***Original Research Article***

# Sex and Age Variation in Electrocardiographic Parameters of Apparently Healthy Nigerian Athletes

## Abstract

**Background**: The Athletic heart (AH) exhibits a complex physiologic variation in function and structure caused by remodeling that accompanies regular athletic training. This study investigated the sex and age variations in the electrocardiographic (ECG) parameters of apparently healthy Nigerian athletes.

**Method**: A cross-sectionaldescriptive survey was done on 340 subjects consisting of 170 athletes (males: 63, females: 107) and 170 non-athletes (75 males and 95 females; serving as control). Subjects' age ranges were 16-35 years. Heart rate, blood pressure, and anthropometric measurements were determined. Physical examination was done to eliminate the existence of co-morbidities. ECG parameters were obtained using a standard-resting 12-lead electrocardiogram. From the results, female athletes were significantly ($P<0.05$) older than male, and had higher SBP and weight.

**Results** The ECG variables of athletes were sex-influenced and not necessarily age-influenced. For the adaptive features, significant differences were found in T-inversion (M=31.7% vs F=16.8%), isolated QRS voltage [Criteria for LVH] (M=11.5% vs F=52.3%), sinus bradycardia (M=14.3% vs F=41.1%), and 1st degree AV block (M=11.1%, F=2.8%). For the mal-adaptive ECGs; left axis Deviation (M=0% vs F=9.3%), repolarization abnormality (M=1.6% vs F=8.4%), abnormal LVH (M=0% vs F=11.3%), and ST-T elevation abnormality (M=1.6% vs F=8.4%) were found higher in females. Sex rather than age influence was indicative as there were significant correlations ($P<0.05$) between age and some ECG parameters; QT-interval, heart rate, and QRS voltage in males but not females.

**Conclusion**, Variability in ECG (adaptive and maladaptive) features of elite Nigerian athletes was indicative of sex influence but not age.

***Keywords:****sex; Age; ECG parameters; Apparently Healthy; and Nigerian athletes*

## Introduction

The Athletic heart (AH) exhibits a complex physiologic variation in function and structure[1] caused by remodeling that accompanies regular athletic training[1, 2, 3, 4]. For example, intense physical exercise causes a six- to eightfold increase in cardiac output and pulmonary oxygen uptake [1]. The heart rate of an athlete ranges from <40 beats/min at rest to >220 beats/min at peak exertion [1, 2, 3, 4]. The left ventricular relaxation in an athlete's heart changes dynamically and this accounts for the increased stroke volume and cardiac output at extreme heart rates [4, 5, 6, 7].

The body's cardiovascular network is a fine-tuned, nonlinear feedback system [1, 4, 5], and its architecture (cardiovascular system; atria, ventricles, and aorta) undergoes continuous nonlinear remodeling that reflects adaptive changes inthe athlete's heart [4, 5, 8], which is dependent on the nature and intensity of the individual athletic activity. Endurance exercise involves sustained elevation in cardiac output with reduced peripheral vascular resistance, resulting in a continuous volume challenge for all cardiac chambers. Long-distance running, cycling, and swimming represent endurance exercise. Alternatively, strength training involves exercise activities that are characterized by cardiac output that is normal or slightly elevated and increased peripheral vascular resistance; this results in increased blood pressure and left ventricular afterload [9, 10, 11, 12. 13]. Weightlifting, football, and wrestling are athletic disciplines representative of strength training. Overlap sports such as soccer, basketball, and hockey, encompass significant constituents of endurance and strength exercise training [9, 13], The variable hemodynamic effects play a major role in the degree and type of individualized cardiovascular remodeling [4, 5, 6, 7].

The development of ECG enabled extensive investigation of the heart's electric activity of trained athletes [14, 15, 16, 17, 18, 19]. The development and rapid dissemination of 2-dimensional echocardiography advanced the understanding of the athlete's heart.[20] Proper descriptions of the enlargement of the ventricular chamber, myocardial hypertrophy, and atrial dilation brought about a comprehensive understanding of the athlete's heart [2, 4, 15, 20, 21, 22]. Studies showed significant differences in heart rate, QRS-axis, QRS duration, QTc interval, and PR interval between men and women, and this was found in cohort studies by both Mason (n= 79,743) and Ramirez (n=32,949) [23, 24].

Further evidence from electrocardiographic and echocardiographic suggest that the competitive athletes' hearts may vary according to sex [25, 26, 27, 28], age [25, 26, 27, 28, 30], sporting category [7, 9, 10, 12, 13, 31, 32], ethnicity [21, 33, 34, 35, 36, 37]. The physiological, morphological, and electrocardiographic variations and changes are distinctive for various athlete populations participating in various sporting activities [1, 2, 4, 25]. In a cohort study of 330 competitive rowers (56% male), Wasfy et al. [38] found significant sex-associated differences in QRS duration, QTc interval, QRS axis, and QRS voltages in selected leads. Significantly higher amounts of sinus bradycardia (38.3% vs. 23.0%), incomplete RBBB (15.0% vs. 3.7%), early repolarisation (4.5% vs. 1.0%), and isolated QRS voltage criteria for LVH (26.3% vs. 4.6%) were found in males [39]. In my opinion, the different training responses are affected by the sex, age, and ethnicity components of the athlete's heart. For example, more male athletes have increased left ventricular thickness of up to 12mm and end-diastolic diameter ≥60mm more than female athletes [25, 33].

