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Electrocardiographic Findings in Apparently Healthy Adolescents in the Niger Delta Region of Nigeria, West Africa

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Authors' contributions

This work was carried out in collaboration between all authors. Author PNT designed the study, wrote the protocol, managed the analysis of the study and wrote the first draft of the manuscript. Author OD performed the statistical analysis and literature searches. Author BEO managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Background: Electrocardiography (ECG) is an inexpensive, quick, non-invasive, widely available and reliable screening tool in the assessment of the electrical activity of the heart, and is vital in the detection of potentially lethal sub-clinical structural or electrophysiological cardiovascular abnormalities. ECG pattern in children have been established in some regions in Nigeria but is however lacking in the Niger-Delta region of Southern Nigeria.

Objective: To determine the ECG pattern of apparently healthy adolescents in the Niger-Delta Region of Southern Nigeria.

Materials and Methods: A cross-sectional study was carried out on 1002 secondary school subjects, aged 10-19 years. The ECG recording was performed using a standard 12 lead, portable digital electrocardiograph.

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Results: There were 595 (59.4%) males and 407 (40.6%) females with a male to female ratio of 1.5:1. The study population had a mean ECG heart rate of 82bpm, PR interval of 0.15 sec, P wave duration of 0.08 sec, QRS duration of 0.08 sec, QTc interval of 0.42 sec, and QRS axis of 58°. The mean heart rate and QTc interval were significantly higher in the females, while the QRS duration was significantly higher in the males. The P wave amplitude in lead II was 1.3 mm, R wave amplitude in V1 and V6 were 4.06 mm and 10.68 mm respectively. The S wave amplitude in V1 and V6 were 11.44 mm and 0.56 mm respectively.

Conclusion: ECG pattern of adolescents in the Niger-Delta region of Southern Nigeria is now established; but shows some differences from the studies in other parts of Nigeria and the world.

Keywords: Electrocardiogram; adolescents; Niger-Delta Region; Southern Nigeria.

1. INTRODUCTION

Awareness of Cardiovascular diseases (CVD) in children in Sub-Saharan Africa has been on the increase in recent times because they have emerged along with other non-communicable diseases as major health and socioeconomic malady [1]. Cardiovascular abnormalities such primary arrhythmia syndromes, cardiomyopathies and inherited dyslipidemia account for approximately 70% of incidences of sudden death globally and are on the increase [2]. CVD also occur in some diseases known to occur commonly in Nigerian children, such as sickle cell anemia and malnutrition [3,4].

Although often asymptomatic [5], advances in non-invasive electrocardiographic (ECG) and echocardiographic techniques have made it possible to observe anatomic and physiologic evidence of CVD in children. Thus the early recognition and prompt treatment of these potentially life threatening cardiovascular diseases in children is imperative to prevent sudden cardiac death [6].

Worldwide, strategies for prevention of CVD and sudden cardiac death include electrocardiographic screening of general population, risk profiling and interventions among patients with identified cardiac disease [7]. However, in Nigeria, there are limited measures in place to screen for, and reduce the burden of sudden cardiac death, especially in children.

Electrocardiography is an inexpensive, quick, non-invasive, widely available and reliable screening tool in the assessment of the electrical activity of the heart [8]. The standard 12-lead ECG helps to identify pathologic cardiac rhythms, conduction system abnormalities, myocardial ischemia/ infarction and hypertrophy of the heart [9]. In addition, it can also identify non-cardiac disorders that may have cardiac effects such as pulmonary infarction, electrolyte imbalance and drug related side effects and toxicity [9]. Ambulatory ECG monitoring on normal healthy infants and children of all ages has confirmed that regular sinus rhythm may be punctuated from time to time by a variety of rhythm changes which could potentially be regarded as abnormal [10,11].

The ECG recordings gives information on the heart physiologic function and structure based on the interpretation of the deflections and intervals.

P wave: The P wave represents atrial depolarization and is important for assessing right and left atrial size.

PR interval: The PR interval is a measure of the atrioventricular conduction time. It ranges from 0.12 to 0.20 seconds in Caucasian adolescents [12]. Prolongation of the PR interval suggests either atrial conduction delay or block within the AV node.

