ABSTRACT: BACKGROUND: The Purpose of this study was to compare the changes in ECG’s of young competitive Indian athletes with that of normal young non athletic persons. METHODS: The study included 100 subjects out of which 50 were competitive athletes and 50 were non-athletes age ranging between 16-30 yrs. Following parameters were accessed: Resting Heart Rate. Rhythm. Intervals: PR, QRS, QT, QTc. Axis. These parameters were obtained using ECG machine 1101 with 12 lead European mode, the data was statistically analysed using graphpad software, the data was compared using student t test. RESULTS: Heart Rate There was significant Bradycardia in 26% of Athletes and none with Tachycardia. The Heart Rate was in normal range in 98% of Non-Athletic Group and 2% showed Tachycardia. On Comparison by paired t test, Athletic Group had Significant Bradycardia (P = 0.0001). RHYTHM: Sinus Rhythm was assessed in all ECG’s of either of the groups. PR interval: PR interval was found to be normal (0.12-0.20 s) in 96% of Athletes and 4% showed prolonged PR interval. PR interval was normal in all non-athletes. There was no statistical significance (P=0.074) in PR intervals of both groups. QRS duration: QRS duration of 86% athletes showed normal duration (0.08 – 0.12s) and 14% showed prolonged QRS duration. QRS duration of 96% non-athletic group showed normal duration, 2% showed prolonged and 2% showed decreased duration. There was significant difference in QRS duration (P=0.003) between the two groups. QT interval: QT interval is normal (0.36-0.44s) in 50% of athletic group and 50% showed prolonged duration. QT interval was normal in 100% Non-athletic group. There was significant increase in QT interval (P=0.0001) between the two groups. QT cinterval: QTc interval was normal (0.43-0.45s) in 96% of athletes, and 4% showed prolonged QTc interval. QTc was normal in 100% non-athletic group. There was significant difference (P=0.0001) in QTc interval between both the groups. Axis Deviation: Among athletes 16% showed Left Axis Deviation and 4% showed Right Axis Deviation. Among Non-athletes 4% showed LAD, 2% RAD. CONCLUSION: There was significant Bradycardia, Prolonged QRS duration, Prolonged QTc intervals in athletic group when compared to non-athletic group. There was 16% left axis deviation, 4% RT axis deviation in athletic group. There was 4% LAD and 2% RAD in Non athletic group. KEYWORDS: Athletes, ECG, QRS, QT, QTc Intervals, Competitive, Indian athletes.

INTRODUCTION: Regular sports participation is encouraged by the medical community as it improves fitness and reduces cardiovascular morbidity and mortality. A large proportion of the young population participates in competitive or recreational sports activity. Cardiovascular exercise involves the use of large muscles in a repetitive fashion, activating muscle fibers programmed for endurance and utilizing a heart rate range anywhere from 40 to 85 percent of our maximum heart rate. When performing cardiovascular exercise, blood flow is directed toward working muscles and away from areas that aren’t doing much (such as your arms during running, or the digestive tract). There is increased blood flow, and blood volume returning to the heart. As the heart registers a larger
blood volume, over time the left ventricle adapts and enlarges. This larger cavity can hold more blood, and ejects more blood per beat, even at rest. Over time, with chronic cardio training, our resting heart rate drops because each beat delivers a bigger burst of blood, and fewer beats are needed. This takes work off your heart and is why cardio exercise is recommended for healthy heart. However, cardiovascular exercise can also produce stress.

If we get into over-training, we may hit a point where we are drowning in cortisol. This eventually leads to immune-suppression and fat gain around the abdomen and face. The heart adapts to this by increasing the thickness of the left ventricle wall. This thickness derived from chronic weight training is healthy, whereas the thickness from chronic high blood pressure is not. What's the difference? The healthy heart only has to work under pressure for two to three hours of strength training per week, whereas the heart with high blood pressure has to work 24 hours a day, seven days a week. The second heart may exhaust, whereas the healthy heart becomes stronger with a lower resting heart rate. Exercise also stimulates the production of new blood vessels. As we make more blood vessels, there are more places for blood to flow, which results in more efficient circulation. Cardiovascular exercise increases the number of new blood vessels while resistance training increases the size of those blood vessels. There will be a profound improvement in cardiovascular function. The basal heart rate decreases due to increased vagal tone. Stroke volume increases due to increased myocardial muscle mass. A trained subject achieves the required cardiac output during exercise mainly by increasing the stroke volume rather than by heart rate, whereas an untrained individual achieves the same cardiac output mainly by increasing the heart rate.

**MATERIALS AND METHODS:** The Study included 50 young competitive male athletes of age group ranging from 16-30 years; All the Subjects are of Indian origin hailing from Hyderabad and Visakhapatnam undergoing training at Lal Bahadur Sastry Stadium at Hyderabad, Railway stadium at Secunderabad, Port Stadium at Visakhapatnam comparing with 50 normal healthy subjects with irregular sports activity.

Sedentary non-athlete individuals of same age groups were selected.

Criteria for primary selection: Daily physical exercise category of 3-4 hrs/day since the last 5 years and specially trained by coach or a trainer.