Studies found that adult athletes demonstrate a greater degree of cardiac remodeling than adolescent athletes of similar sex and sporting discipline [9, 11, 25]. Wilhelm and Seiler [31, 40] found that the presence of left atrial hypertrophy which was more conspicuous in suffering competitors appeared differently from strength-prepared competitors. Against this background, this study investigated the sex and age variations in the electrocardiographic (ECG) parameters of apparently healthy Nigerian athletes.

## Materials and Methods

### 2.1 Research Designand Population

This investigation was a cross-sectionaldescriptive survey involving 170 purposively sampled elite athletes (63 males and 107 females) utilizing the University of Port Harcourt (UPH) sports complex and Rivers State Sports Council complex, Port-Harcourt, Nigeria; between 2018 and 2019. The research study was conducted at the medical suite of the ultra-modern UPH gymnasium and Rivers United football club infirmary, Rivers State Sports Complex, Elekahia.

The study included athletes who fall within the age range of 16-35 years, who are Nigerians by birth and traced to the second generation, and who lived in Nigeria with at least a year of regular training experience; signed an informed consent to participate in the study. Athletes excluded were those that; did not meet the inclusion criteria; have a history of cardiovascular diseases; are pregnant or breast-feeding athletes; have electrolyte disturbances or are on fluid therapy (for example recent blood transfusion within the past 3 months); took anabolic steroids or drank heavy alcohol i.e., more than 24 units of beer or greater than 3 units of spirit every day [41]; are current smokers - smoking recently or during the two years preceding this research [42].

### 2.2 Materials

The materials used for this study included; Cardiovit AT-2plus model standard resting 12 – lead ECG (Schiller AG, Altgasse 68 CH 6341, Bear Switzerland) with a paper velocity of twenty-five (25) mm/sec and standardized at 0.1mv/mm was employed for determination of ECG; Non-irritant electrode gel; sphygmomanometer (Accoson Works, Harlow Essex, UK); stethoscope; Seca weight and height scale; reclining bed; power source and an alternative power supply (e.g., UPS).

### 2.3 Study Procedure

The following anthropometric profiles; height, weight, and BMI were determined using standard procedure and equipment [43]. Body Mass Index (BMI) was derived by dividing weight in Kg by the square of the height in M (Kg/m2). BMI status was classified in line with WHO benchmarks as normal weight (18.9-24.9Kg/m2), overweight (25.0-29.9Kg/m2), class 1 obesity (30.0-34.9 Kg/m2), class 11 obesity (35.0-39.9 Kg/m2), and morbid obesity (BMI >40.0 Kg/m2).

Systolic (SBP) and diastolic (SBP) blood pressure were carried out following the American Heart Association (AHA) Guidelines for In-Clinic blood pressure measurement [44] using an Accoson Duplex Hand Model Aneroid sphygmomanometer (with 12.5cm x 40.0cm size cuff) [45]. Exercise, Smoking, and alcohol were avoided for a minimum of half an hour before the BP measurement with the subject quietly seated for at least 5minutes before the values were recorded [44]. With the placement of the appropriate cuff size at heart level and 2cm above the elbow, we measured the Blood pressure inthe right arm twice and the average was recorded [43].

The mean arterial pressure was determined from the SBP and DBP using the MAP formula: MAP=1/3 × SBP + 2/3 × DBP.

Cardiac Auscultation of the participant was determined. In a calm,quiet examination room had a physical examination. After inspection and palpation, auscultation was done with a Littman classic M3. Low-pitch heart sounds S3 and S4 were researched using the bell of the stethoscope, with the participant lying [43].

The Electrocardiography (ECG) Recording of the subjects was determined using the guidelines of the American College of Cardiology and American Heart Association relating to leads, instrument specifications, and subjects' placements [46]. The subjects were asked to relax in the supine position for about 10 minutes on the reclining bed. The relaxed mental and physical state of the subject was confirmed. No bodily activity or training was allowed before ECG determination. The limb leads were then clamped to the upper/lower limbs after applying the electrocardiograph gel for effective conductivity. The chest leads were positioned on the chest wall to identifytheir different placement positions; V1 was placed on the 4th intercostal space, right sternal border; V2 was placed on the 4th intercostal space left sternal border; V3 was placed midway between V2 & V4; V4 was placed on the 5th inter-costal space at the midclavicular line; V5 was placed on the 5th intercostal space, anterior axillary line; V6 was positioned at the 5th intercostal-space, mid axillary line.

