2017.03.043.
27. Yu L, Ye X, Yang Z, Yang W, Zhang B. Prevalence and associated factors of electrocardiographic abnormalities in Chinese adults: a cross-sectional study. *BMC Cardiovasc Disord*. 2020;20:414. https://doi.org/10.1186/s12872-020-01698-5.
28. Bayés de Luna A, Brugada J, Baranchuk A, et al. Current electrocardiographic criteria for diagnosis of Brugada pattern: a consensus report. *J Electrocardiol*. 2012;45(5):433–442. https://doi: 10.1016/j.jelectrocard.2012.06.004.

29. Antzelevitch C, Brugada P, Borggrefe M, et al. Brugada syndrome: report of the second consensus conference: endorsed by the heart rhythm society and the European heart rhythm association. *Circulation*. 2005;111(5):659, 70 htpps://10.1161/01.CIR.0000152479.54298.51.
30. Tsuji H, Sato T, Morisaki K, Iwasaka T. Prognosis of subjects with Brugada-type electrocardiogram in a population of middle-aged Japanese diagnosed during a health examination. *Am J Cardiol*. 2008;102:584−587. https://doi: 10.1016/j.amjcard.2008.04.066.
31. Gallagher MM, Forleo GB, Behr ER, et al. Prevalence and significance of Brugada-type ECG in 12,012 apparently healthy European subjects. *Int J Cardiol*. 2008;130:44−48. https://doi: 10.1016/j.ijcard.2007.07.159.
32. Patel SS, Anees SS, Ferrick KJ. Prevalence of a Brugada pattern electrocardiogram in an urban population in the. *United States PACE*. 2009;32:704. −08 https://doi: 10.1111/j.1540-8159.2009.02354.x.
33. Shi S, Barajas-Martinez H, Liu T, et al. Prevalence of spontaneous Brugada ECG pattern recorded at standard intercostal leads: a meta-analysis. *Int J Cardiol*. 2017;254:151−156. https://doi.org/10.1016/j.ijcard.2017.11.113.
34. Vutthikraivit W, Rattanawong P, Putthapiban P, et al. Worldwide prevalence of Brugada syndrome: a systematic review and meta-analysis. *Acta Cardiol Sin*. 2018;34:267−277. https://doi.org/10.6515/ACS.201805_34(3).20180302B.
35. Walsh JA, Lukianoff L, Soliman EZ, et al. Natural history of the early repolarization pattern in a biracial cohort: CARDIA (coronary artery risk development in young adults) study. *J Am Coll Cardiol*. 2013;61:863−869. https://doi.org/10.1016/j. jacc.2012.11.053.
36. Uberoi A, Jain NA, Perez M, et al. Early repolarization in an ambulatory clinical population. *Circulation*. 2011;124:2208−2214. https://doi.org/10.1161/CIRCULATIONAHA.111.047191.
37. Mattaa MG, Gulayina PE, Garcıa-Zamora S, et al. Epidemiology of early repolarization pattern in an adult general population. *Acta Cardiol*. 2020;75(8): 713−723. https://doi.org/10.1080/00015385.2019.1667623.
38. Sun G, Ye N, Chen Y, Zhou Y, Li Z, Sun Y. Early repolarization pattern in the general population: prevalence and associated factors. *Int J Cardiol*. 2017;230: 614−618. https://doi.org/10.1016/j.ijcard.2016.12.045.
39. Ter Haar CC, Kors JA, Peters RJG, et al. Prevalence of ECGs exceeding thresholds for ST-segment elevation myocardial infarction in apparently healthy individuals: the role of ethnicity. *J Am Heart Assoc*. 2020;9, e015477. https://doi.org/10.1161/JAHA.119.015477.