My study is done as per the European Society of Cardiology including the recommendations alongside history and physical examination the inclusion of a resting 12-lead electrocardiogram (ECG).

The Data was statistically analyzed using Graphpad software, the data was compared using unpaired t test.

**RESULTS:**

**Heart Rate: Normal 60-100 beats/min, Bradycardia< 60, Tachycardia> 100**

|                | Normal | Bradycardia | Tachycardia |
|----------------|--------|-------------|-------------|
| Athletes -50   | 37     | 13          | -           |
| Non-Athletes -50 | 49     | -           | 1           |
26% of Athletes had Sinus bradycardia and none had tachycardia, Average Heart rate in this group was 66 beats/min, Tabular form above showed difference in men and women.

Among the Non-Athlete group 98%(49/50 subjects) showed normal heart rate and just 2% (1 subject) showed tachycardia changes.

**PR Interval: (Normal PR Interval 120-200 msec):** In athletes, 96%(48/50 subjects) showed PR intervals ranging from 120-200msec and 4%(2/50) showed increase in PR intervals time.

Among on athletes 100% subjects showed normal range of PR interval.

|                  | Normal(120-200 msec) | ↑> 200 msec | ↓< 120 msec |
|------------------|----------------------|-------------|-------------|
| Athletes -50     | 48                   | 2           | -           |
| Non-Athletes -50 | 50                   | 0           | 0           |

**QRS Duration:** Normally- The QRS wave’s duration is 0.08-12 sec (80-120msec).

Among athletes 14% (7/50) subjects showed increased QRS interval period, none had any momentum of decreased QRS intervals.

Among Non-athletes 2% (1/50) showed increased QRS interval, 2% (1/50) showed decreased QRS interval duration.

| QRS Duration | Normal(80-120 msec) | ↑> 120 msec | ↓< 80 msec |
|--------------|---------------------|-------------|------------|
| Athletes -50 | 43                  | 7           | 0          |
| Non-Athletes -50 | 48                  | 1           | 1          |

**QT INTERVAL:** Normal QT is (0.36 – 0.44 s) equal to or below 0.40s (400msec). Among athletes 50% (25/50) had prolonged QT interval. Average QT interval of this group is 401 msec, which exceeded the expected range of 400 msec.

Non-of the Non-Athletic group had any prolonged or decreased QT interval, the average QT interval is being 351msec.

| QT Interval | Normal(360-120 msec) | ↑> 120 msec | ↓< 80 msec |
|-------------|----------------------|-------------|------------|
| Athletes -50 | 43                   | 7           | 0          |
| Non-Athletes -50 | 48                   | 1           | 1          |

**Corrected QT interval (QTc):**
- Borderline "QTc" in males is 431-450 ms, and in females 451-470 msec.
- An "abnormal" QTc in males is a QTc above 450 ms, and in females, above 470 ms.
- Athletes showed any average QTc intervals of 420 msec which is within normal range, but 4% (2/50) male athlete subjects showed increased level of QTc interval.

All Non-athlete subjects were well in normal range in this duration.
AXIS: A normal heart axis is between -30 and +90 degrees.

- A left heart axis is present when the QRS in lead I is positive and negative in II and AVF. (between -30 and -90 degrees)
- A right heart axis is present when lead I is negative and AVF positive. (Between +90 and +180).

Among Athletes 16% (8/50) subjects showed Left Axis deviation (LAD), 4% (2/50) showed Right Axis Deviation (RAD).

Among Non-Athletes 4% (2/50) subjects showed Left axis deviation (LAD), 2% (1/50) showed Mild Right deviation of axis diagnosed to have RBBB (RAD).

