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Original Article

The prevalence of abnormal ECG in trained sportsmen

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ABSTRACT

Background: Competitive sports training causes structural and conductive system changes manifesting by various electrocardiographic alterations. We undertook this study to assess the prevalence of abnormal ECG in trained Indian athletes and correlate it with the nature of sports training, that is endurance or strength training.

Methods: We evaluated a standard resting, lying 12 lead Electrocardiogram (ECG) in 66 actively training Indian athletes. Standard diagnostic criteria were used to define various morphological ECG abnormalities.

Results: 33/66 (50%) of the athletes were undertaking endurance training while the other 33 (50%) were involved in a strength-training regimen. Overall 54/66 (81%) sportsmen had significant ECG changes. 68% of these changes were considered as normal training related features, while the remaining 32% were considered abnormal. There were seven common training related ECG changes–Sinus Bradycardia (21%), Sinus Arrhythmia (16%), 1st degree Atrioventricular Heart Block (6%), Type 1 2nd-degree Atrioventicular Heart Block (3%), Incomplete Right bundle branch block (RBBB) (24%), Early Repolarization (42%), Left Ventricular Hypertrophy (LVH) (14%); while three abnormal ECG changes–T-wave inversion (13%), RBBB(4%), Right ventricular hypertrophy (RVH) with strain (29%) were noted. Early repolarization (commonest change), sinus bradycardia, and incomplete RBBB were the commoner features noticed, with a significantly higher presence in the endurance trained athletes.

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Conclusion: A high proportion of athletes undergoing competitive level sports training are likely to have abnormal ECG recordings. Majority of these are benign, and related to the physiological adaptation to the extreme levels of exertion. These changes are commoner during endurance training (running) than strength training (weightlifting).

Introduction

Professional and competitive sports training can lead to reversible physiological changes in the heart. These changes can manifest by various electrocardiographic alterations mimicking changes seen in patients with structural heart disease. We undertook this study to assess the prevalence of abnormal Electrocardiogram (ECG) in trained athletes and correlate it with the nature of sports training.

Material and methods

Between July 2012 and August 2012 all the athletes training for competitive sports in one of the premier training institutes of Indian Armed Forces were recruited for the study. Athletes had been screened by detailed history, clinical examination and investigation for any organic disease prior to joining the institute hence a mere willingness to participate in the study was used as the inclusion criteria. All the participants were divided into 2 groups depending on the type of the exercise training; Group 1 was constituted by athletes undergoing endurance training (long distance runners) while Group 2 was constituted by athletes undergoing strength training (weightlifters). The institutional ethics committee of the hospital approved the study protocol. Informed consent was obtained from all participants prior to the study.

A standard 12 lead ECG recorded using a digital electrocardiograph (Model Eli 250, Mortara Instrument Inc, Milwaukee, WI or Model MAC5000, GE Medical Systems, Freiburg, Germany) in the supine position after 3 min of rest during quiet respiration at paper speed of 25 mm/sec. Each ECG was interpreted for rate, rhythm, conduction abnormality, hypertrophy/enlargement, axis, and or ischemia/infarction. Particular attention was paid to heart rate (beats/minute), PR interval (milliseconds), QRS duration (milliseconds), QT interval corrected for the heart rate (milliseconds), P-wave morphologic abnormality (P-wave duration, amplitude, and terminal negative deflection in the right precordial leads), presence of Q-waves, R amplitude in precordial leads (V1 and V5) (mm), and T-wave inversion. Standard diagnostic criteria were used to define various ECG abnormalities.[1–3]

Data was recorded in a predesigned performa and managed on an excel spreadsheet. The ECG changes were divided into 2 groups. All the values were checked for any possible keyboard error. Distribution of continuous variables was assessed for approximate normal distribution. Continuous variables are presented as mean ± SD. Categorical variables are presented as frequencies and percentages. Categorical variables were compared using chi-square tests and continuous variables using independent two-sample t-test. All the analysis was done using SPSS software. In this study all the statistical tests were two-tailed and p-value of <0.05 was considered statistically significant.

Results

A total of 66 athletes were enrolled in the study of which 33 athletes were in Group 1 (endurance training) and 33 were in Group 2 (strength training).

