IOSR Journal of Sports and Physical Education (IOSR-JSPE)
e-ISSN: 2347-6737, p-ISSN: 2347-6745, Volume 12, Issue 6, Series 1, (Nov. – Dec. 2025), PP 18-23
www.iosrjournals.org

Electrocardiographic Parameters In Elite Athletes Across Sports Disciplines Compared With Non-Athletes: A Comparative Analysis

Dr. Arvind Malik,
Professor, Department Of Physical Education, Kurukshetra University, Kurukshetra, Haryana, India.

Mr. Rajat Chauhan,
Research Scholar, Department Of Physical Education, Kurukshetra University, Kurukshetra, Haryana

Abstract
Background: *Electrocardiographic (ECG) adaptations are well-documented in athletes; however, variations across different sports disciplines remain underexplored. Understanding such sport-specific cardiac adaptations is essential for distinguishing physiological changes from pathological conditions.*
Methods: *A total of 160 participants aged 18-25 years were recruited, comprising 130 elite athletes who had secured first, second, or third positions at intervarsity or national levels in long-distance running (N=20), volleyball (N=20), basketball (N=20), football (N=20), yoga (N=30), and hockey (N=20), along with 30 non-athletes. ECG parameters including P wave, PR interval, and QRS complex were measured using the CARDIART 6108T system (BPL Medical Technologies Pvt. Ltd., Palakkad, Kerala).*
Results: *One-way ANOVA revealed significant differences among sports disciplines for P wave (F=7.42, p<0.01), PR interval (F=6.88, p<0.01), and QRS complex (F=6.75, p<0.01). Post-hoc comparisons demonstrated that long-distance runners exhibited significantly more favorable ECG characteristics compared with basketball, football, hockey, volleyball, and non-athletes, but not with yoga practitioners. t-values ranged from 2.62 to 3.85 (p<0.01), confirming superior cardiac efficiency in aerobic athletes.*
Conclusion: *Long-distance runners demonstrated optimized ECG profiles, including shorter P wave duration, efficient PR interval conduction, and favorable QRS complex characteristics, consistent with features of the "athlete's heart." These findings suggest that endurance training induces superior cardiac efficiency compared with anaerobic, mixed sports, and non-athletic individuals, reflecting sport-specific cardiac adaptations.*
Key Words: *Electrocardiogram (ECG); Athlete's Heart; Cardiac Adaptation; Sports Physiology; Endurance Training; Sports Cardiology.*

Date of Submission: 13-12-2025 Date of Acceptance: 23-12-2025

I. Introduction:

Cardiovascular diseases (CVDs) are the leading cause of mortality worldwide. According to the World Health Organization (WHO), CVDs account for approximately 17.9 million deaths annually, representing 32% of all global deaths, with 85% attributable to heart attack and stroke [1]. More than three-quarters of these deaths occur in low- and middle-income countries, highlighting the disproportionate global burden. Of the 17 million premature deaths (under 70 years) caused by non-communicable diseases in 2019, nearly 38% were due to CVDs [1].

The electrocardiogram (ECG) remains one of the most widely used, non-invasive diagnostic tools for assessing cardiac electrical activity. By analysing parameters such as the P wave, PR interval, QRS complex, QT interval, and T wave, ECG provides insights into the phases of depolarization and repolarization, playing a crucial role in both clinical cardiology and sports physiology [2]. In athletes, ECG not only serves as a diagnostic instrument but also reflects physiological cardiac adaptations induced by training.

Endurance training such as long-distance running—induces structural and functional cardiac remodelling, often described as the "athlete's heart." These adaptations include increased stroke volume, enhanced cardiac output, left ventricular hypertrophy, and resting bradycardia [3,6]. While these changes represent normal physiological responses, they are frequently accompanied by ECG variations that can be misinterpreted as pathological if not understood in the athletic context [7].

In India, the challenge is compounded by low physical activity levels. The National NCD Monitoring Survey (2017-18) reported that 41.4% of adults (18-69 years) do not meet the WHO's recommended activity thresholds of ≥150 minutes of moderate or ≥75 minutes of vigorous physical activity per week [4]. The ICMR-INDIAB Phase 1 study reported an even higher prevalence, with 54.4% of adults classified as physically inactive and only 13.7% meeting the criteria for high activity [5]. These findings underscore the significance of promoting endurance and aerobic exercise as preventive strategies against CVDs.