### 2.4 Data analysis

Numeric data obtained from the study were presented as absolute values, percentages, and mean±SD of mean where necessary. Statistical Packages for Social Sciences (version 20.0) Statistical package was used to analyze the data. The mean and SD standard deviation were determined for various parameters and were summarized in tabular forms. The Z-test was employed to compare continuous variables like height, weight, BMI, and mean arterial pressure, while proportions or categorical parameters like sex were analyzed with the chi-square test or 2-2-tailed Fisher's exact test (used when expected cell counts were <5). 95% CIs wereobtained using univariate and multivariate analyses) as appropriate. With variance at infinity, a p-value <0.05 was regarded as significant. To ascertain the association between anthropometric parameters and ECG parameters of respondents, Pearson's correlation was used. A 'logistic regression model' was used to predict factors that may influence the incidence of ECG maladaptations.

## Results

The results of the study are presented as categorical (frequency & percentages) and continuous (mean±standard deviation; S.D) variables. The age distribution of the athletes was presented in Table 1, while Table 2 represents the mean (S.D) values and test of difference in male and female anthropometric values. The distribution and sex- and age-- association difference in the adaptive ECG features in athletes was presented in Table 3, while sex and age comparison between the maladaptive ECG features in athletes was presented in Table 4. The correlation between age and ECG values is presented in Table 5.

The female athletes (25.91±4.48 years) were significantly (t=3.595; P-value=0.0004; md=-2.37) older than male athletes (23.54±3.52 years) and this was associated with the higher proportion of females in the age group 26-35 (57; 47.3%) compared to males (16; 25.4%) (Table 1). From Table 2, the difference in the SBP and weight of males and females were 4.46 and 10.94 respectively; with females having significantly greater values than males (DBP; t=2.701, P=0.008, and Weight; t=6.072, P<0.001).

Table 3 represents the prevalence of adaptive ECG features in male and female athletes. The % of athletes with a normal variant of T-wave Inversion and 1st-degree AV-block was found to be markedly higher in males than in females ($\chi^2$ =5.09; P=0.035); and ($\chi^2$ =4.94; P=0.040) respectively. While the % of isolated QRS voltage criteria for LVH and sinus bradycardia in females are markedly higher than in males ($\chi^2$ =2020, p= 0.001 and $\chi^2$ =13.31; P=0.001). The prevalence of adaptive ECG features in athletes compared by age category. The age of all athletes was grouped thus: 16 to 25 years and 26 years& above. No significant difference was seen in the two age categories (p>0.05).

The result in Table 4 presents the prevalence of maladaptive ECG features in athletes as compared by sex and age category. The percentage of athletes with LAD, repolarization abnormality, abnormal LVH, and ST-T elevation were significantly higher in females than males ($\chi^2$=6.26, P=0.01); ($\chi^2$=5.60, P=0.03); ($\chi^2$=7.68, P=0.01) and ($\chi^2$=4.30, P=0.04) respectively. The prevalence of maladaptive ECG features in athletes compared by age category. No (significant) difference was detected in age categories of 16 to 25 years and 26 years and beyond in all athletes (p>0.05).

The correlation result in Table 5 indicates that a significant correlation with age was observed for male athletes but not females. In males, QT-interval was significantly positively correlated with age (r=0.276; P=0.004) but age was negative with heart rate (r=-0.252; P=0.009), and QRS Voltage (r=-0.206; P=0.033).

**Table 1:** Age distribution of the athletes

| **Age group** | **male (n=63)** | **Female (n=107)** |
|---|---|---|
| **16-25 years** | 47 (74.6) | 50 (46.7) |
| **26-35 years** | 16 (25.4) | 57 (47.3) |
| **Mean Age (m±SD) in years** | 23.54±3.52 | 25.91±4.48** |

***P-value=0.0004; md=-2.37; t=3.595*

**Table 2:** The descriptive characteristics of anthropometric variables of the athletes

| **Variables** | **Male Athletes** | **female Athletes** | ***MD*** | **t-value** | **p-value** |
|---|---|---|---|---|---|
| **SBP (mmHg)** | 113.32±10.12 | 117.78±10.56 | -4.46 | 2.701 | 0.008* |
| **DBP (mmHg)** | 71.16±9.60 | 72.23±8.84 | -1.07 | 0.738 | 0.461 |
| **MAP (mmHg)** | 85.21±8.80 | 87.41±7.97 | -2.20 | 1.672 | 0.0964 |
| **Height (m)** | 1.79±0.18 | 1.68±0.12 | 0.11 | 4.7751 | 0.0001** |
| **Weight (Kg)** | 61.33±12.46 | 72.27±10.64 | -10.94 | 6.072 | 0.0001** |
| **BMI (kg-$^{2}$)** | 22.50±3.62 | 23.48±2.95 | -0.98 | 1.920 | 0.057 |