The baseline parameters are in Table 1A and the comparison of these baseline parameters between Group 1 and Group 2 are in Table 1B. There was a wide variation in the weight (range 35 Kg to 128 Kg; SD 13.99). The mean height ($p = 0.0$), was significantly higher, and the body mass index (BMI) lower in Group 1 (runners) than that of the Group 2 (weightlifters).

The baseline ECG parameters for all athletes and the comparison of these parameters between Group 1 and Group 2 are in Tables 2A and 2B respectively. Overall 54/66 (81%) athletes had noticeable alterations in the ECG. The overall heart rate varied widely from 32 beats/min to 98 beats/min (SD 13.91), and so did the PR interval (range 110–240 ms, SD 27.4). The QRS Axis (range -19° to 102°; SD 9.19), QRS duration (range 78–120 ms; SD 9.19) and the QTc interval (330 ms–446 ms; SD 21.9) were also noted in the individual athletes.

The PR-interval ($p = 0.0$), QRS duration ($p = 0.0$) and LVH ($p = 0.007$) was significantly higher I Group 1 (runners) than that of the Group 2 (weightlifters). None of the athletes had prolonged QTc. The mean heart rate of the runners was significantly lower ($p = 0.0$) than that of the weightlifters.

The normal and abnormal ECG changes noted in the athletes are tabulated in Table 3 (statistical analysis by difference of proportion using chi-square test). There were seven common training related ECG changes (Table 3). These were Sinus Bradycardia, Sinus Arrhythmia, 1st degree Atrioventricular Heart Block, Type 1, 2nd-degree Atrioventicular Heart Block, Incomplete RBBB, Early Repolarization and Left Ventricular Hypertrophy.

The 'Abnormal' ECG findings are either unrelated to the regular training or exaggerated by it. There were three such changes observed, i.e. T-wave inversion, RBBB, and RVH with strain.

The common training related changes (normal physiological variations) were seen in 33/66 (50%) athletes while 21/66 (32%) number of athletes had significant ECG changes warranting them to be labeled "abnormal". Among the common training related changes 44/54 (81%) were in Group 1 (runners) while only 10/54 (19%) were in Group 2 (weightlifters). Even the abnormal labeled ECGs were significantly higher in Group 1, 21/31 (68%), with a $p < 0.006$.

Among the common ECG changes, Sinus Bradycardia, 1st and 2nd degree (Type I) heart blocks were seen only in Group 1 (runners) performing endurance exercise. Nearly one-forth (24%) athletes showed partial RBBB, with a significant difference ($p < 0.03$) between Group 1 (runners) and Group 2 (weightlifters). Early repolarization was a finding seen in over 40% athletes, with a significant difference ($p = 0.00$) between the two groups. Isolated LVH by voltage criteria was seen in 13% athletes with a significant proportion being group 1. 80% of the athletes had identifiable U-waves, but none had abnormal U-waves. The total 'common' ECG changes noticed were more than the number of the athletes as multiple ECG features were present in an individual athlete.

Among the abnormal ECG changes, 9/66 (14%) had symmetrical T-wave inversion. It was noted in 6/33 (9.1%) of Group 1 and 3/33 (4.5%) in Group 2, with the difference between both the groups being significant ($p < 0.06$). 8 of the 9 athletes having T-inversions had associated features of Right Ventricular Hypertrophy (RVH), but none had associated LVH. Only one runner (Group 1) had isolated T-inversion. 3/66 (4%) athletes, all in Group 1 had complete RBBB. None was symptomatic with chronotropic incompetence. 19/66 (28%) athletes had RVH with strain – 12/33 (36%) were in Group 1 while only 7/33 (21%) in Group 2 showed the above features, the difference being significant ($p < 0.02$).

None of the athletes showed ECG changes of ST-depression, pathological Q-waves, Left axis deviation, complete heart block, LBBB, WPW syndrome or long QT syndrome noted.

Discussion

This is the first study among Indian (Asian Indians) athletes to ascertain the ECG abnormalities after competitive sports training. The aim of undertaking this study was twofold: one, to ascertain the prevalence of abnormal ECG changes in trained athletes and second to correlate these changes with the type of sport training–endurance or strength.