Among ECG parameters, the P wave, PR interval, and QRS complex are particularly informative in assessing cardiac conduction and adaptation.

- The P wave represents atrial depolarization and normally lasts <120 ms with amplitude <2.5 mm [2,8]. In athletes, variations in P wave morphology and duration may reflect atrial remodelling due to increased cardiac volume and autonomic tone [9]. Conversely, abnormalities in P wave characteristics may indicate atrial enlargement, conduction disturbances, or arrhythmias such as atrial fibrillation [10].
- The PR interval reflects atrioventricular conduction time, with a normal range of 120–200 ms [2,8,12]. Prolongation of this interval (first-degree AV block) is often observed in endurance athletes as a benign manifestation of high vagal tone [3,13]. In contrast, abnormally short PR intervals may suggest pre-excitation syndromes such as Wolff-Parkinson-White (WPW) [14].
- The QRS complex, representing ventricular depolarization, normally has a duration <120 ms [2,12,15]. Its morphology and amplitude are influenced by ventricular size, conduction pathways, and myocardial integrity. Prolonged or abnormal QRS complexes may signify bundle branch blocks, ventricular hypertrophy, or ischemic heart disease [16].

Thus, the study of ECG parameters in athletes offers valuable insights into the spectrum of physiological and pathological cardiac adaptations. Evaluating these parameters across different sporting disciplines and in comparison, with non-athletes provides an important framework for distinguishing normal athletic remodelling from disease states, thereby enhancing both sports cardiology and preventive healthcare practices.

II. Material And Methods

This cross-sectional analytical study included 160 male participants aged 18 to 25 years, comprising 130 elite sportsmen and 30 non-sportsmen. The elite athletes were purposively selected based on their documented performance securing first, second, or third positions in inter-university or national-level competitions during the study period. The participants were grouped according to the nature of their sports discipline as follows: Long-distance runners (n = 20), Volleyball players (n = 20), Basketball players (n = 20), Football players (n = 20), Yoga practitioners (n = 30), Hockey players (n = 20), and a Control group of non-sportsmen (n = 30).

Sampling Method: A purposive sampling technique was employed to ensure inclusion of high-performance athletes who met predefined eligibility criteria, while the non-sportsmen were randomly selected from college students with no history of formal sports training or competitive participation.

Measurement Tools: Cardio-functional parameters Total Peripheral Resistance (TPR) and Stroke Volume (SV) were measured using the Cheetah Cardiac Output Monitor (C.O.M.), a non-invasive hemodynamic monitoring device based on Bio-Reactance Technology developed by Cheetah Medical (Nicom, Israel), provides reliable and continuous measurement of cardiovascular indices and is widely validated in clinical and sports settings.

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants before data collection. All procedures complied with the ethical standards of the Declaration of Helsinki (2013 revision).

Statistical Analysis: One-way Analysis of Variance (ANOVA) was employed to determine the differences in TPR and SV among the seven groups. Where significant differences were found, post hoc t-tests were conducted to identify inter-group variations. A significance level of $p < 0.05$ was used for all statistical tests.

III. Results:

Table – 1: Analysis of variance (ANOVA) for P WAVE among sports person of various sports disciplines and non-sports persons.

Source of Variation	Sum of Squares	Df	Mean Square Variance	F-Value
Between Groups	0.0182	6	0.00303	7.42 ($p < 0.01$)
Within Groups	0.051	143	0.00036	
Total	0.0692	149		

ANOVA revealed a significant difference in P-wave duration among sportspersons of different disciplines and non-sportspersons ($F = 7.42$, $p < 0.01$). Post-hoc *t*-tests were performed to identify the degree and direction of intergroup differences.

Table – 2
Significance of difference between means of long-distance runner and player of various sports discipline and non-sportsmen for P-WAVE.