***Note:*** *SBP=Systolic blood pressure; DBP=Diastolic blood pressure; MAP=Mean atrial pressure; BMI=Body Mass Index*

**Table 3:** The adaptive ECG features in athletes compared by sex

| **ECG features** | **Sex category** | | | **Age category (%)** | | |
|---|---|---|---|---|---|---|
| | **Male (%) n=63 (37.1)** | **Female (%) n=107 (62.9)** | **Chi-square (p-value)** | **16 to 25 yrs n=97 (57.1)** | **26 to 35 yrs n=73 (42.9)** | **Chi-square (p-value)** |
| **ST-Segment Elevation (NV)** | | | | | | |
| **No** | 97(90.7) | 62(98.4) | 3.94 (0.056) | 89(91.8) | 70(95.9) | 1.18(0.355) |
| **Yes** | 10(9.3) | 1(1.6) | | 8 (8.2) | 3 (4.1) | |
| **T inversion (NV)** | | | | | | |
| **No** | 89(83.2) | 43(68.3) | 5.09 (0.035)* | 78(80.4) | 54(74.0) | 0.995(0.355) |
| **Yes** | 18(16.8) | 20(31.7) | | 19(19.6) | 19(26.0) | |
| **Early repolarization** | | | | | | |
| **No** | 101(94.4) | 63(100.0) | 3.66 (0.086) | 94(96.9) | 70(95.9) | 0.126(0.998) |
| **Yes** | 6(5.6) | 0(0.0) | | 3(3.1) | 3(4.1) | |
| **Isolated QRS voltage. Criteria for LVH** | | | | | | |
| **No** | 51(47.7) | 52(82.5) | 20.20 (<0.001)** | 62(63.9) | 41(56.2) | 1.05(0.343) |
| **Yes** | 56(52.3) | 11(17.5) | | 35(36.1) | 32(43.8) | |
| **Right Axis Deviation** | | | | | | |
| **No** | 104(97.2) | 63(100.0) | 1.80 (0.296) | 96(99.0) | 71(97.3) | 0.702(0.577) |
| **Yes** | 3(2.8) | 0(0.0) | | 1(1.0) | 2(2.7) | |
| **Sinus arrhythmias** | | | | | | |
| **No** | 100(93.5) | 58(92.1) | 1.18(0.763) | 90(92.8) | 68(93.2) | 0.09(1.000) |
| **Yes** | 7(6.5) | 5(7.9) | | 7(7.2) | 5(6.8) | |
| **Sinus bradycardia** | | | | | | |
| **No** | 63(58.9) | 54(85.7) | 13.31 (<0.001)** | 72(74.2) | 45(61.6) | 3.07(0.095) |
| **Yes** | 44(41.1) | 9(14.3) | | 25(25.8) | 28(38.4) | |
| **1st deg. AV block** | | | | | | |
| **No** | 104(97.2) | 56(88.9) | 4.94 (0.040)* | 94(96.9) | 66(90.4) | 3.18(0.101) |
| **Yes** | 3(2.8) | 7(11.1) | | 97(100.0) | 73(100.0) | |

