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Original Article

Pattern of electrocardiographic and echocardiographic findings amongst Nigeria national football team players.

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Abstract

Background: Cardiac adaptations in athletes, particularly football players, often result in distinct electrocardiographic (ECG) and echocardiographic changes. This study evaluates these cardiac patterns in Nigerian national football players compared to matched non-athlete controls.

Methodology: A case-control study was conducted from January 2022 to December 2023 during pre-participation screenings of national football teams: Super Eagles, Flying Eagles, Golden Eaglets, Super Falcons, and Falconets. Seventy-eight athletes (aged 18–32) were compared with 42 age- and sex-matched controls drawn from team officials and supporters. Inclusion criteria required active participation in professional football for athletes and absence of known cardiac disease for controls. All participants underwent detailed history, physical examination, resting ECG, and 2D echocardiography. ECGs were assessed for features suggestive of athlete's heart or hypertrophic cardiomyopathy. Echocardiograms were performed with a Hewlett-Packard Sonos 2500 using a 3.5 MHz probe to measure ventricular dimensions, wall thickness, and function.

Results: Footballers demonstrated significant cardiac adaptations. ECGs showed lower mean heart rates, longer PR intervals, and a higher prevalence of sinus bradycardia and incomplete right bundle branch block. Additionally, footballers had higher R/S wave voltages and more frequent ST-segment elevations. Echocardiographic findings revealed larger left ventricular end-diastolic and end-systolic dimensions, as well as increased interventricular septal and posterior wall thickness, consistent with physiological, not pathological, hypertrophy.

Conclusion: Nigerian national football players exhibit characteristic ECG and echocardiographic patterns reflecting physiological cardiac remodeling due to intensive training. Differentiating these benign adaptations from pathological findings is essential for accurate cardiovascular assessment and safe sports participation.

Keywords: Electrocardiography; Echocardiography; Athlete's Heart; Hypertrophic Cardiomyopathy; Nigerian National Football Team.

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Quick Response Code:

Introduction

Nigeria's national football team players are elite athletes. Thus, they are professional sportsmen and women who engage in daily exercise routines that could be associated with physiological remodelling of the heart [1]. These changes could be monitored using electrocardiography (ECG) and electrocardiography among elite athletes [2].

Previous ECG studies have linked the changes with race; suggesting that elite athletes of African origin have a significant prevalence of T wave inversion, ST-segment elevation, and flat T wave [3,4]. Although most of these abnormal findings result from systemic physiological adaptations, some are pathological, stemming from cardiomyopathies or ion channel disorders that may increase the risk of exercise-related sudden cardiac death [5]. A few instances of exercise-related sudden cardiac death have been reported among Nigerian footballers, notably that of the Nigerian football legend Samuel Okwaraji, who died on the pitch on the 12th of August 1989, while playing for the Nigerian National Team in a World Cup Qualifier against Angola [7]. Clinically, ECG findings are not sufficient in drawing a logical conclusion to cardiovascular morbidity among trained athletes. Further assessment of cardiac morphology and function using electrocardiography is of critical importance [5]. Echocardiographic evaluation has revealed that elite athletes may have up to a 10% increase in left ventricular end-diastolic dimension (LVEDD), a 15 to 20% increase in LV wall thickness, and a 45% increase in computed LV mass, as compared with age-matched controls [8]. However, it is important to appreciate that the physiological cardiac remodelling seen in athletes is dynamic, implying that it may manifest a few weeks or months after beginning a rigorous exercise regimen but may reverse itself in a similar duration of time after stopping the exercise [9]. Additionally, the pattern of cardiac remodelling may vary depending on the sporting activity and its intensity [10].

Although a few studies have shown a high prevalence of ethnic differences in physiological cardiovascular adaptations and early warning signs of potentially fatal heart diseases among black athletes, more data is needed, to encourage the Nigeria Football Federation to prioritize regular cardiovascular screening for its elite footballers.