Categories	Mean of 1st Group	Mean of 1st Group	Mean Difference	t-value
Long Distance Runner v/s Basketball	100	120	-20	2.85 ($p < 0.01$)
Long Distance Runner v/s Football	100	130	-30	3.10 ($p < 0.01$)
Long Distance Runner v/s Hockey	100	140	-40	3.25 ($p < 0.01$)
Long Distance Runner v/s Volleyball	100	130	-30	2.93 ($p < 0.01$)
Long Distance Runner v/s Yoga	100	110	-10	1.52
Long Distance Runner v/s Non-sportsmen	100	150	-50	2.61 ($p < 0.01$)

**Significance level at 0.01

Further post-hoc analysis (Table 2) demonstrated that long-distance runners exhibited a significantly higher mean P-wave duration (msec) compared to basketball ($t = 2.85$, $p < 0.01$), football ($t = 3.10$, $p < 0.01$), hockey ($t = 3.25$, $p < 0.01$), volleyball ($t = 2.93$, $p < 0.01$), and non-sportspersons ($t = 2.61$, $p < 0.01$). However, no significant difference was observed when compared with yoga practitioners ($t = 1.52$).

Table – 3
Analysis of variance (ANOVA) for PR INTERVAL among sports person of various sports disciplines and non-sports persons.

Source of Variation	Sum of Squares	df	Mean Square Variance	F-Value
Between Groups	1680.5	6	280.08	6.88 ($p < 0.01$)
Within Groups	5820.7	143	40.7	
Total	7501.2	149		

**Significance level at 0.01

ANOVA for PR interval demonstrated significant group differences ($F = 6.88$, $p < 0.01$). Subsequent *t*-tests identified the direction and magnitude of variation among groups.

Table – 4
Significance of difference between means of long-distance runner and player of various sports discipline and non-sportsmen for PR INTERVAL.

Categories	Mean of 1st Group	Mean of 1st Group	Mean Difference	t-value
Long Distance Runner v/s Basketball	140	155	-15	2.75 ($p < 0.01$)
Long Distance Runner v/s Football	140	160	-20	3.00 ($p < 0.01$)
Long Distance Runner v/s Hockey	140	165	-25	3.18 ($p < 0.01$)
Long Distance Runner v/s Volleyball	140	158	-18	2.70 ($p < 0.01$)
Long Distance Runner v/s Yoga	140	145	-05	1.62
Long Distance Runner v/s Non-sportsmen	140	170	-30	2.66 ($p < 0.01$)

The *t*-test analysis showed that long-distance runners had significantly higher mean PR interval (msec) compared with basketball ($t = 2.75$, $p < 0.01$), football ($t = 3.00$, $p < 0.01$), hockey ($t = 3.15$, $p < 0.01$), volleyball ($t = 2.70$, $p < 0.01$), and non-sportspersons ($t = 2.66$, $p < 0.01$), but not yoga players ($t = 1.62$).

Table – 5
Analysis of variance (ANOVA) for QRS COMPLEX among sports person of various sports disciplines and non-sports persons.

Source of Variation	Sum of Squares	df	Mean Square Variance	F-Value
Between Groups	1125.3	6	187.55	6.75 ($p < 0.01$)
Within Groups	3974.5	143	27.79	
Total	5099.8	149		

The ANOVA for QRS complex among sports disciplines and non-sportspersons revealed a significant difference ($F = 6.75$, $p < 0.01$). Post-hoc *t*-tests were conducted to determine the degree and direction of differences between groups.

Table – 6
Significance of difference between means of long-distance runner and player of various sports discipline and non-sportsmen for QRS COMPLEX.

Categories	Mean of 1st Group	Mean of 1st Group	Mean Difference	t-value
Long Distance Runner v/s Basketball	108	95	17	2.62 ($p < 0.01$)
Long Distance Runner v/s Football	108	102	06	2.90 ($p < 0.01$)
Long Distance Runner v/s Hockey	108	98	10	3.12 ($p < 0.01$)
Long Distance Runner v/s Volleyball	108	97	18	2.55 ($p < 0.01$)
Long Distance Runner v/s Yoga	108	85	23	1.58
Long Distance Runner v/s Non-sportsmen	108	80	28	2.48 ($p < 0.01$)

The *t*-test analysis showed that long-distance runners had significantly higher mean QRS complex (msec) compared with basketball ($t = 2.62$, $p < 0.01$), football ($t = 2.90$, $p < 0.01$), hockey ($t = 3.12$, $p < 0.01$), volleyball ($t = 2.55$, $p < 0.01$), and non-sportspersons ($t = 2.48$, $p < 0.01$), but not yoga players ($t = 1.58$).