*Significant at *p<0.05, **P<0.01*

**Table 4:** Mal-adaptive ECG features in athletes compared by sex and age

| Mal adaptive features | Sex |  | Chi-square (p-value) | Age category |  | Chi-square (p-value) |
|---|---|---|---|---|---|---|
|  | Male | Female |  | 16-25 yrs | 26 -30 yrs |  |
| **Lat. Subepicardial injury** |  |  |  |  |  |  |
| **No** | 63(100.0) | 106(99.1) | 0.59(1.00) | 97(100.0) | 72(98.6) | 1.34(0.43) |
| **Yes** | 0(0.0) | 1(0.9) |  | 0(0.0) | 1(1.4) |  |
| **Pericarditis** |  |  |  |  |  |  |
| **No** | 62(98.4) | 107(100.0) | 1.71(0.37) | 96(99.0) | 73(100.0) | 7.57(1.00) |
| **Yes** | 1(1.6) | 0(0.0) |  | 1(1.0) | 0(0.0) |  |
| **Path. Q-wave** |  |  |  |  |  |  |
| **No** | 63(100.0) | 106(99.1) | 0.59(1.00) | 97(100.0) | 72(98.6) | 1.34(0.43) |
| **Yes** | 0(0.0) | 1(9.0) |  | 0(0.0) | 1(1.4) |  |
| **T-wave abnormality** |  |  |  |  |  |  |
| **No** | 63(100.0) | 105(98.1) | 1.19(0.53) | 95(97.9) | 73(100.0) | 1.52(0.51) |
| **Yes** | 0(0.0) | 2(1.9) |  | 2(2.1) | 0(0.0) |  |
| **Left axis Deviation** |  |  |  |  |  |  |
| **No** | 63(100.0) | 97(90.7) | 6.26(0.01)* | 91(93.8) | 69(94.5) | 0.38(1.00) |
| **Yes** | 0(0.0) | 10(9.3) |  | 6(6.2) | 4(5.5) |  |
| **Complete LBBB** |  |  |  |  |  |  |
| **No** | 63(100.0) | 106(99.1) | 0.59(1.00) | 97(100.0) | 72(98.6) | 1.34(0.43) |
| **Yes** | 0(0.0) | 1(9.0) |  | 0(0.0) | 1(1.4) |  |
| **Inferior Ischeamia** |  |  |  |  |  |  |
| **No** | 63(100.0) | 105(98.1) | 1.19(0.53) | 97(100.0) | 71(97.3) | 2.69(0.18) |
| **Yes** | 0(0.0) | 2(1.9) |  | 0(0.0) | 2(2.7) |  |
| **Short QT Interval** |  |  |  |  |  |  |
| **No** | 62(100.0) | 105(98.1) | 1.19(0.53) | 95(97.9) | 73(100.0) | 1.52(0.51) |
| **Yes** | 0(0.0) | 2(1.9) |  | 2(2.1) | 0(0.0) |  |
| **Repolarization Abnormality** |  |  |  |  |  |  |
| **No** | 63(98.4) | 98(91.6) | 5.60(0.03)* | 92(94.8) | 69(94.5) | 0.09(1.00) |
| **Yes** | 1(1.6) | 9(8.4) |  | 5(5.2) | 4(5.5) |  |
| **Abnormal LVH** |  |  |  |  |  |  |
| **No** | 63(100.) | 94(88.7) | 7.68(0.01)* | 89(91.8) | 68(94.4) | 4.54(0.56) |
| **Yes** | 2(0.0) | 12(11.3) |  | 8(8.2) | 4(5.6) |  |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Right ventricular hypertrophy** | | | | | | |
| **No** | 63(100.0) | 106(99.1) | 0.59(1.00) | 96(99.0) | 73(100.0) | 7.57(1.00) |
| **Yes** | 0(0.0) | 1(9.0) | | 1(1.0) | 0(0.0) | |
| **P-Mitrale Left Atrial Hypertrophy** | | | | | | |
| **No** | 62(98.4) | 102(95.3) | 1.11(0.41) | 95(97.9) | 69(94.5) | 1.43(0.40) |
| **Yes** | 1(1.6) | 5(4.7) | | 2(2.1) | 4(5.5) | |
| **ST-T elevation abnormality** | | | | | | |
| **No** | 62(98.4) | 100(93.5) | 4.30(0.04)* | 95(97.9) | 68(93.2) | 2.42(0.24) |
| **Yes** | 1(1.6) | 7(6.5) | | 2(2.1) | 5(6.8) | |

**Table 5:** Correlation of age & ECG parameters among male and female athletes

| | **Age in years [r(p-value)]** | |
|---|---|---|
| **ECG parameters** | **Athletes (M=63)** | **Athlete (F=107)** |
| **MAP (mmHg)** | 0.068 (0.487) | 0.066 (0.609) |
| **P-axis ($^0$)** | 0.139 (0.154) | -0.044 (0.732) |
| **QRS-axis ($^0$)** | 0.082 (0.402) | -0.222 (0.083) |
| **T-axis ($^0$)** | -0.115 (0.238) | -0.113 (0.383) |
| **PR-interval (ms)** | 0.102 (0.297) | 0.222 (0.082) |
| **QRS-interval (ms)** | 0.126 (0.195) | -0.103 (0.427) |
| **QT-interval (ms)** | 0.276 (0.004)* | 0.126 (0.330) |
| **QTc-interval (ms)** | -0.012 (0.904) | -0.108 (0.405) |
| **Heart Rate (bpm)** | -0.252 (0.009)* | -0.098 (0.448) |
| **QRS Voltage (mv)** | -0.206 (0.033)* | -0.010 (0.939) |

***Bold**** *Significant at P-value <0.05; r=Pearson's correlation coefficient.*

## Discussion

Athletes always have cardiac adaptations to sports which can be identified on the ECG. The ECG presents it as an alteration of normal electric activity to an abnormal pattern. In other to avoid cardiovascular-related sudden cardiac death; which is the leading cause of death during sports[47], errors in interpretation has to be curtailed. The variations in the adaptive and maladaptive ECG presentation of athletes about sex and age have to be investigated and defined. This study investigated the sex- and age-associated variations in ECG features of elite Nigerian athletes.

The results from the descriptive data showed female athletes were significantly older than male athletes with a mean difference of 2.37 years and this was because there were more females in a group 26-35 compared to males; however, the extent to which this difference influenced the outcome of the ECG parameters were not significant. The SBP and weight of females were significantly greater than the male values.

The ECG features in athletes that are an adaptation to exercise in this study show that Isolated LVH was the most abundant adaptive feature, followed by sinus bradycardia, then T-wave inversion (normal variant), then 1st-degree AV-block, etc in both male & female athletes. The female athletes had a greater proportion of the ECG changes apart from 1st-degree AV-block which is more in male athletes. Some adaptive and abnormal ECG features seen in athletes mimic each other (e.g., LVH). However, the 'Seattle criteria'XYZhelped draw a clear-cut line to determine those features that are maladaptive and suggest risk factors of sudden cardiac death (SCD). Abnormal ECG features that might be pathological were ascertained using The Seattle Criteria. They include (from most prevalent to least): abnormal LVH, repolarization abnormality, left-axis-deviation (LAD), P-mitrale, ST-T elevation abnormality, etc.