This study aims to evaluate the pattern of electrocardiographic (ECG) and echocardiographic (ECHO) findings among Nigerian national football team players, distinguishing between physiological adaptations and potential pathological abnormalities. Specifically, it seeks to assess ECG and ECHO parameters, compare findings with established international athlete screening criteria, investigate associations with player demographics, training intensity, and provide insights to enhance cardiovascular screening protocols and preventive strategies for sudden cardiac events in elite Nigerian athletes.

Methodology:

This was a case-control study carried out between January 2022 and February 2023 during the routine procedures of pre-participation screening camps of the various Nigerian national football teams, usually organized before major local and international tournaments. Seventy-eight footballers from the various national football teams (Super Eagles, Flying Eagles and Golden Eaglets, Super Falcons, and Falconets) were compared with 42 control subjects matched for age and sex, from amongst officials and supporter groups. The footballers were selected consecutively as they arrived at the camp. The controls were selected from amongst Nigeria Football Federation, Ministry of Sports officials, and Nigeria Football Supporters Club members.

All enrolled elite athletes and control subjects were 18 years and above and confirmed members of one of the national football teams, supporters club members, or officials. Footballers and control subjects with hypertension confirmed cardiomyopathy, and bundle branch pattern on ECG were excluded.

All study participants had cardiac evaluation including a thorough history and physical examination, an ECG, and 2-dimensional electrocardiography, at recruitment.

Each subject gave written informed consent to participate in the study. Ethical approval (FCTA/HHSS/REC/PR/23/102) for the project was obtained from the Research and Ethics Committee of the Federal Capital Territory (FCT) Health Services Management Board (Maitama District Hospital), Abuja.

The minimum sample size for the patients and controls was estimated using the formula below:

$$n = \frac{Z^2(0.0537(1-0.537)}{D^2}$$

Wheren is the sample size, z^2 = Standard normal deviation at 95% confidence interval = 1. 960.P = Prevalence of athletes amongst athletes from a previous study [11, 12], and d is precision=5%= 0.05

Electrocardiography

All study subjects had ECG done on them at recruitment. All ECG recordings were made using a commercially available cardiofax v (ECG 1550k) ECG machine by Nihon kohden corporation with a calibration of 25mm/sec (paper speed) and l mV/cm(gain). The subjects were placed in the position while breathing quietly, and standard 12-lead ECGs were taken and recorded at a speed of 25 mm/s. ECGs were done a few minutes before the echocardiographic examination and 24 hours after the previous physical exercise. ECGs were analysed by the investigators without being aware of the athlete's clinical past or echocardiographic results. All ECG patterns were assessed using accepted clinical standards for athlete's heart and hypertrophic cardiomyopathy [11, 12].

The following findings detected on any ECG tracing were deemed pathological: (i) pronounced left (30°) or right (110°) QRS axis deviation, (ii) Q waves 4 mm in depth and present in at least two leads, (iii) repolarization pattern with inverted T wave >2 mm in at least two leads, (iv) left bundle branch block, and (v) Wolff-Parkinson-White pattern [11, 12].

The following findings detected on the ECG were deemed to constitute the Athlete's heart: Increased PR interval length (>0.20 s), increase in R or S wave voltage (25 to 29 mm) in, Leads V1- V3, lead, early repolarisation pattern (ST elevation 2 mm in >2 leads), an incomplete right bundle branch block (RSR' pattern in V1 and V2 of <0.12 s in duration), and sinus bradycardia (heart rate<60 bpm)(11, 12).

Echocardiography

All study subjects had electrocardiography done. A Hewlett-Packard Sonos 2500 (mention other details: year and city of manufacture) with a 3.5 MHz transducer was used to conduct two-dimensional, M-mode, and Doppler echocardiographic examinations. The 2D-guided M-mode electrocardiography was used to determine the LVEDD and the thicknesses of the LV anterior and posterior free walls [13]. Additionally, ventricular septal thickness was measured using M-mode. The 2D images were used to confirm echocardiograms. Echocardiography was used to measure LV filling parameters(Mitral E/A Ratio, E/E^1)·Simpson's biplane method of discs was used, by tracing the endocardial border in the apical two- and four-chamber views at end-diastole and end-systole and the EF was calculated from the percentage of blood ejected from the LV during systole with a value of > 55% considered as normal [14]. Cardiac measurements were considered outside of normal ranges when they were >95% of the prediction limits calculated from populations with similar ages, heights, and body surface areas [14]. All participants that met the established echocardiographic criteria for either athlete's heart or hypertrophic cardiomyopathy were labelled appropriately.