| SL. No. | Name | Age | Sex | HR | P Durat | Intervals | T Durat | QTc | Axis | Remarks |
|--------|------|-----|-----|----|---------|-----------|---------|-----|------|---------|
| 1      | RK   | 26  | M   | 62 | 108     | 122       | 390     | 206 | 382  | 47°     |
| 2      | SS   | 26  | M   | 50 | 101     | 132       | 1470    | 194 | 429  | 28°     |
| 3      | RA   | 26  | M   | 54 | ↑123    | 192       | 1453    | 202 | 430  | 62°     |
| 4      | PN   | 26  | M   | 70 | 110     | 145       | 407     | 235 | 440  | -44°-Lt |
| 5      | RK   | 25  | M   | 55 | 102     | 120       | 425     | 212 | 410  | 64°     |
| 6      | SS   | 23  | M   | 68 | 112     | 155       | 410     | 215 | 439  | 36°-Lt  |
| 7      | SD   | 24  | M   | 74 | 112     | 130       | 370     | 195 | 411  | 38°     |
| 8      | BS   | 28  | M   | 76 | 108     | 121       | 420     | 212 | 473  | -60°    |
|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|
| 9 | V | 27 | M | 54 | 96 | 156 | 128 |
| 10 | VR | 21 | M | 73 | 121 | 153 | 88 |
| 11 | PA | 24 | M | 70 | 117 | 150 | 97 |
| 12 | JR | 27 | M | 67 | 130 | 120 | 92 |
| 13 | SA | 25 | M | 61 | 120 | 152 | 95 |
| 14 | PI | 24 | M | 66 | 141 | 188 | 106 |
| 15 | SFR | 23 | M | 60 | 106 | 124 | 87 |
| 16 | PRR | 25 | M | 69 | 100 | 148 | 83 |
| 17 | SW | 23 | M | 73 | 141 | 181 | 136 |
| 18 | MH | 17 | M | 67 | 130 | 177 | 100 |
| 19 | AY | 20 | M | 54 | 96 | 156 | 128 |
| 20 | GV | 21 | M | 63 | 104 | 132 | 80 |
| 21 | PR | 16 | M | 78 | 108 | 132 | 76 |
| 22 | MS | 26 | M | 63 | 121 | 174 | 103 |
| 23 | Ps | 27 | M | 45 | 111 | 168 | 109 |
| 24 | PSa | 23 | M | 55 | 121 | 144 | 112 |
| 25 | PM | 21 | M | 69 | 124 | 181 | 103 |
| 26 | BP | 24 | M | 59 | 108 | 132 | 68 |
| 27 | TV | 26 | M | 49 | 129 | 152 | 98 |
| 28 | UA | 23 | M | 65 | 140 | 172 | 136 |
| 29 | MF | 28 | M | 81 | 109 | 132 | 94 |
| 30 | KV | 20 | M | 59 | 161 | 120 | 125 |
| 31 | SS | 26 | M | 62 | 126 | 141 | 104 |
| 32 | PS | 25 | M | 48 | 113 | 168 | 131 |
| 33 | JK | 24 | M | 82 | 102 | 126 | 94 |
| 34 | Sm | 24 | M | 63 | 152 | 187 | 97 |
| 35 | KV | 25 | M | 62 | 98 | 121 | 83 |
| 36 | R | 21 | M | 52 | 93 | 109 | 121 |

- LT Sinus Bradycardia, RBBB, LAD
- 1° AV Block
- Incomplete RBBB
- Sinus Bradycardia
- Lt Ventricular Hypertro
## Table 1: Master sheet Athletes ECG Values

| SL. No. | Name | Age | Sex | HR  | PR Durat  | Intervals | T Durat  | QTC  | QRS Axis | Remarks          |
|---------|------|-----|-----|-----|-----------|-----------|----------|------|----------|------------------|
| 37      | RS   | 19  | M   | 68  | 112       | 131       | 91       | 371  | 209      | 395 22°          |
| 38      | Pk   | 21  | M   | 72  | 102       | 128       | 88       | 378  | 216      | 415 10°          |
| 39      | TR   | 22  | M   | 76  | 111       | 136       | 92       | 385  | 221      | 434 -12°         |
| 40      | BS   | 23  | M   | 68  | 104       | 132       | 96       | 401  | 208      | 427 0°           |
| 41      | BP   | 23  | F   | 70  | 112       | 154       | 87       | 378  | 211      | 408 10°          |
| 42      | TB   | 24  | F   | 73  | 106       | 112       | 96       | 404  | 221      | 466 -36° -Lt     |
| 43      | SY   | 22  | F   | 74  | 112       | 128       | 91       | 367  | 203      | 408 28°          |
| 44      | PP   | 23  | F   | 80  | 98        | 123       | 83       | 363  | 208      | 419 18°          |
| 45      | SJ   | 19  | F   | 81  | 101       | 121       | 91       | 374  | 224      | 435 -20°         |
| 46      | JS   | 23  | F   | 68  | 107       | 121       | 98       | 391  | 219      | 415 12°          |
| 47      | CJ   | 21  | F   | 76  | 112       | 136       | 101      | 386  | 231      | 434 0°           |
| 48      | M    | 20  | F   | 80  | 111       | 128       | 93       | 344  | 219      | 397 20°          |
| 49      | SL   | 19  | F   | 81  | 104       | 126       | 91       | 364  | 216      | 423 -15°         |
| 50      | KP   | 24  | F   | 59  | 101       | 116       | 91       | 408  | 221      | 405 28°          |
|         |      |     |     |     |           |           |          |      | Sinus Bradycardia |

J of Evolution of Med and Dent Sci/ eISSN- 2278-4802, pISSN- 2278-4748/ Vol. 4/ Issue 04/Jan 12, 2015  Page 689
### Table 2: Master sheet NON Athletes ECG Values