The first endeavor while interpreting ECGs in athletes is to determine if the ECG is 'normal' or 'abnormal'–the former needing no further investigation while the latter necessitating further evaluation. However, the analysis of the ECGs must be done in consultation with a specialist attuned to the changes seen in athletes' heart and cardiac conditions associated with sudden cardiac death.

The normal training related changes are early repolarization, left ventricular hypertrophy by the voltage criteria, sinus bradycardia, sinus arrhythmia, first degree or Type 1-2nd degree Atrioventricular block, and RBBB. Though significant these changes are manifestations of physiological changes in the cardiac anatomy and conduction, and thus do not put the athletes at a higher risk of arrhythmic events.

The abnormal ECG changes include T-wave inversions, ST depression, pathological Q-waves, left axis deviation, and conduction delays or aberrancy.[1] These changes are not related to physiological changes during training may indicate

Table 1A – Baseline parameters for all athletes.

Variables	Mean ± SD
Height (cm)	167.53 ± 9.16
Weight (Kg)	62.39 ± 13.99
BMI (Kg/m^2)	21.40 ± 3.23

Table 1B – Baseline Parameters for Group 1 and Group 2 athletes.

	Group 1	Group 2	p-value
Mean height	174.08 (4.7)	162.03 (8.3)	0000 (Sig)
Mean weight	59.42 (6.4)	64.89 (17.8)	0.10 (NS)
BMI	18.59 (1.61)	24.21 (4.85)	0.000 (Sig)

Table 2A – Baseline ECG Parameters for all athletes.

	Variables	Mean ± SD
ECG parameters	Heart Rate (Beats/min)	61.92 ± 13.91
	PR interval (ms)	154.88 ± 27.47
	QRS Axis (ms)	93.94 ± 9.19
	QRS Duration (ms)	93.94 ± 9.19
	QTc Interval (ms)	404.15 ± 21.90

Table 2B – Baseline ECG Parameters for Group 1 and Group 2 athletes.

	Group 1	Group 2	p-value
Mean HR	51.65 (107.11)	72.18 (84.89)	0.000 (Sig)
PR interval	170.38 (985.28)	141.7 (244.99)	0.000 (Sig)
QRS axis	60.23 (478.42)	58.39 (563.64)	0.74 (NS)
QRS duration	97.77 (58.02)	89.74 (88)	0.000 (Sig)
LVH criteria	28.65 (105.43)	22.52 (55.99)	0.007 (Sig)
QTc	399.62 (649.44)	405.77 (310.91)	0.25 (NS)

Table 3 – Normal and Abnormal ECG changes noted in athletes.

ECG change	Group 1 n = 33 (%)	Group 2 n = 33 (%)	Difference (p-value)
Common ECG changes			
Sinus bradycardia	14 (42%)	0	NA
Sinus arrhythmia	4 (12%)	6 (18%)	0.37
1st degree AV Block	4 (12%)	0	NA
2nd degree AV Block	2 (6%)	0	NA
Incomplete RBBB	11 (33%)	5 (15%)	0.03
Early repolarization	21 (64%)	7 (21%)	0.000
Left ventricular hypertrophy	8 (24%)	1 (3%)	0.004
Abnormal ECG changes			
T-wave inversion	6 (16%)	3 (8%)	0.006 (Sig)
RBBB	3 (8%)	0	NA
RVH with strain	12 (36%)	7 (21%)	0.02 (Sig)

Statistical analysis by difference of proportion using chi-square test.

an underlying pathological state thereby placing the athlete to a higher risk of arrhythmic events including sudden cardiac death.

Overall 54/66 (81%) number of our sportsmen had significant ECG changes. These included bradycardia, prolonged PR-interval, sinus arrhythmia, heart block, LVH, early repolarization, T-wave inversion, RBBB, and RVH with strain. This was far more than that observed in the average general population. Various studies have estimated the prevalence of significant ECG abnormalities in the general population to be from 4% to 9.6%.[4–9]