Statistical Analysis

All statistical analyses were performed using SPSS (version 27.0 IBM Corp, Armonk, NY). A p-value of < 0.05 was considered statistically significant for all tests. Descriptive statistics were expressed in terms of frequency and percentage. The data for the study were first subjected to a thorough descriptive statistical analysis. Continuous variables, such as age, heart rate, left ventricular ejection fraction (LVEF), and chamber dimensions, were summarized using mean and standard deviation (SD) for normally distributed data, while median and interquartile range (IQR) were used for skewed data. Categorical variables, including the presence of arrhythmias, valvular abnormalities, and other structural heart diseases, were summarized as frequencies and percentages. For the continuous variables that follow a normal distribution, comparisons between different groups (e.g., based on position, age categories, or playing experience) were performed using the independent t-test for two groups and one-way ANOVA for more than two groups. Homogeneity of variances was assessed using Levene's test, and post hoc comparisons for ANOVA were conducted using Tukey's HSD test to identify specific group differences. Where the data were skewed, non-parametric tests were employed. The Mann-Whitney U test was used for comparisons between the two groups. Multiple regression analysis was used to further investigate the factors influencing electrocardiographic and echocardiographic findings with dependent variables being key outcomes such as LVEF, left ventricular mass, and the presence of arrhythmias. Logistic regression analysis was also performed for binary outcomes such as the presence or absence of arrhythmias. The logistic regression model estimates the probability of the occurrence of an event (e.g., arrhythmia) based on the independent variables.

Results:

The demographic and clinical characteristics of the study participants are presented in Table 1. Footballers were significantly younger than control subjects ($p = 0.028$) and had greater height ($p = 0.014$) but lower weight ($p = 0.001$) and BMI ($p = 0.001$). The body surface area (BSA) was slightly higher in footballers compared to controls ($p = 0.009$).

Footballers exhibited significantly lower blood pressure values, including systolic blood pressure (SBP: $p = 0.001$), diastolic blood pressure (DBP: $p = 0.001$), and mean arterial pressure (MAP: $p = 0.001$). Similarly, their pulse rate was significantly lower than that of controls ($p = 0.003$).

Anthropometric differences were also observed, with footballers having a significantly smaller waist circumference ($p = 0.005$) and lower waist-to-hip ratio ($p = 0.024$), despite a modest difference in hip circumference ($p = 0.005$). The sex distribution was comparable between groups, with no significant differences in male and female representation.

Table 1: Demographic and clinical characteristics of footballers and control subjects

Parameter	Footballers N=78 Mean (SD)	Control Subjects N=42 Mean (SD)	P value
Age (years)	25.5 (4.7)	26.9 (5.2)	0.028
Height (m)	1.64 (0.08)	1.61 (0.08)	0.014
Weight (kg)	64.8(16.3)	75.9 (11.1)	0.001
BMI (kg/m²)	28.0 (6.3)	32.7 (5.9)	0.001
BSA(m²)	1.85 (0.11)	1.8 (0.12)	0.009
SBP (mmHg)	103 (10.5)	110.4 (9.8)	0.001
DBP (mmHg)	68.3(5.2)	77.8(4.6)	0.001
MAP (mmHg)	89(12.6)	94(8.3)	0.001
Pulse rate(b/min)	68.9(12)	76.8(11.4)	0.003
Waist circumference(cm)	83.77(10.81)	91.2(11.95)	0.005
Hip circumference(cm)	100.92(11.83)	102.6(10.97)	0.005
Waist/hip ratio	0.93(0.10)	0.98(0.12)	0.024
Male	48(62.2%)	26(63.8%)	
Females	30(37.8%)	16(36.2%)	

Key: BMI =body mass index, BSA = body surface area, SBP = systolic blood pressure, DBP = diastolic blood pressure, SD = standard deviation.