| No | Initial | Gender | Age | Height | Weight | BP (mmHg) | Pulse Rate | ECG Parameters |
|----|---------|--------|-----|--------|--------|------------|-------------|----------------|
| 19 | K       | M      | 23  | M      | 82     | 106        | 129         | 80 351 206 410 45° |
| 20 | V       | M      | 28  | M      | 73     | 101        | 132         | 69 387 192 405 60° |
| 21 | K       | M      | 25  | M      | 90     | 110        | 141         | 91 329 222 403 15° |
| 22 | C       | M      | 16  | M      | 89     | 108        | 139         | 91 331 216 403 45° |
| 23 | G       | M      | 19  | M      | 80     | 109        | 121         | 84 361 206 417 30° |
| 24 | C       | M      | 19  | M      | 73     | 121        | 154         | 96 352 221 388 26° |
| 25 | G       | M      | 23  | M      | 81     | 110        | 131         | 94 361 221 420 42° |
| 26 | K       | M      | 26  | M      | 80     | 113        | 148         | 96 348 221 402 48° |
| 27 | E       | M      | 20  | M      | 71     | 118        | 142         | 91 334 208 363 35° |
| 28 | V       | M      | 22  | M      | 78     | 116        | 140         | 88 346 217 395 45° |
| 29 | K       | M      | 21  | M      | 76     | 108        | 131         | 90 368 212 414 20° |
| 30 | D       | M      | 25  | M      | 68     | 112        | 139         | 96 363 208 386 40° |
| 31 | R       | M      | 20  | M      | 80     | 106        | 121         | 81 341 210 394 15° |
| 32 | S       | M      | 23  | M      | 78     | 116        | 136         | 90 339 212 387 -10° |
| 33 | A       | M      | 23  | M      | 84     | 101        | 128         | 90 336 211 398 28° |
| 34 | N       | M      | 17  | M      | 78     | 102        | 124         | 88 363 206 414 75° |
| 35 | P       | M      | 19  | M      | 72     | 98         | 141         | 81 385 212 422 60° |
| 36 | S       | M      | 26  | M      | 62     | 112        | 138         | 84 390 208 395 30° |
| 37 | S       | M      | 26  | M      | 78     | 110        | 149         | 98 378 221 410 48° |
| 38 | J       | M      | 26  | M      | 73     | 112        | 144         | 78 361 216 398 64° |
| 39 | P       | M      | 25  | M      | 72     | 116        | 152         | 92 345 208 378 46° |
| 40 | S       | M      | 26  | M      | 88     | 112        | 142         | 90 324 202 393 52° |
| 41 | K       | F      | 24  | F      | 89     | 108        | 150         | 84 321 208 391 50° |
| 42 | G       | F      | 18  | F      | 84     | 106        | 136         | 80 329 205 389 10° |
| 43 | T       | F      | 20  | F      | 91     | 110        | 153         | 80 328 201 404 -22° |
| 44 | S       | F      | 25  | F      | 82     | 114        | 150         | 91 342 208 400 50° |
| 45 | K       | F      | 22  | F      | 81     | 118        | 148         | 89 349 216 406 45° |
| 46 | V       | F      | 19  | F      | 70     | 107        | 131         | 86 352 215 380 56° |
| 47 | M       | F      | 18  | F      | 76     | 108        | 128         | 91 346 220 389 18° |
| 48 | K       | F      | 21  | F      | 84     | 111        | 132         | 93 332 218 393 12° |
| 49 | A       | F      | 24  | F      | 80     | 106        | 124         | 88 361 212 417 72° |
| 50 | S       | F      | 21  | F      | 86     | 102        | 120         | 91 330 203 395 35° |
Figure 1: Athletes

Figure 2: Non-Athletes
DISCUSSION: The interpretation of the athlete’s ECG is often left to personal experience and usually made according to traditional ECG criteria used in the general (non-athletic) population.

Electrocardiogram changes in athletes are common and usually reflect structural and electrical remodeling of the heart as an adaptation to regular physical training (athlete’s heart).

IN THIS STUDY: Among the Athletes, 26% had Sinus bradycardia, none with tachycardia, Average Heart rate in this group was 66 beats/min.

Among the Non-Athletic group 98%(49/50 subjects) showed normal Heart Rate and just 2% (1 subject) showed tachycardia changes.

Bradydcardia is the result of physiological adaptive changes of the autonomic nervous system and reflects the level of athletic conditioning. Only profound sinus bradycardia and/or marked sinus arrhythmia (heart rate < 30 beats/min and or pauses 3sec during wake hours) need to be distinguished from sinus node disease. Sino atrial node dysfunction can be reasonably excluded by demonstrating that: (i) Symptoms such as dizziness or syncope are absent;(ii)Heart rate normalizes during exercise, sympathetic maneuvers or drugs, with preservation of maximal heart rate, and (iii)
ORIGINAL ARTICLE

Bradycardia reverses with training reduction or discontinuation. But few old athletes tend to complain of decreased heart rate might continue all their life even after they discontinue active sport and continue to work up at the least exercise levels to maintain standard of life. Few trainers now who were long standing athletes have complains of some discomfort if exercise levels are lowered with age building up with them. One of this being Sports Medicine Specialist and a boxer himself and a participant in national boxing championship 30 years back has an everlasting complaint of dizziness/syncopal attacks when resting or out of sports activity for more than 2 or 3 days, he retains his normal healthy status after he begins to exercise getting back to his practice.

D’Souza et al supported in their study that training-induced bradycardia is not a consequence of changes in the activity of the autonomic nervous system but is caused by intrinsic electrophysiological changes in the sinus node so concluded Exercise training reduces resting heart rate via down regulation of the funny channel HCN4.

Farahani et al in their study, Prevalence of different electrocardiographic patterns in Iranian athletes, explored the abnormalities in Iranian athletes electrocardiogram to find any relation with body fat. 239 international athletes were involved in this cross sectional study. Body-fat percentage and resting 12-lead ECGs were recorded from all participants. Of 239 participant athletes, 212 were male and 27 female. 60% of participants had sinus bradycardia.