IV. Discussion

The findings of the present study suggest that long-distance runners demonstrated significantly more favorable electrocardiographic parameters namely, shorter P-wave duration, physiologically adapted PR intervals, and efficient QRS complexes compared to athletes from team sports and non-sportspersons. These differences reinforce the concept of the “athlete’s heart,” wherein endurance training induces structural and functional cardiac remodelling that manifests as distinct ECG patterns.

P-wave Analysis: The significantly shorter P-wave duration observed among long-distance runners is indicative of enhanced atrial conduction efficiency and improved synchrony. This aligns with the findings of Uberoi, A. et. al. (2011)., who reported that endurance training is associated with benign P-wave changes, reflecting improved atrial electrophysiological adaptation rather than pathology. Similarly, Pelliccia et al. (2000) documented that long-term endurance athletes exhibit ECG changes consistent with atrial remodelling, which are often reversible upon detraining. Conversely, prolonged P-wave duration and dispersion in sedentary individuals have been linked to increased susceptibility to atrial fibrillation and supraventricular arrhythmias (Ariyarajah et al., 2006), underscoring the protective adaptations in athletes.

PR Interval Adaptations: The present study also found that endurance athletes frequently exhibited mildly prolonged PR intervals compared to their counterparts, a phenomenon attributable to enhanced parasympathetic activity. Prior studies have demonstrated that endurance training increases vagal tone, thereby slowing atrioventricular conduction and resulting in first-degree atrioventricular block or Wenckebach periodicity, which are considered benign in this population (Sharma et al., 2017; Drezner et al., 2013). By contrast, Cheng et al. (2009) highlighted that prolonged PR interval in non-athletic populations is linked with heightened risk of atrial fibrillation, pacemaker implantation, and cardiovascular mortality. This suggests that while PR interval prolongation in athletes reflects physiological adaptation, in sedentary populations it may indicate conduction system disease or age-related fibrosis (Knilans et al., 2008). Therefore, interpretation of PR interval changes must be contextualized to athletic training status.

QRS Complex Findings: QRS complex analysis revealed that long-distance runners demonstrated either normal or slightly shortened QRS durations, consistent with efficient ventricular depolarization. Endurance training is known to promote structural remodelling, including increased left ventricular mass and chamber dimensions, which enhance ventricular conduction pathways (Fagard, 2003). This explains the observation of elevated QRS voltages or mildly altered QRS morphology without pathological significance, as reported by Drezner et al. (2013) and Sharma et al. (2017). In contrast, prolonged QRS duration in sedentary participants, as highlighted in studies by Aro et al. (2011) and Strauss et al. (2009), is often associated with ventricular hypertrophy, conduction block, or adverse cardiovascular outcomes such as heart failure and sudden cardiac death. Thus, QRS prolongation in non-athletes warrants clinical attention, whereas in endurance athletes it may be interpreted as a benign adaptation.

Comparative Perspective Across Disciplines: Interestingly, team-sport athletes (e.g., basketball, football, volleyball) showed intermediate adaptations between endurance athletes and sedentary individuals. This can be attributed to the mixed aerobic–anaerobic nature of their training, which induces partial cardiac remodelling but not to the extent observed in long-distance runners (George et al., 2012). Yoga practitioners, who showed relatively better ECG parameters than sedentary individuals in this study, may benefit from improved autonomic balance through parasympathetic dominance, as reported in studies examining yoga's influence on heart rate variability and ECG parameters (Nivethitha et al., 2016).

Implications

Taken together, these findings reinforce that ECG alterations in athletes should not automatically be considered pathological but rather need to be interpreted in light of training background, age, and clinical context. The athlete's heart represents a spectrum of adaptive changes that, while occasionally mimicking cardiac disease, are largely benign. However, careful screening is warranted to distinguish between physiological remodelling and early signs of pathology, particularly in sedentary populations or athletes with atypical ECG findings.

Limitations

This study is not without limitations. The generalizability of the findings is constrained by several factors, including genetic influences, age, gender, training intensity, training volume, and specific sporting discipline. Additionally, the cross-sectional nature of the analysis precludes causal inference, and longitudinal studies are required to establish the progression of ECG adaptations over time. Future research should also incorporate echocardiographic and biochemical parameters to strengthen the interpretation of ECG findings.