QRS complex: The QRS complex is reflective of ventricular mass and activity. Children have comparatively shorter QRS complex duration than adults, possibly because of decreased muscle mass. In a study by Rijinbeek et al. [13] the mean QRS duration in children aged 12 to 16 years was 90 ms.

QT interval: The QT interval represents the electrical depolarization and repolarization of the ventricles. It varies greatly with heart rate and is usually corrected (QTc), most commonly using Bazett's formula [14]: Studies by Rijnbeek et al. [13] and Mason et al. [15] showed an upper limit of normal for the QTc interval of approximately 0.45 sec in adolescents. Prolonged QTc interval, which occurs when QTc is > 0.45 sec in males and >0.46 in females, is of great concern because affected patients are predisposed to ventricular tachyarrhythmia (torsade de pointes) which results in syncope and sudden death [16].

ST segment: The normal ST segment is isoelectric starting from the end of the S-wave to the beginning of the T-wave. It represents the interval between ventricular depolarization and repolarization. An ST segment elevation of ≥ 2mm or depression of ≤ 2 mm in any lead is usually considered abnormal. Studies [17] have however shown that in some cases, ST segment elevation may be considered a normal variant. Early repolarization for example, characterized by marked constant elevation of the J point and ST segment elevation of 2-4 mm has been to shown to occur in normal male and female adolescents [17].

T wave: The T wave represents ventricular repolarization. It is of significant interest in adults, particularly in ischemic heart disease. In the paediatric population, its usefulness is seen more in reflecting electrolyte abnormalities (such as hyperkalemia and hypocalcaemia) and drug toxicities [18].

U wave: This is a positive flat deflection that may be seen after the T wave usually in leads V_5 and V_6. It is believed that the U wave represents repolarization of the Purkinje fibers and its absence in most cases has no significance [17].

Few studies on the ECG pattern of children in Nigeria exist in literature. Kolawole et al. [19] in Ilorin and Aliyu et al. [14] in Kano have studied ECG parameters in younger children (0 to 12 years) in Western and Northern Nigeria respectively, but similar studies in the Delta Region of Southern Nigeria are lacking. Davignon et al. [12] in Canada, and Rijnbeek et al. [13] in the Netherlands have studied ECG parameters of Caucasian adolescents and established ECG rates and values for their respective adolescent populations.

This study therefore set out to determine the ECG pattern in apparently healthy Nigerian adolescent children and determine the rates and values for the different ECG parameters; and make comparisons with those of Caucasians adolescents as studied by Davignon et al. [12] and Rinjebeek et al. [13].

Aim: To determine the electrocardiographic pattern of adolescents in secondary schools in Port Harcourt, Southern Nigeria.

2. METHODS

A multi-staged sample technique was used to select 1002 adolescents from 18 secondary schools distributed within the three school districts of Port Harcourt. Port Harcourt is the capital city of River State located in the oil-rich Niger Delta Region of Southern Nigeria, West Africa.

This study was carried out within one school term from April 2014 to July 2014. Ethical clearance for the study was obtained from the Ethical committee of the University of Port Harcourt Teaching Hospital (UPTH) and informed consent obtained from the students and their parents. Permission for the study was also obtained all principals of selected schools.

Students with known existing chronic illnesses including Sickle cell anaemia, Epilepsy, HIV infection, renal disorders, asthma and congenital or acquired heart disease were excluded from the study.

A structured investigator administered questionnaire was used to obtain information from recruited students on biodata, past medical history (suggestive of chronic illnesses), drug history (use of antiepileptic, antiretroviral, antiarrhythmic etc.) and family and social history. The review of the cardiovascular, respiratory, central nervous system, genito-urinary and haematologic systems was done.

Afterwards, the basal blood pressure, weight and height measurements were obtained and their ECG was recorded. The Body Mass Index (BMI) was calculated using the formula weight (kg)/height (m^2). The BMI of each adolescent was then plotted on the WHO percentile chart for age and sex. Any BMI below the 5^{th} percentile was regarded as underweight. BMI between the 5^{th} and less than the 85^{th} was regarded as normal, while BMI between the 85^{th} percentile to less than the 95^{th} percentile was regarded as overweight and BMI equal to or greater than the 95^{th} percentile was regarded as obese [20].