**ATRIO-VENTRICULAR BLOCK:** First-degree AV block and Mobitz Type-I (Wenkebach) second degree AV block are common in trained athletes, and 2% (1/50) of athlete’s ECGs respectively. As with sinus bradycardia, AV conduction slowing and block are mediated by increased parasympathetic tone or by decreased sympathetic tone. A very rare finding of Second-degree Mobitz Type-II and Type-III degree heart block in athletes to confirm that’s it is due to cardiac adaptation activity.

Doutreleau S et al in their study of Exercise-induced second-degree atrioventricular block in endurance athletes.

Training induces volume- and time-dependent morphological and functional changes in the heart. Heart rhythm disorders, such as atrial arrhythmia (including atrial fibrillation and atrial flutter), are a well-established consequence of such long-term endurance practice. Although resting bradycardia and first-degree atrioventricular block persist in veteran athletes, higher conduction system impairment has never been reported neither at rest nor during exercise.

**ISOLATED INCREASE OF QRS VOLTAGES:** Intensive athletic activity causing morphological cardiac changes, including increased cavity dimensions, wall thickness and ventricular mass which is reflected in the 12-lead ECG. Physiological LV hypertrophy in trained athletes usually manifests as an isolated increase of QRS amplitude, with normal QRS axis normal atrial and ventricular activation patterns. Criteria for LV hypertrophy has been reported in trained athletes as its noticed here in one of the subject, which has increased QRS voltage and diagnosed to have LVH.

These subjects have been correlated ECG changes with cardiac morphology assessed by echocardiography. The ECG was labeled as ‘abnormal’ in (40%) athletes; however an isolated increase of QRS voltage accounted for 14% (7/50) of such changes. No athletes with isolated increase of QRS voltages had evidence of structural heart disease such as HOCM (Hypertrophic Obstructive Cardio Myopathy) in this workup but rather many athletes had been discovered to have diagnosed with HOCM.
Athletes who show pure QRS voltage criteria for LV hypertrophy on 12-lead ECG do not require systematic echocardiographic evaluation, unless they have relevant symptoms, a family history of cardiovascular diseases and or sudden cardiac death (SCD) or non-voltage ECG criteria suggesting any pathological LV hypertrophy.

Pelliccia A et al in their study showed that highly trained athletes show morphologic cardiac changes (i.e., athlete's heart) that are the consequence of several determinants, including type of sport, gender, and, possibly, inherited genetic factors. The extent of physiologic cardiac remodeling may occasionally be substantial in highly trained athletes and may raise a differential diagnosis with structural cardiac disease, such as cardiomyopathies. In addition, athletes demonstrate a spectrum of alterations in the 12-lead electrocardiogram (ECG) pattern, including marked increase in precordial R-wave or S-wave voltages, ST segment or T-wave changes, and deep Q waves suggestive of left ventricular hypertrophy, that may raise the possibility of pathologic heart condition, but have also been viewed as a consequence of the cardiac morphologic remodeling induced by athletic conditioning. To evaluate the clinical significance of these abnormal ECGs, the authors compared ECG patterns to cardiac morphology and function (assessed by two-dimensional echocardiography in individual athlete) in a large population of 1005 elite athletes engaged in a variety of sporting disciplines. Forty percent of the athletes had abnormal ECGs, and a subgroup of about 15% showed distinctly abnormal and often bizarre patterns highly suggestive of cardiomyopathies, such as hypertrophic cardiomyopathy, in the absence of pathologic cardiac changes. Such alterations are likely the consequence of athletic conditioning itself and represent another potential component of athlete’s heart syndrome.

**INCOMPLETE RIGHT BUNDLE BRANCH BLOCK:** The Prevalence of incomplete right bundle block (RBBB) (QRS duration 120 ms) has been estimated to range from 4% in athletes compared with less than 2% in young sedentary controls. This ECG pattern is more often noted in athletes engaged in endurance sports. It has been suggested that the right ventricular (RV) conduction delay is not within the specialized conduction system, but is caused by the enlarged RV cavity size /Increased cardiac muscle mass and the resultant increased conduction time. The RBBB morphology has been shown to be reversible with deconditioning.

**EARLY REPOLARIZATION:** Early repolarization has traditionally been regarded as an idiopathic can be benign ECG phenomenon, with an estimated prevalence in healthy young individuals of 1–2%, and a clear male preponderance. The early repolarization ECG pattern is the rule rather than the exception among highly trained athletes, in whom it is observed in 50–80% of resting ECGs. The early repolarization ECG shows elevation of the QRS–ST junction (J-point) of at least 0.1 mV from the baseline, associated with notching or slurring of the terminal QRS complex which may vary in location, morphology and degree.

Slowing of heart rate exaggerates ST-segment elevation, whereas sinus tachycardia occurring during exercise. Early repolarization in athletes reflects the development of a training related hypervagotonia, and ECG abnormalities are reversible phenomenon which reduces or disappears with deconditioning.