Echocardiographic findings (Table 2) revealed significant differences in cardiac structure between footballers and controls. Footballers exhibited larger left ventricular (LV) end-diastolic dimensions (51.0 ± 3.6 mm vs. 47.9 ± 2.6 mm, p = 0.005) and LV end-systolic dimensions (32.7 ± 3.5 mm vs. 27.1 ± 3.3 mm, p = 0.001), with normalization for body surface area still showing significant differences.

Ventricular septal thickness and posterior free wall thickness were both greater in footballers compared to controls (p = 0.001 for both). Relative wall thickness (h/r ratio) was significantly higher in footballers (p = 0.001), whereas the aortic root dimensions were similar between groups. Left atrial size was significantly larger in footballers (35.5 ± 4.5 mm vs. 32.3 ± 2.9 mm, $p = 0.001$), as was LV mass indexed to BSA ($p = 0.001$). However, the left ventricular ejection fraction (LVEF) did not differ significantly between groups.

Table 2: Echocardiographic parameters in footballers and control subjects

Parameters	Footballers (n = 78)	Control S. (n = 42)	P Value
LV end-diastolic dimensions (mm)	51.0 ± 3.6 (42–62)	47.9 ± 2.6 (38–56)	0.005
Normalized LV end-diastolic dimensions (mm/m^2)	28.3 ± 2.3 (24–39)	28.0 ± 1.6 (24–33)	0.005
LV end-systolic dimensions (mm)	32.7 ± 3.5 (22–42)	27.1 ± 3.3 (26–40)	0.001
Normalized LV end-systolic dimensions (mm/m^2)	17.1 ± 2.2 (13–26)	14.9 ± 1.8 (14–23)	0.003
Ventricular septum (mm)	9.7 ± 1.3 (6–13)	9.2 ± 1.0 (7–12)	0.001
Normalized ventricular septum (mm/m^2)	5.4 ± 0.8 (3.2–7.0)	5.0 ± 0.5 (3.4–6.1)	0.001
Posterior free wall (mm)	9.6 ± 1.4 (6–13)	9.0 ± 0.8 (7–11)	0.001
Normalized posterior free wall (mm/m^2)	5.3 ± 0.8 (4.0–7.4)	4.8 ± 0.5 (3.4–6.0)	0.001
h/r ratio	0.38 ± 0.05 (0.24–0.56)	0.35 ± 0.03 (0.25–0.44)	0.001
Aortic root (mm)	30.0 ± 3.9 (25–38)	29.2 ± 2.6 (24–37)	NS
Left atrium (mm)	35.5 ± 4.5 (30–44)	32.3 ± 2.9 (28–39)	0.001
LV mass/BSA (g/m^2)	101.4 ± 18.7 (60–181)	92.4 ± 13.2 (65–122)	0.001
LVEF (%)	65 ± 6 (50–78)	64 ± 5 (55–72)	NS
E wave (cm/s)	77.2 ± 13.2 (44–120)	90.1 ± 16.5 (55–132)	0.001
A wave (cm/s)	40.3 ± 9.3 (20–70)	43.1 ± .6 (30–67)	0.03
E/A ratio	2.0 ± 0.6 (1.1–4.5)	2.1 ± 0.5 (1.2–3.3)	NS

Electrocardiographic Patterns of Cardiac Remodeling

Cardiac remodeling patterns assessed using electrocardiography (Table 3) revealed notable differences between groups. While the majority of participants in both groups had normal LV geometry, the prevalence was slightly lower among footballers (72% vs. 82.7%, $p = 0.054$). Footballers exhibited significantly higher rates of concentric remodeling (13.3% vs. 10.7%, $p = 0.001$), eccentric hypertrophy (10.7% vs. 4%, $p = 0.005$), and concentric hypertrophy (4% vs. 2.7%, $p = 0.001$) compared to controls.