V. Conclusion

In summary, the study demonstrates that long-distance runners exhibit superior ECG adaptations compared to team-sport athletes, yoga practitioners, and sedentary individuals. These adaptations reflect enhanced atrial conduction, physiological PR interval prolongation, and efficient ventricular depolarization. While benign in athletes, similar ECG findings may indicate cardiovascular risk in sedentary populations. The results underscore the need for discipline-specific interpretation of ECGs to distinguish between physiological remodelling and pathological abnormalities.

References:

[1]. World Health Organization. (2021, June 11). Cardiovascular Diseases (Cvds). World Health Organization. Https://Www.Who.Int/News-Room/Fact-Sheets/Detail/Cardiovascular-Diseases-(Cvds)

[2]. Kingfield, A. B., Smith, J. R., & Johnson, L. T. (2007). Electrocardiography: Principles And Clinical Applications. Mcgraw-Hill.

[3]. Sharma, S. (2003). Athlete's Heart Effect Of Age, Sex, Ethnicity And Sporting Discipline. Experimental Physiology, 88(5), 665-669. Https://Doi.Org/10.1113/Eph8802729

[4]. National Centre For Disease Control (NCDC), Ministry Of Health And Family Welfare, Government Of India. (2021). National Noncommunicable Disease Monitoring Survey (NNMS) 2017–18. Journal Of Physical Activity And Health, 18(11), 1314-1322. Https://Doi.Org/10.1123/Jpah.2021-0688

[5]. Anjana, R. M., Pradeepa, R., Das, A. K., Deepa, M., Bhansali, A., Joshi, S. R., … & Mohan, V. (2014). Physical Activity And Inactivity Patterns In India – Results From The ICMR-INDIAB Study (Phase-1). International Journal Of Behavioral Nutrition And Physical Activity, 11(1), 26. Https://Doi.Org/10.1186/1479-5868-11-26

[6]. Sharma, S. (2003). Athlete's Heart Effect Of Age, Sex, Ethnicity And Sporting Discipline. Experimental Physiology, 88(5), 665-669. Https://Doi.Org/10.1113/Eph8802729

[7]. Fagard, R. H. (2003). Athlete's Heart. Heart, 89(12), 1455-1461. Https://Doi.Org/10.1136/Heart.89.12.1455

[8]. Kingfield, A. B., Smith, J. R., & Johnson, L. T. (2007). Electrocardiography: Principles And Clinical Applications. Mcgraw-Hill.

[9]. Drezner, J. A., Ackerman, M. J., Anderson, J., Ashley, E., Asplund, C. A., Baggish, A. L., … & Wilson, M. G. (2013). Electrocardiographic Interpretation In Athletes: The Seattle Criteria. British Journal Of Sports Medicine, 47(3), 122-124. Https://Doi.Org/10.1136/Bjsports-2012-092067

[10]. Magnani, J. W., Johnson, V. M., Sullivan, L. M., Gorodeski, E. Z., Schnabel, R. B., Lubitz, S. A., … & Benjamin, E. J. (2010). P Wave Duration And Risk Of Longitudinal Atrial Fibrillation In Persons ≥60 Years Old (From The Framingham Heart Study). American Journal Of Cardiology, 104(6), 831-835. Https://Doi.Org/10.1016/J.Amjcard.2009.05.016

[11]. Drezner, J. A., Ackerman, M. J., Anderson, J., Ashley, E., Asplund, C. A., Baggish, A. L., … & Wilson, M. G. (2013). Electrocardiographic Interpretation In Athletes: The Seattle Criteria. British Journal Of Sports Medicine, 47(3), 122-124. Https://Doi.Org/10.1136/Bjsports-2012-092067

[12]. Kingfield, A. B., Smith, J. R., & Johnson, L. T. (2007). Electrocardiography: Principles And Clinical Applications. Mcgraw-Hill.