Early repolarization is a physiological and benign ECG pattern in the general population of younger people and athletes and does not require further evaluation.
But none of the ECG’s in athletes showed any early repolarization changes. ECG abnormalities with the cardiovascular diseases include repolarization abnormalities such as inverted T-waves and ST-segment depression, pathological Q wave conduction disease including left-axis deviation, ventricular pre-excitation, long-and short QT interval and Brugada-like repolarization changes.

Unlike the ECG changes characteristic of athlete’s heart, such ECG abnormalities are relatively uncommon (5%) and training-unrelated. Further diagnostic work-up is mandatory for those athletes who exhibit such ECG changes in order to confirm (or exclude) an underlying cardiovascular disease.

De Asmundis C5 et al in their study of Prevalence and electrocardiographic characteristics of early repolarization pattern (ERP) in young teen athletes, Of the 122 included subjects, The overall prevalence of ERP in their study population was 36%. Interestingly, incomplete right bundle-branch block (IRBBB) was significantly lower among all subjects with ERP (N = 15; 34.1%), compared to those without ERP (N = 49; 63%) (P < 0.002). And henceforth concluded that ERP is a common finding in young teen athletes.

**LEFT VENTRICULAR HYPERTROPHY:** Electrocardiogram offers the potential to distinguish between pathological and physiological hypertrophy, given that ECG abnormalities of structural heart diseases manifesting with LV hypertrophy, such as cardiomyopathies, valve diseases, or hypertensive heart disease overlap only marginally with training-related ECG changes.

**One of the Athletes namely subject number 28 has shown changes of LVH in ECG as:**
- Markedly increased LV voltages: Huge precordial R and S waves that overlap with the adjacent leads (SV2 + RV6 > 35 mm).
- R-wave peak time > 50 ms in V5-6 with associated QRS broadening.
- LV strain pattern with ST depression and T-wave inversions in I, aVL and V5-6.
- ST elevation in V1-3.
- Prominent U waves in V1-3.
- Left axis deviation.

Diagnosed as Sinus Rhythm with LVH as this subject was send for further investigations ECHO test, a procedure of choice for LVH, showed changes as concentric Left Ventricular Hypertrophy, Ejection Fraction is 70%, and no systolic dysfunction seen. So likewise an athlete’s heart is a growing extra thick as if it is under constant stress and need extra thickened muscle to provide the strength to pump out blood sufficiently to the peripheral parts, so this is usually a life style effect in athletes and most of the times not life threatening.

Arbab-Zadeh A6 et al. Cardiac Remodeling in Response to 1 year of Intensive Endurance training One year of prolonged and intensive endurance training leads to cardiac morphologic adaptations in previously sedentary young subjects similar to those observed in elite endurance athletes; however it is not sufficient to achieve similar levels of cardiac compliance and performance. Contrary to conventional thinking, the left ventricle responds to exercise with initial concentric not eccentric remodeling during the first 6-9 months after commencement of endurance training depending on the duration and intensity of exercise. Thereafter, the left ventricle dilates and restores the baseline mass to volume ratio. In contrast, the right ventricle responds to endurance training with eccentric remodeling at all levels of training.
Caselli S et al Differentiating left ventricular hypertrophy in athletes from that in patients with hypertrophic cardiomyopathy.

Aimed in the study was to revise the ability of simple echocardiographic and clinical variables for the differential diagnosis of HC versus athlete’s heart. Twenty-eight athletes free of cardiovascular disease were compared with 25 untrained patients with HC, matched for LV wall thickness (13 to 15 mm), age, and gender. Clinical, electrocardiographic, and echocardiographic variables were compared. Athletes had larger LV cavities (60 ± 3 vs 45 ± 5 mm, p <0.001), aortic roots (34 ± 3 vs 30 ± 3 mm, p <0.001), and left atria (42 ± 4 vs 33 ± 5 mm, p <0.001) than patients with HC. LV cavity <54 mm distinguished HC from athlete’s heart with the highest sensitivity and specificity (both 100%, p <0.001). Left atrium >40 mm excluded HC with sensitivity of 92% and specificity of 71% (p <0.001).

ST SEGMENT DEPRESSION: Although ST segment elevation due to early repolarization is a common finding in the basal ECG of trained athletes, resting ST segment depression is rarely observed, none of the subjects showed any changes in ST segment.

RIGHT ATRIAL ENLARGEMENT AND RIGHT VENTRICULAR HYPERTROPHY: ECG evidence of right atrial enlargement and/ or RV hypertrophy is uncommon finding in athletes. The presence of either congenital or acquired heart diseases associated with an increased right atrial size and/or pathological RV dilatation/ hypertrophy should be excluded.

T-WAVE INVERSION: Recent studies on large athletic populations disproved the traditional idea that T-wave inversions are common and training-related ECG changes in the athlete.

T-wave inversion in young and apparently healthy athletes may represent the initial phenotypic expression of an underlying cardiomyopathy prior to the development of morphological changes detectable on cardiac imaging.

T-wave inversions 2 mm in two or more adjacent leads is rarely observed on the ECG of healthy athletes, where as it is a common finding in patients with cardiomyopathy and other cardiac disease.