Each student had a standard 12-lead ECG recording using a portable digital electrocardiograph in the standard way based on the American Heart Association specifications [21].

Data was analyzed using Statistical Package for Social Sciences (SPSS) version 20.0 software.

The following were determined from the data;

1. Demographic pattern of the study population.

2. Weight, Height and BMI categories of study population
3. ECG parameter values derived from the horizontal axis (Mean Heart rate, P-wave duration, PR-interval, QRS duration, QRS axis and QT_c duration) according to age and sex.
4. ECG parameter values derived from vertical axis (Mean P-wave amplitude, QRS amplitude, T-wave amplitude, U-wave amplitude) according to age and sex.
5. Overall ECG pattern in the adolescents.
6. Comparison of ECG parameters in the study population with findings from Caucasian adolescent populations [12,13].

The student t- test and ANOVA were used for comparison of means, while chi square test was used for proportions. These data are presented as charts and tables. Statistical significance at 95% confidence interval was p-value <0.05.

3. RESULTS

3.1 Age and Sex Distribution of the Adolescents

The age and sex distribution of the study population is shown in Table 1. The mean age of the study population was 15 ± 2 years, with a male to female ratio of 1.5:1.

3.2 Weight Distribution of the Subjects by Age and Sex

The weight distribution of the student population is as shown in Table 2. The mean weight was 49.5 kg with a range of 19 and 98.9 kg.

3.3 Height Distribution of the Subjects by Age and Sex

The mean height of the students was 1.68 m (range-1.27 m to 1.93 m). This is illustrated in Table 3.

3.4 Body Mass Index of the Subjects

The BMI of the students ranged between 11 and 39 kg/m^2 with a mean of 19.51 kg/m^2. The overall mean BMI of the female subjects was significantly higher at 20.43 kg/m^2 compared to that of the males which was 18.89 kg/m^2 (p = 0.0001). This is illustrated in Table 4.

Fig. 1 illustrates the BMI categories of the study population. Eight hundred and forty-seven (84.5%) of the students had a normal BMI, 74 (7.4%) were underweight, 52 (5.2%) overweight and 29 (2.9%) were obese.

3.5 Electrocardiographic (ECG) Parameters of Study Population

3.5.1 ECG parameters derived from horizontal axis by age

Table 5 describes the mean heart rate, PR and QTc interval, P wave and QRS duration, and QRS axis of the study population. The mean heart rate decreased from 82 bpm in the 10 to 14 age group to 80 bpm in the students above 15 years of age. The difference was statistically significant (p = 0.005). There was a significant decrease in the QTc interval and QRS axis with increasing age.

Table 1. Age and sex distribution

Age group (years)	Sex		Total (%)
	Male (%)	Female (%)	
10-14	322 (54.1)	154 (37.8)	476 (47.5)
15-19	273 (45.9)	253 (62.2)	526 (52.5)
Total	595 (59.4)	407 (40.6)	1,002 (100)

Table 2. Weight (Kg) according to age and sex (mean, range)

Age groups	Weight (kg)				
	Sex		Total	T-test	P-value
	Male	Female			
10-14 years	42.2 (19-98.6)	46.4 (22.5-76.8)	43.56 (19-98.6)	-4.117	0.000
15-19 years	55.7 (33.5-87.4)	53.8 (36-98.9)	54.80 33.5-98.9)	2.365	0.018
Total	48.42 (19-98.6)	50.98 (22.5-98.9)	49.5 (19-98.9)	-0.876	0.009

Table 3. Height (m) according to age and sex (mean, range)

Age groups	Height (m)				
	Male	**Female**	**Total**	**T-test**	**P-value**
10-14 years	1.55 (1.27-1.85)	1.62 (1.30-1.70)	1.57 (1.27-1.85)	-1.959	0.051
15-19 years	1.78 (1.52-1.93)	1.79 (1.44-1.90)	1.78 (1.44-1.93)	-0.515	0.606
Total	1.65 (1.27-1.93)	1.72 (1.30-1.90)	1.68 (1.27-1.93)	-1.237	0.329

Table 4. Body mass index (Kg/m^2) according to age and sex (mean, range)