In this study, ECG variables of athletes were sex-influenced and not necessarily age-influenced. This was indicative as there were significant correlations between age and some ECG parameters; QT-interval, heart rate, and QRS voltage in males but not females. Sex-associated differences in ECG parameters; QRS duration, QTc interval, QRS axis, and QRS voltages were found in a study by Wasfy et al. [38] However, our study found significant differences in adaptive ECG feature; with males presenting with more T-inversion (M=31.7% vs F=16.8%) and 1st degree AV block(M=11.1%, F=2.8%), compared to females; andfemales presenting with more of isolated QRS voltage [Criteria for LVH] (M=11.5% vs F=52.3%) and sinus bradycardia (M=14.3% vs F=41.1%) compared to males. Bessem et al. [39]however, found that more male athletes had sinus bradycardia (38.3% vs. 23.0%) and isolated QRS voltage criteria for LVH (26.3% vs. 4.6%) compared to female athletes. The mal-adaptive ECG features; left axis Deviation (M=0% vs F=9.3%), repolarization abnormality (M=1.6% vs F=8.4%), abnormal LVH (M=0% vs F=11.3%), and ST-T elevation abnormality (M=1.6% vs F=8.4%) were found in females. It should be noted that the study is cautious about drawing any conclusion because of the greater proportionof older (25-36 years) female athletes.

## Conclusion

The ECGs of elite Nigerian athletes demonstrate sex-related differences in PR interval, heart rate, QRS duration, and lead voltages, but not age differences. Correlations between ECG parameters and age were only indicative for males. Therefore, the study recommends that sex differences should be considered when using these characteristics in the screening of athletes so as not to introduce bias.

## Consent & Ethical Approval

This research was carried out in conformity with the Helsinki Declaration of 1975 as amended in 2000 [48] and institutional ethical approval (UPH/R&D/REC/0434) was obtained from the Research and Ethics Committee of the University of Port Harcourt. Informed consent was obtained from all participants. This research is non-invasive and the participants/subjects were not exposed to any harmful effects. The study's nature and objective were described to participants before enrolment. Subjects with identified abnormalities were advised and had referrals to the cardiology department of the University of Port-Harcourt Teaching Hospital for management. Participants were free to withdraw without any repercussions.

## Study Limitations

The study noted with concern the disproportionate distribution of athletes (more females) and the observed higher proportion of maladaptive features in females. This restricts the assertiveness of the study; thus, it a great limitation.

## References

1. Paterick TE, Gordon T, Spiegel D. Echocardiography: profiling of the athlete’s heart. Journal of the American Society of Echocardiography. 2014 Sep 1;27(9):940-8.
2. Prior DL, La Gerche A. The athlete's heart. Heart. 2012 Jun 15;98(12):947-55.
3. Pluim BM, Zwinderman AH, van der Laarse A, van der Wall EE. The athlete’s heart: a meta-analysis of cardiac structure and function. Circulation. 2000 Jan 25;101(3):336-44.
4. Fagard R. Athlete’s heart. Heart. 2003 Dec 1;89(12):1455-61.
5. Fagard RH, Unit CR, Leuven KU. Impact of different sports and training on cardiac structure and function. Cardiology clinics. 1997 Aug 1;15(3):397-412.
6. Venckunas T, Raugaliene R, Mazutaitiene B, Ramoskeviciute S. Endurance rather than sprint running training increases left ventricular wall thickness in female athletes. European journal of applied physiology. 2008 Feb;102:307-11.
7. Urhausen A, Monz T, Kindermann W. Sports-specific adaptation of left ventricular muscle mass in athlete's heart. International journal of sports medicine. 1996 Nov;17(S 3):S145-51.