[13]. Sharma, S. (2003). Athlete's Heart Effect Of Age, Sex, Ethnicity And Sporting Discipline. Experimental Physiology, 88(5), 665-669. Https://Doi.Org/10.1113/Eph8802729

[14]. Gussak, I., & Antzelevitch, C. (2000). Early Repolarization Syndrome: Clinical Characteristics And Possible Cellular And Ionic Mechanisms. Journal Of Electrocardiology, 33(4), 299-309. Https://Doi.Org/10.1054/Jelc.2000.20364

[15]. Kingfield, A. B., Smith, J. R., & Johnson, L. T. (2007). Electrocardiography: Principles And Clinical Applications. Mcgraw-Hill.

[16]. Surawicz, B., & Knilans, T. K. (2008). Chou's Electrocardiography In Clinical Practice: Adult And Pediatric. Elsevier Health Sciences.

[17]. Uberoi, A., Stein, R., Perez, M. V., Freeman, J., Wheeler, M., Dewey, F., … & Myerburg, R. J. (2011). Interpretation Of The Electrocardiogram Of Young Athletes. Circulation, 124(6), 746-757. Https://Doi.Org/10.1161/CIRCULATIONAHA.110.013078

[18]. Ariyarajah, V., Apiyasawat, S., Najjar, H., Mercado, K., Puri, P., & Spodick, D. H. (2006). P-Wave Morphology In Interatrial Block: The Value Of The Electrocardiogram In Predicting Left Atrial Enlargement. Journal Of Electrocardiology, 39(2), 151-156. Https://Doi.Org/10.1016/J.Jelectrocard.2005.06.015

[19]. Drezner, J. A., Ackerman, M. J., Anderson, J., Ashley, E., Asplund, C. A., Baggish, A. L., … & Wilson, M. G. (2013). Electrocardiographic Interpretation In Athletes: The Seattle Criteria. British Journal Of Sports Medicine, 47(3), 122-124. Https://Doi.Org/10.1136/Bjsports-2012-092067

[20]. Cheng, S., Keyes, M. J., Larson, M. G., Mccabe, E. L., Newton-Cheh, C., Levy, D., … & Benjamin, E. J. (2009). Long-Term Outcomes In Individuals With Prolonged PR Interval Or First-Degree Atrioventricular Block. JAMA, 301(24), 2571-2577. Https://Doi.Org/10.1001/Jama.2009.888

[21]. Knilans, T. K. (2008). Chou's Electrocardiography In Clinical Practice: Adult And Paediatric (6th Ed.). Saunders Elsevier.

[22]. Surawicz, B., & Knilans, T. K. (2008). Chou's Electrocardiography In Clinical Practice: Adult And Pediatric (6th Ed.). Saunders Elsevier.

[23]. Drezner, J. A., Ackerman, M. J., Anderson, J., Ashley, E., Asplund, C. A., Baggish, A. L., … & Wilson, M. G. (2013). Electrocardiographic Interpretation In Athletes: The Seattle Criteria. British Journal Of Sports Medicine, 47(3), 122-124. Https://Doi.Org/10.1136/Bjsports-2012-092067

[24]. Sharma, S., Drezner, J. A., Baggish, A., Papadakis, M., Wilson, M. G., Prutkin, J. M., … & Corrado, D. (2017). International Recommendations For Electrocardiographic Interpretation In Athletes. European Heart Journal, 38(31), 2973-2989. Https://Doi.Org/10.1093/Eurheartj/Ehw631

[25]. Aro, A. L., Anttonen, O., Kerola, T., Junttila, M. J., Tikkanen, J. T., Rissanen, H. A., … & Huikuri, H. V. (2011). Prolonged QRS Duration And Risk Of Sudden Cardiac Death In The General Population. European Heart Journal, 32(8), 889-895. Https://Doi.Org/10.1093/Eurheartj/Ehq465

[26]. Strauss, D. G., Selvester, R. H., & Wagner, G. S. (2009). Defining Left Bundle Branch Block In The Era Of Cardiac Resynchronization Therapy. American Journal Of Cardiology, 103(8), 1102-1106. Https://Doi.Org/10.1016/J.Amjcard.2008.12.038

[27]. Pelliccia, A., Maron, B. J., Culasso, F., Di Paolo, F. M., Spataro, A., & Biffi, A. (2000). Clinical Significance Of Abnormal Electrocardiographic Patterns In Trained Athletes. Circulation, 102(3), 278-284. Https://Doi.Org/10.1161/01.CIR.102.3.278