Age group	Body Mass Index (kg/m^2)				
	Sex		**Total**	**T-test**	**P-value**
	Male	**Female**			
10 – 14 years	17.9 (14.9-26.47)	19.4 (10.57-31.04)	18.40 (10.57-31.04)	-5.490	0.0001
15 – 19 years	19.88 (12.5-35.35)	21.42 (16.25-38.6)	20.62 (12.5-38.6)	-5.721	0.0001
Total	18.89 (12.5-35.35)	20.43 (10.57-38.6)	19.51 (10.57-38.6)	-5.606	0.0001

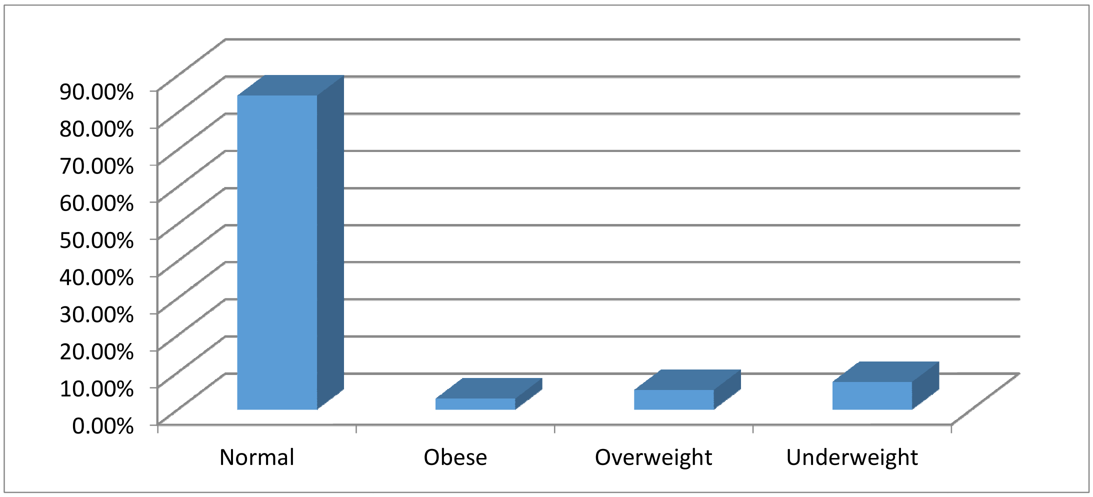

Fig. 1. Body mass index of students

Table 5. Electrocardiographic parameters derived from the horizontal axis by age (mean, range)

Variables	Age groups		T-test	P-value
	10-14 years	**15-19 years**		
Heart rate (bpm)	82 (50-142)	80 (45-132)	*2.738*	*0.005**
P-wave duration (seconds)	0.07 (0.04-0.16)	0.08 (0.06-0.12)	*-0.430*	*0.667*
PR interval (seconds)	0.15 (0.10-0.26)	0.16 (0.10-0.28)	*-1.865*	*0.062*
QRS duration (seconds)	0.08 (0.06-.10)	0.08 (0.06-0.09)	*-1.870*	*0.062*
QTc interval (seconds)	0.42 (0.35-0.50)	0.41 (0.33-0.49)	*5.292*	*0.000**
QRS axis (º)	59.18 (36-82)	57.0 (27-82)	*2.755*	*0.006**

**Statistically significant*

3.5.2 ECG parameters derived from horizontal axis by sex

Table 6 describes the sex distribution of the mean heart rate, PR and QTc interval, P wave and QRS duration, and QRS axis of the study population. The mean heart rate and QTc interval were significantly higher in the females. There was no difference in the P wave duration, PR interval and QRS duration between the males and females.

3.5.3 ECG parameters derived from the vertical axis

3.5.3.1 P wave amplitude

The P-wave amplitude according to age is illustrated in Table 7. There was no significant difference between the age groups.

The specific P-wave amplitude according to sex is shown in Table 8. There was no significant difference between the females and males.

3.5.3.2 Q wave amplitude

The mean Q wave amplitude was less in the older age group in most of the leads but the difference was not statistically significant. This is illustrated in Table 9.

Table 10 shows the Q wave amplitude was significantly higher in the males in lead V_5 (p=0.000).