8. Rawlins J, Carré F, Kervio G, Papadakis M, Chandra N, Edwards C, Whyte GP, Sharma S. Ethnic differences in physiological cardiac adaptation to intense physical exercise in highly trained female athletes. Circulation. 2010 Mar 9;121(9):1078-85.
9. Banks L, Bentley RF, Currie KD, Vecchiarelli E, Aslam A, Connelly KA, Yan AT, Konieczny KM, Dorian P, Mak S, Sasson Z. Cardiac remodeling in middle-aged endurance athletes and recreationally active individuals: challenges in defining the “Athlete's Heart”. Journal of the American Society of Echocardiography. 2020 Feb 1;33(2):247-9.
10. Oxborough D, Sharma S, Shave R, Whyte G, Birch K, Artis N, Batterham AM, George K. The right ventricle of the endurance athlete: the relationship between morphology and deformation. Journal of the American Society of Echocardiography. 2012 Mar 1;25(3):263-71.
11. Wasfy MM, Weiner RB, Wang F, Berkstresser B, Lewis GD, DeLuca JR, Hutter AM, Picard MH, Baggish AL. Endurance exercise-induced cardiac remodeling: not all sports are created equal. Journal of the American Society of Echocardiography. 2015 Dec 1;28(12):1434-40.
12. Haddad F, Peter S, Hulme O, Liang D, Schnittger I, Puryear J, Gomari FA, Finocchiaro G, Myers J, Froelicher V, Garza D. Race differences in ventricular remodeling and function among college football players. The American journal of cardiology. 2013 Jul 1;112(1):128-34.
13. Paterick TE, Gordon T, Spiegel D. Echocardiography: profiling of the athlete’s heart. Journal of the American Society of Echocardiography. 2014 Sep 1;27(9):940-8.
14. Arstila M, Koivikko A. Electrocardiographic and vector cardiographic signs of left and right ventricular hypertrophy in endurance athletes. The Journal of Sports Medicine and Physical Fitness. 1966 Sep 1;6(3):166-75.
15. Chignon JC, Distel R, Arnaud P. Morphologic variations of horizontal vectorcardiograms in athletes. Journal de physiologie. 1967;59(4 Suppl):375.
16. Van Ganse W, Versee L, Eylenbosch W, Vuylsteek K. The electrocardiogram of athletes Comparison with untrained subjects. Heart. 1970 Mar 1;32(2):160-4.
17. Erz G, Mangold S, Franzen E, Claussen CD, Niess AM, Burgstahler C, Kramer U. Correlation between ECG abnormalities and cardiac parameters in highly trained

asymptomatic male endurance athletes: evaluation using cardiac magnetic resonance imaging. The International Journal of Cardiovascular Imaging. 2013 Feb;29:325-34.

18. Hanne-Paparo N, Wendkos MH, Brunner D. T wave abnormalities in the electrocardiograms of top-ranking athletes without demonstrable organic heart disease. American Heart Journal. 1971 Jun 1;81(6):743-7.
19. Arstila M., A. K.-T. J. of sports medicine and physical, and undefined 1966, “Electrocardiographic and vector cardiographic signs of left and right ventricular hypertrophy in endurance athletes.,” *europepmc.org*, Accessed: Mar. 24, 2021. [Online]. Available: https://europepmc.org/article/med/4224096.
20. Baggish AL, Wood MJ. Athlete's heart and cardiovascular care of the athlete: scientific and clinical update. Circulation. 2011 Jun 14;123(23):2723-35.
21. Basavarajaiah S, Boraita A, Whyte G, Wilson M, Carby L, Shah A, Sharma S. Ethnic differences in left ventricular remodeling in highly-trained athletes: relevance to differentiating physiologic left ventricular hypertrophy from hypertrophic cardiomyopathy. Journal of the American College of Cardiology. 2008 Jun 10;51(23):2256-62.
22. Fagard RH. Athlete's heart: a meta-analysis of the echocardiographic experience. International journal of sports medicine. 1996 Nov;17(S 3):S140-4.
23. Mason JW, Ramseth DJ, Chanter DO, Moon TE, Goodman DB, Mendzelevski B. Electrocardiographic reference ranges derived from 79,743 ambulatory subjects. Journal of electrocardiology. 2007 May 1;40(3):228-34.
24. Ramirez AH, Schildcrout JS, Blakemore DL, Masys DR, Pulley JM, Basford MA, Roden DM, Denny JC. Modulators of normal electrocardiographic intervals identified in a large electronic medical record. Heart Rhythm. 2011 Feb 1;8(2):271-7.
25. Zaidi A, Sharma S. The athlete's heart. British Journal of Hospital Medicine. 2011 May;72(5):275-81.
26. Pelliccia A, Maron BJ, Culasso F, Spataro A, Caselli G. Athlete's heart in women: echocardiographic characterization of highly trained elite female athletes. Jama. 1996 Jul 17;276(3):211-5.