However, our subjects were sportsmen training for competitive sports, and thus represented a specific subset of individuals in the general population. Pelliccia et al reported a much higher prevalence at 12% among 32,652 Italian athletes studied.[10] In an observational study (n = 73) on Polish athletes preparing for the Olympics ECG alterations were noticed in 89% of the athletes, while completely normal ECG were noticed in only 11%. 65% athletes showed 'benign' or common features associated with an athletes heart (i.e. sinus Bradycardia, 1st degree Atrioventricular block, early repolarization, right bundle branch block, and isolated features of left ventricular hypertrophy), while 23% had features of 'suspected' or uncommon features (i.e. left posterior fascicular hemiblock, complete bundle branch block, ventricular arrhythmias, T-wave inversion or pathological QRS axis deviation).[11] In an Iranian observational comparative study (n = 100), 17/50 (34%) athletes and 14/50 (20%) non-athletes showed abnormal ECGs; however the difference was insignificant.[12]

We also observed ECG changes in 81% of our athletes, which correlates with the above studies in athletes. 68% of these changes were considered as normal training related features, while the remaining 32% were considered abnormal. The high prevalence of abnormal ECG finding among athletes is probably due to ECG criteria that are designed to increase the sensitivity, thereby increasing the false positive subset of athletes.[1] However, this is contrary to the new ESC guidelines, which were designed to increase the specificity of these changes.[2]

Early repolarization, sinus bradycardia, and incomplete RBBB were the commoner features noticed, with a significantly higher presence in the endurance trained athletes. This is in concordance with similar observations made in other studies.[11]

Early repolarization was the commonest ECG change noticed in our athletes, with statistically significant higher proportion among the runners. Unlike the pattern of only J-point elevation of more than 0.1 mV seen in Caucasians our patients showed the variance seen in the athletes of African-Caribbean descent.[2,3] They showed an upwardly convex ST-segment elevation, followed by a negative T-wave. These features are reversible, and proportional to the severity of bradycardia[2,3,13–15] and hence regress or disappear with deconditioning or adrenergic stimulation. Though they are occasionally associated with subclinical structural heart disease like ARVC HCM[16] and idiopathic ventricular fibrillation they do not necessitate further clinical evaluation.[3]

Sinus bradycardia, 1st and Type 1-2nd degree heart were commoner in runners. The average PR-interval was significantly higher among the runners than the weightlifters, though the values were below the values to label them as 1st degree AV-block. These changes have been attributed to an absolute or relative increase in vagal tone among athletes.[2] Similar to the PR-interval the QRS duration and the LV voltages were higher among the runners than the weightlifters but their absolute values were within the normal range. This observation points towards a trend towards left ventricular hypertrophy among the runners vis-à-vis the weightlifters.

The difference in the heights between the two groups of athletes was probably because of a selection bias wherein shorter, and stockier athletes were weightlifters and thinner and taller ones were runners.

The 'abnormal' features noted in our athletes were T-inversion, complete RBBB and RVH with strain. RVH with strain was noticed in 29% cases, predominantly in runners. This prevalence was far higher than the 0.6% noticed by Pelliccia et al,[17] and 12% reported by Sharma et al.[18]

Isolated T-wave inversion was seen in 14% athletes with a significantly higher incidence in the runners. This was far higher than the 2–3% noted in the general population.[16] This 'abnormal' ECG finding may be a marker of asymptomatic cardiomyopathy or a harbinger of it in future. However, athletes of African descent have a high incidence of isolated T-wave inversion in the absence of any structural heart disease.[18,19] This ethnic variability could be the reason for the higher incidence noted in our athletes too.

Isolated RBBB has also been considered as an abnormal finding among athletes. It was seen in 3/33 (8%) runners, without any weightlifter showing this feature. This incidence is much higher than that in the general population or among athletes.[3] Isolated RBBB when associated with a left anterior or posterior hemiblock may be a marker of a future degenerative conductive disorder like complete heart block and thus needs to be investigated by a TMT and a 24-h Holter monitoring.

The high prevalence (29%) of Right Branch Block Bundle (RBBB), Right Ventricular Hypertrophy (RVH), especially associated with strain is much higher than reported too.[17,18] Not only have these features been less reported and studied, but its correlation with the type of training, reversibility and adverse effects are not known.