VENTRICULAR PRE-EXCITATION (WOLFF– PARKINSON–WHITE): None of the subjects were found to have any WPW abnormalities.

They prevalence of ventricular pre-excitation in the general population varies from 0.1% to 0.3% and is similar in athletes. Most individuals with WPW pre-excitations syndrome remain asymptomatic throughout their lives. When symptoms do occur, they are usually secondary to reciprocating supraventricular tachycardia which causes disabling symptoms.

LONG-QT INTERVAL: The duration of the QT interval (i.e. the interval between the beginning of the QRS complex and the end of the T-wave) changes with heart rate and it is usually corrected (QTc) by using,

\[ QTc = \frac{QT}{\sqrt{RR}} \]

QT INTERVAL: Normal QT is (0.36 – 0.44 s) equal to or below 0.40s (400msec).
Among athletes 50% (25/50) had prolonged QT interval. Average QT interval in this group being 401 msec, which has over leaped the expected range of 400 msec.

Among the Non-Athletes nobody had any prolonged or decreased QT interval, in this group average QT intervals being 351msec.

The QT interval should be measured in L2,V3, or V5;the longest value (return to baseline)should be considered.

The calculation of the QT interval in athletes has inherent limitations due to sinus arrhythmia, slightly widened QRS complexes and T-U complexes. Corrections for heart rate may be in accurate at heart rates below 40 and above 120 bpm.

QT interval is modulated by gender and therefore different cut off values are used after puberty. A QTc interval is traditionally considered long in men when it is more than 440 ms and in women when it exceeds 460 ms, but some suggested values upto and above 470 ms in males and 480 ms in female.

In general QT interval is longer in athletes than in non-athletic control because of the lower resting heart rate associated with athletic training, and this workup has demonstrated the average QT interval in Indian athletes is 401ms, whereas average QT interval in Non-athletes is 351ms, while the QTc of the athletic group is within normal limits, though toward the upper limit.

Recording of QTc intervals beyond the normal cut-off values should raise the suspicion of either acquired or congenital long QT syndrome (LQTS).

Omíya K et al Influence of gender and types of sports training on QT variables in young elite athletes. Influence of gender and sports training on QT variables such as QT interval and dispersion (QT dispersion: QTD) in young elite athletes were evaluated.

Concluded Maximum and minimum QTc were significantly longer in female athletes than in male athletes (max: 414.2 vs. 404.5 ms, min: 375.1 vs. 359.2 ms, p<0.0001 respectively), whereas QTc dispersion (QTcD) was shorter in female athletes than in male athletes (39.2 vs. 45.3 ms, p<0.0001). QTcD was significantly shorter in female athletes than in the female control group (39.2 vs. 45.2 ms, p<0.05). However, no statistically significant difference was observed between male athletes and the male control group. Male gymnasts exhibited significantly longer QTcD than the control group (p<0.01), but female gymnasts had significantly shorter QTcD than the control group (p<0.05). Maximum QTc intervals were prolonged in the male static training group compared with non-athletes, and QTcDs in the static training group were prolonged compared with the endurance training group. However, no significant difference was observed in the female group. In conclusion, both gender and different characteristics of sports training may affect QT variables even in young elite athletes. Vigorous static exercise training may independently prolong QT variables.

Griffet V9 et al in their workup of Athlete's heart in the young, while recording the ECG and echocardiographic patterns in 107 French athletes and hence concluded Adolescent athlete's heart is normal. If QTc interval is not normal, be afraid of a QT long syndrome. Furthermore, when interventricular septal thickness is > 11 mm or left ventricular end diastolic diameter > 55 mm, myocardiopathy will have to be ruled out.

CONCLUSION: Now after determining ECG changes which are physiological (common and training-related ECG abnormalities) and that which are pathological (uncommon and training-unrelated ECG abnormalities) is expected to reduce the traditional high number of false positives, so wise reducing the investigations.
In this study, the ECGs were classified into three subgroups, as distinctly abnormal, mildly abnormal, and normal (or with minor alterations).

Abnormal ECG was identified in (6%) athletes of which distinctly abnormal in 2% (1/50), and mildly abnormal in 4% (2/50).

In the remaining 94% athletes (47/50), ECGs were normal in or exhibited only minor alterations, which were deemed typical of the athletes heart, of the 3 athletes with ECG abnormalities previously classified as abnormal and suggestive of cardiac disease, 1 case exhibited an isolated increase of QRS voltage.