27. Churchill TW, Petek BJ, Wasfy MM, Guseh JS, Weiner RB, Singh TK, Schmied C, O'Malley H, Chiampas G, Baggish AL. Cardiac structure and function in elite female and male soccer players. JAMA Cardiology. 2021 Mar 1;6(3):316-25.
28. Krysztofiak H, Młyńczak M, Małek ŁA, Folga A, Braksator W. Left ventricular mass normalization in child and adolescent athletes must account for sex differences. Plos one. 2020 Jul 27;15(7):e0236632.
29. Makan J, Sharma S, Firoozi S, Whyte G, Jackson PG, McKenna WJ. Physiological upper limits of ventricular cavity size in highly trained adolescent athletes. British journal of sports medicine. 2005 Aug 1;39(8):531-.
30. Sharma S, Maron BJ, Whyte G, Firoozi S, Elliott PM, McKenna WJ. Physiologic limits of left ventricular hypertrophy in elite junior athletes: relevance to the differential diagnosis of athlete's heart and hypertrophic cardiomyopathy. Journal of the American College of Cardiology. 2002 Oct 16;40(8):1431-6.
31. Wasfy MM, Weiner RB, Wang F, Berkstresser B, Lewis GD, DeLuca JR, Hutter AM, Picard MH, Baggish AL. Endurance exercise-induced cardiac remodeling: not all sports are created equal. Journal of the American Society of Echocardiography. 2015 Dec 1;28(12):1434-40.
32. Weiner RB, DeLuca JR, Wang F, Lin J, Wasfy MM, Berkstresser B, Stoehr E, Shave R, Lewis GD, Hutter Jr AM, Picard MH. Exercise-induced left ventricular remodeling among competitive athletes: a phasic phenomenon. Circulation: Cardiovascular Imaging. 2015 Dec;8(12):e003651.
33. Pelliccia A. Differences in Cardiac Remodeling Associated With Race: Implications for Pre-Participation Screening and the Unfavorable Situation of Black Athletes. Journal of the American College of Cardiology. 2008 Jun 10;51(23):2263-5.
34. Basavarajaiah S, Boraita A, Whyte G, Wilson M, Carby L, Shah A, Sharma S. Ethnic differences in left ventricular remodeling in highly-trained athletes: relevance to differentiating physiologic left ventricular hypertrophy from hypertrophic cardiomyopathy. Journal of the American College of Cardiology. 2008 Jun 10;51(23):2256-62.

35. Rawlins J, Carré F, Kervio G, Papadakis M, Chandra N, Edwards C, Whyte GP, Sharma S. Ethnic differences in physiological cardiac adaptation to intense physical exercise in highly trained female athletes. Circulation. 2010 Mar 9;121(9):1078-85.
36. Sheikh N, Papadakis M, Carre F, Kervio G, Panoulas VF, Ghani S, Zaidi A, Gati S, Rawlins J, Wilson MG, Sharma S. Cardiac adaptation to exercise in adolescent athletes of African ethnicity: an emergent elite athletic population. British journal of sports medicine. 2013 Jun 1;47(9):585-92.
37. Sedehi D, Ashley EA. Defining the limits of athlete's heart: implications for screening in diverse populations. Circulation. 2010 Mar 9;121(9):1066-8.
38. Wasfy MM, DeLuca J, Wang F, Berkstresser B, Ackerman KE, Eisman A, Lewis GD, Hutter AM, Weiner RB, Baggish AL. ECG findings in competitive rowers: normative data and the prevalence of abnormalities using contemporary screening recommendations. British journal of sports medicine. 2015 Feb 1;49(3):200-6.
39. Bessem B, de Bruijn MC, Nieuwland W. Gender differences in the electrocardiogram screening of athletes. Journal of science and medicine in sport. 2017 Feb 1;20(2):213-7.
40. Wilhelm M, Seiler C. The athlete's heart: different training responses, gender and ethnicity dependencies. Cardiovascular medicine. 2012;15(3):69-78.
41. Pelliccia A, Adami PE, Quattrini F, Squeo MR, Caselli S, Verdile L, Maestrini V, Di Paolo F, Pisicchio C, Ciardo R, Spataro A. Are Olympic athletes free from cardiovascular diseases? Systematic investigation in 2352 participants from Athens 2004 to Sochi 2014. British journal of sports medicine. 2017 Feb 1;51(4):238-43.
42. Ramakrishnan S, Bhatt K, Dubey AK, Roy A, Singh S, Naik N, Seth S, Bhargava B. Acute electrocardiographic changes during smoking: an observational study. BMJ open. 2013 Jan 1;3(4):e002486.
43. Al-Khelaifi F, Diboun I, Donati F, Botrè F, Alsayrafi M, Georgakopoulos C, Suhre K, Yousri NA, Elrayess MA. A pilot study comparing the metabolic profiles of elite-level athletes from different sporting disciplines. Sports medicine-open. 2018 Dec;4:1-5.
44. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, Jones DW, Kurtz T, Sheps SG, Roccella EJ. Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the

American Heart Association Council on High Blood Pressure Research. Circulation. 2005 Feb 8;111(5):697-716.

45. ACCOSON, "Duplex Hand Model Aneroid | Accoson." https://www.accoson.com/products/duplex-hand-model-aneroid/ (accessed Mar. 25, 2021).
46. Kligfield P, Gettes LS, Bailey JJ, Childers R, Deal BJ, Hancock EW, Van Herpen G, Kors JA, Macfarlane P, Mirvis DM, Pahlm O. 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 endorsed by the International Society for Computerized Electrocardiology. Circulation. 2007 Mar 13;115(10):1306-24.
47. Bohm P, Scharhag J, Egger F, Tischer KH, Niederseer D, Schmied C, Meyer T. Sports-related sudden cardiac arrest in Germany. Canadian journal of cardiology. 2021 Jan 1;37(1):105-12.
48. Rimbert S, Lindig-León C, Bougrain L. Profiling BCI users based on contralateral activity to improve kinesthetic motor imagery detection. In2017 8th International IEEE/EMBS Conference on Neural Engineering (NER) 2017 May 25 (pp. 436-439). IEEE.