Though the ECG features of Complete RBBB, RVH with strain and T-inversion has been considered as abnormal (because of the hypertrophy with associated T-wave inversion) it could also have resulted from the physiological cardiac adaptation of intense training leading to increased right ventricular wall thickness and cavity dilatation. As RV hypertrophy is commoner in the younger age group,[20] and our athletes were young too, it could also be the cause of this higher prevalence. Though no study has commented about the presence or effect of RVH with strain in athletes leading to increased mortality or morbidity, congenital and acquired heart diseases like atrial septal defect, pulmonary stenosis, cyanotic congential heart diseases, Arrhythmogenic RV cardiomyopathy (ARVC), and Brugada Syndrome will need exclusion.[2] This was done in all our cases too.

Thus, in the absence of structural heart disease, right ventricular hypertrophy and strain could serve as a marker of cardiac adaptation to strenuous endurance training. However, its presence in endurance athletes need detailed investigation and correlation with the level of training.

While comparing the ECG changes noticed, there was a significant difference in the heart rate, rhythm, early repolarization and isolated left ventricular hypertrophy between the two groups of athletes, i.e. the runners and weightlifters. Physiological ECG aberrations in trained athletes are related to the level of fitness, type of sport, gender and race.[1] This has been attributed to the higher resting vagal tone seen in the athletes undergoing endurance training which could be due to the activation of the high-pressure C-fibers in the myocardium due to higher LVEDd in these athletes.[2,3]

These ECG changes seen in athletes may also be seen in many amateur sportsmen, tradesmen engaged in physical labor intensive professions and soldiers who may not necessarily be involved in competitive sport. These changes may be detected during routine medical examinations and if not suspected may unnecessarily put the athlete through special and invasive testing.

Sudden Death in an athlete is a catastrophic event, which not only leads to the irreparable loss of life, but also adversely affects the training and performance of fellow colleagues. As a screening measure to reduce the incidence of this unfortunate occurrence most sporting organizations recommend a comprehensive cardiovascular examination along with an ECG.

Cardiovascular-related sudden death, especially due to arrhythmias is the leading cause of mortality in athletes during sport. Athletes with structural or electrical heart disease like hypertrophic cardiomyopathy, WPW syndrome, Brugada Syndrome, anomalous origin and course of coronary arteries predispose the athletes to develop fatal arrhythmias during strenuous training or competitive sport. Since the ECG changes in these illnesses are similar to the ones seen in physiologically adapted heart of athletes, few athletes with structurally abnormal hearts may be allowed to participate in competitive sport thus jeopardizing their life.

Though in the sportsmen screened by us there were none who were detected to have a cardiac illness necessitating termination of training, it is strongly recommended that all sports personnel engaging in competitive sport should undergo comprehensive screening.

Sports and exercise is rapidly being accepted as an integral part of 'healthy living' and 'lifestyle changes'. Many people will train hard (especially endurance training) and thus develop ECG changes akin to trained athletes. Further, many professions like farming, plumbing, masonry work, and even soldiers could develop these benign changes in course of their daily work. Hence, these changes must be suspected and investigates with due consideration to the overall physical capacity of the person.

The ECG changes seen in training athletes are likely to increase with the increasing competitiveness in sports. In recent years, guidelines (eg:ESC) have been written so as to assist the physicians in interpreting ECGs in sportsmen and help distinguish ECG changes due to intensive training from ones suggestive of underlying cardiac pathology. Thus these changes must be included as part of routine teaching at undergraduate and postgraduate level. This could go a long way in preventing unnecessary invasive or non-invasive investigations.

Though this study was undertaken to observe the abnormal ECG changes among Indian athletes it did not compare these changes with a matched 'non-trained' cohort. This has prevented us from comparing these changes in these two groups. Also, these electrical changes should have been compared with their associated anatomical changes on echocardiography. This would help correlate the physiological anatomical adaptation with their electro-conductive manifestations. This however, is being done as a follow-up of this study.

Conclusion

A high proportion of athletes undergoing competitive level sports training are likely to have abnormal ECG recordings. Majority of these are benign, and related to the physiological adaptation to the extreme levels of exertion. Right ventricular strain appears commoner than previously reported. These changes are commoner during endurance training (running) than strength training (weightlifting). Variations in these changes due to ethnic variability need to be considered during the analysis of these changes.

Conflicts of interest

The authors have none to declare.

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