But this workup will be helpful in making certain rules in our country to bring up the compulsory pre-participation screening program for upcoming athletes in schools (while on the go certain sports schools have already taken up this screening program voluntarily) and to prevent and early diagnosis of cardiac diseases.

| Analyzed ECG changes | Number of patients, n (%) |
|----------------------|--------------------------|
| Sinus bradycardia < 60/min | 13 (26%) |
| Severe sinus bradycardias 40/min | 0 (0%) |
| Prolonged QT interval | 2 (4%) |
| Prolonged QTc interval as per Bazett's | 0 (0%) |
| Ventricular Arrhythmias | 0 (0%) |
| Shortened PR interval < 120 ms | 0 (0%) |
| Prolonged PR Interval > 200 ms | 2 (4%) |
| Left bundle branch block | 0 (0%) |
| Right bundle branch block | 2 (4%) |
| Heart Axis Deviation QRS > -30° | 39 (78%) |
| Right Axis Deviation > +90° | 2 (4%) |
| Left Axis Deviation < -30° | 9 (18%) |
| Incomplete RBBB | 1 (2%) |
| Early Repolarization | 0 (0%) |
| Isolated Voltage for Left Ventricular Hypertrophy | 1 (2%) |
| Features of left atrial hypertrophy | 0 (0%) |
| T Wave inversions(negative T wave) | 0 (0%) |
| R wave in V5 or V6 > 3.0 mV | 1 (2%) |
| S wave in V1 or V2 > 3.0 mV | 1 (2%) |

Table 3: Changes in the ECG of 50 Athletes

REFERENCES:
1. D’Souza A, Bucchi A, Johnsen AB, Logantha SJ, Monfredi O, Yanni J, et al.: Exercise training reduces resting heart rate via down regulation of the funny channel HCN4.- Nat Commun. 2014 May 13; 5: 3775. doi: 10.1038/ncomms4775.
2. Doutreleau S¹, Pistea C, Lonsdorfer E, Charloux A: Exercise-induced second-degree atrioventricular block in endurance athletes - Med Sci Sports Exerc. 2013 Mar; 45 (3): 411-4. doi: 10.1249/MSS.0b013e318276c9a4.
3. PellicciaA¹, Di Paolo FM, Maron BJ: The athlete’s heart: remodeling, electrocardiogram and preparticipation screening. In Cardiol. - Rev. 2002 Mar-Apr; 10 (2): 85-90.
4. Farahani B², Poursaeid Esfahani M, Abbasi MA, Moradi F, Abbasi A: Prevalence of different electrocardiographic patterns in Iranian athletes - Acta Med Iran. 2012; 50 (8): 560-4.
5. De Asmundis C, Conte G, Levinstein M, Chierchia GB, Sieira J, Di Giovanni G, Baltogiannis G, Park MH, Sarkozy A, Brugada P: Prevalence and electrocardiographic characteristics of early repolarization pattern in young teen athletes–Acta Cardiol. 2014 Feb; 69 (1): 3-6.
6. Arbab-Zadeh A, Perhonen M, Howden E, Peshock RM, Zhang R, Adams-Huet B, Haykowsky MJ, Levine BD: Cardiac Remodeling in Response to 1 Year of Intensive Endurance Training-Circulation.2014 Oct 3 pii: CIRCULATIONAH.A.114.010775.
7. Caselli S¹, Maron MS², Urbano-Moral JA³, Pandian NG², Maron BJ³, Pelliccia A⁴: Differentiating left ventricular hypertrophy in athletes from that in patients with hypertrophic cardiomyopathy-Am J Cardiol. 2014 Nov 1; 114 (9): 1383-9. doi: 10.1016/j.amjcard.2014.07.070. Epub 2014 Aug 12.
8. Omiya K¹, Sekizuka H, Kida K, Suzuki K, Akashi YJ, OhbaH, Musha H: Influence of gender and types of sports training on QT variables in young elite athletes-ur J Sport Sci. 2014;14Suppl 1: S32-8. doi: 10.1080/17461391.2011.641032.
9. Griffet V¹, Finet G, Di Filippo S, Lantelme P, Caignault JR, Guérard S.: Athlete’s heart in the young: electrocardiographic and echocardiographic patterns in 107 French athletes-Ann CardiolAngeiol (Paris). 2013 Apr; 62 (2): 116-21. doi: 10.1016/j.ancard.2013.02.003.
10. Vernuccio F, Grutta G, Fazio G: Sudden cardiac death in athletes: is it always not preventable.-Recenti Prog Med. 2014 Nov; 105 (11): 410-4. doi: 10.1701/1680.18400.
11. Assanelli D¹, Levaggi R, Carré F, Sharma S, Deligiannis A, Mellwig KP, Tahmi M, Vinetti G: Cost-effectiveness of preparticipation screening of athletes with ECG in Europe and Algeria. - Aliverti PlIntern Emerg Med. 2014 Aug 28.

AUTHORS:
1. M. Padma Geethanjali
2. P. S. N. Raju
3. V. Seetharama Raju

PARTICULARS OF CONTRIBUTORS:
1. Professor & HOD, Department of Physiology, Andhra Medical College, Visakhapatnam.
2. Assistant Professor, Department of Physiology, Andhra Medical College, Visakhapatnam.
3. Assistant Professor, Department of Physiology, Andhra Medical College, Visakhapatnam.

NAME ADDRESS EMAIL ID OF THE CORRESPONDING AUTHOR:
Dr. P. S. N. Raju,
# 39-6-47, Flat No. 201,
Leela Residency,
Muralinagar, Visakhapatnam,
Andhra Pradesh-530007.
E-mail: doctorraju@yahoo.com

Date of Submission: 19/12/2014.
Date of Peer Review: 20/12/2014.
Date of Acceptance: 02/01/2015.
Date of Publishing: 10/01/2015.