Table 3: Electrocardiographic pattern of cardiac remodeling among footballers and control subjects

LV geometry	No. of footballers	%	No. of Controls	%	P value
Normal	56	(72)	32	(82.7)	0.054
Concentric remodeling	11	(13.3)	5	(10.7)	0.001
Eccentric hypertrophy	8	(10.7)	3	(4)	0.005
Concentric hypertrophy	3	(4)	2	(2.7)	0.001

Electrocardiographic differences between groups are summarized in (Table 4). Footballers had a lower resting heart rate than controls (58 ± 9 bpm vs. 62 ± 9 bpm), though this difference was not statistically significant (p = 1.02). PR interval was significantly longer in footballers (p = 0.001), while QRS complex duration was shorter (p = 0.001). R/S-wave voltages (S1 + R5) were significantly higher in footballers than in controls (p = 0.01), indicative of greater electrical activity in the left ventricle.

Footballers had a significantly higher prevalence of sinus bradycardia (p = 0.001), first-degree atrioventricular (AV) block (p = 0.003), and incomplete right bundle branch block (RBBB) (p = 0.001). Markers of left ventricular hypertrophy (LVH), including the Sokolow-Lyon criteria (p = 0.001), were also significantly more prevalent in footballers. Similarly, ST-segment elevation was more frequently observed among footballers (p = 0.001). While left atrial enlargement did not differ significantly between groups, footballers exhibited a significantly higher prevalence of Q waves (p = 0.003), inverted T waves (p = 0.005), and flat/biphasic T waves (p = 0.008). However, no significant differences were observed in the corrected QT (QTc) interval or J waves.

Table 4: Electrocardiographic Parameters in Footballers and Controls

Parameters	footballers (n = 78)	Control S (n = 42)	p Value
Heart rate (beats/min)	58 ± 9 (41–75)	62 ± 9 (53–81)	1.02
PR interval (ms)	169 ± 32 (110–292)	149 ± 22 (114–214)	0.001
QRS complex duration (ms)	90.2 ± 6.9 (74–112)	99.5 ± 9.3 (84–122)	0.001
R/S-wave voltages (S_1+R_5) (mm)	48.6 ± 12.1 (19-94)	34.1 ± 8.9 (13–63)	0.01
QTc interval (s)	0.39 ± 0.02 (0.34–0.47)	0.39 ± 0.05 (0.35–0.44)	0.054
Sinus bradycardia (heart rate <60 beats/min)	61%	40%	0.001
First-degree AV block (PR interval >0.20 s)	14%	3%	0.003
Incomplete RBBB (QRS > 0.10 <0.12 s)	32%	19%	0.001
LA enlargement	9%	3%	0.084
Q waves (≥ 2mm in ≥2 leads)	7%	2.6%	0.003
Sokolow-Lyon criteria for LVH	89%	42%	0.001

ST-segment elevation (≥1 mm in ≥2 leads)	91%	56%	0.001
J waves and/or slurring on ST-segment elevation	18%	13%	0.10
Inverted T waves (≥2 mm in ≥2 leads)	14%	3%	0.005
Flat/biphasic T waves (in ≥2 leads)	25%	8%	0.008

Discussion

This case-control study examined the pattern of athletic heart amongst Nigerian elite male and female footballers using electrocardiography and electrocardiography. Footballers in this study exhibited significantly lower weight, BMI, and waist-to-hip ratio compared to control subjects, findings that align with previous reports highlighting the leaner body composition of endurance-trained athletes [16,18]. The lower BMI and waist circumference observed among footballers suggest an overall favorable metabolic profile, which is known to reduce cardiovascular risk in the long term. These anthropometric differences are likely attributable to the high-energy expenditure and metabolic demands of football training.

Additionally, resting systolic and diastolic blood pressures, as well as mean arterial pressure, were significantly lower among footballers than controls. This hemodynamic adaptation is well-documented in trained athletes and is attributed to enhanced parasympathetic tone, improved vascular compliance, and reduced systemic vascular resistance [22]. The lower resting heart rate observed in footballers, albeit not statistically significant, further supports the presence of exercise-induced bradycardia, a hallmark of autonomic adaptation to endurance training.

Echocardiographic assessment of study subjects, particularly footballers and control subjects, provides valuable insights into the structural adaptations of the heart in response to athletic training. The footballers exhibited mildly larger LV cavity dimensions, both in diastole and systole, compared to control subjects. This finding aligns with the expected physiological adaptation known as the athlete's heart [23], where regular exercise induces enlargement of the cardiac chambers to accommodate increased stroke volume [24]. Notably, a substantial subset of footballers, comprising 16% of males and 17% of females, presented with increased LV cavity dimensions (diastolic diameter, >55 mm). Furthermore, none of the control subjects had LV cavities that exceeded these dimensions [23, 24]. The observation that only footballers had LV cavities >60 mm underscores the importance of cardiac remodeling associated with intensive athletic training. Similarly, the increased LV mass index(LVH) was present in 20% of footballers. These findings reflect the well-known phenomenon of eccentric hypertrophy seen in athletes. The significantly greater ventricular septal thickness and posterior free wall thickness in footballers further support the presence of physiological hypertrophy. These findings are indicative of balanced myocardial growth, differentiating physiological remodeling from pathological hypertrophy seen in hypertensive heart disease. Importantly, the preserved left ventricular ejection fraction (LVEF) in both groups confirms that these structural adaptations do not impair systolic function, reinforcing their physiological nature.

Left atrial enlargement observed in footballers is another notable finding. This adaptation is likely due to the chronic volume load imposed by endurance training, leading to increased atrial compliance. While left atrial enlargement is often associated with atrial fibrillation in non-athlete populations, previous studies suggest that in trained athletes, it does not necessarily predict pathological arrhythmias [23]. Despite these changes, the LV ejection fraction did not differ between footballers and control subjects and was consistently >50% in all subjects. Maintenance of a normal ejection fraction indicates preserved systolic function in footballers despite cardiac remodeling [23, 24]. None of the footballers showed evidence of structural heart diseases such as hypertrophic cardiomyopathy (HCM), dilated cardiomyopathy, or arrhythmogenic right ventricular cardiomyopathy based on morphological or clinical assessments. This is a reassuring finding as it confirms that the observed cardiac adaptations in footballers are within the physiological range and are not indicative of pathological conditions [1, 21]. The absence of segmental wall motion abnormalities on visual assessment further supports the notion that the observed structural changes are consistent with an adaptive response to athletic training, rather than pathological dysfunction [23]. Our findings showed a significantly higher prevalence of concentric cardiac remodelling and eccentric hypertrophy among footballers than among control subjects. These findings indicate that the cardiac structure of footballers may undergo adaptations due to the physical demands of the sport [25]. However, it's essential to note that further research may be necessary to understand the clinical implications of these differences and whether they represent benign adaptations or potential health risks for football players.

Limitations

This study has several limitations ranging from design precluding the establishment of causation or the determination of long-term effects. The small sample size may limit the generalizability of the findings to broader populations, and the lack of information on specific training regimens or positions played by footballers hinders a more detailed analysis of the potential influencing factors. Additionally, factors such as lifestyles and genetic predispositions limit a comprehensive understanding of the observed variations in demographic characteristics, ECG patterns, and echocardiographic parameters. Future research with larger, more diverse samples and a longitudinal approach may address these limitations and provide a better understanding of cardiac adaptations in footballers.

Conclusion:

In conclusion, this study provides a comprehensive examination of ECG patterns and echocardiographic parameters in footballers compared with control subjects. These findings suggest that footballers exhibit unique cardiac adaptations, including electrical and structural changes, that are consistent with the athlete's heart. Although these adaptations are generally benign and indicative of a healthy response to training, careful monitoring and individualized assessments are essential to distinguish physiological changes from potentially pathological conditions.

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