3.5.3.3 R wave amplitude according to age group

R wave amplitude in leads V_1 and V_2 was significantly higher in the 10 to 14 years' age group while in leads V_5 and V_6, the R wave amplitude was significantly higher in the 15 to 19 years' age group. This is shown in Table 11.

Table 6. ECG parameters derived from the horizontal axis by sex (mean, range)

Variables	Sex		T-test	P-value
	Male	**Female**		
Heart rate (bpm)	78 (50-132)	86 (52-142)	*-8.380*	*0.000**
P wave duration (seconds)	0.08 (0.06-0.16)	0.08 (.04-0.12)	*0.151*	*0.880*
PR interval (seconds)	0.15 (0.12-0.22)	0.15 (0.10-0.28)	*0.733*	*0.464*
QRS duration (seconds)	0.08 (0.06-0.10)	0.08 (0.06-0.09)	*4.305*	*0.000*
QTc interval (seconds)	0.41 (0.35-0.49)	0.43 (0.36-0.50)	*-8.507*	*0.000**
QRS axis (º)	58.29 (34-82)	56.99 (26-77)	1.194	0.233

**Statistically significant*

Table 7. P wave amplitude (mm) according to age group (mean, range)

Leads	P- wave	Amplitude(mm)	T-test	P-value
	Age	**Groups**		
	10-14 years	**15-19 years**		
II	1.28 (0.1-3.0)	1.35 (0.2-3.0)	*-1.654*	*0.099*
V_1	0.70 (0.2-1.8)	0.74 (0.3-1.8)	*-1665*	*0.096*
V_2	0.60 (0.2-2)	0.56 (0.2-1.8)	*1.449*	*0.148*

Table 8. P wave amplitude (mm) according to sex (mean, range)

Leads	P wave	Amplitude (mm)	T-test	P-value
	Sex			
	Male	**Female**		
II	1.29 (0.1-3.0)F	1.36 (0.2-3.0)	*-1.582*	*0.114*
V_1	0.73 (0.2-1.8)	0.71 (0.4-1.5)	*1.017*	*0.310*
V_2	0.57 (0.2-2.0)	0.58 (0.3-1.8)	*-0.184*	*0.854*

Table 9. Q wave amplitude (mm) according to age group (mean, range)

Leads	Q wave	Amplitude (mm)	T-test	P-value
	Age	**Groups**		
	10-14 years	**15-19 years**		
AVF	0.19 (0.1-1.5)	0.14 (0.1-4.0)	*1.791*	*0.074*
I	0.24 (0.1-2.0)	0.27 (0.1-3.0)	*-1.177*	*0.239*
II	0.14 (0.1-2.5)	0.13 (0.1-4.0)	*0.605*	*0.545*
III	0.26 (0.1-2.5)	0.23 (0.1-4.0)	*0.945*	*0.345*
V_5	0.50 (0.1-3.5)	0.42 (0.1-4.0)	*1.569*	*0.117*
V_6	0.64 (0.1-3.5)	0.62 (0.1-4.0)	***0.105***	***0.916***

Table 10. Q wave amplitude (mm) according to sex (mean, range)

Leads	Q Wave Amplitude (mm) Sex		T-test	P-value
	Male	**Female**		
AVF	0.18 (0.1-4.0)	0.15 (0.1-2.0)	***0.847***	***0.397***
I	0.26 (0.1-3.0)	0.25 (0.1-2.0)	***0.310***	***0.757***
II	0.13 (0.1-4.0)	0.14 (0.1-2.5)	***-0.718***	***0.473***
III	0.24 (0.1-4.0)	0.25 (0.1-2.0)	***-0.181***	***0.857***
V_5	0.59 (0.1-4.0)	0.27 (0.1-2.4)	***6.803***	***0.000****
V_6	0.73 (0.1-4.0)	0.48 (0.1-3.0)	***1.504***	***0.133***

**Statistically significant*

Table 11. R wave amplitude (mm) according to age group (mean, range)

Leads	R wave Age	Amplitude (mm) Group	T-test	P-value
	10-14	**15-19**		
V_1	4.42 (2-21)	3.52 (1-18)	5.038	0.000*
V_2	8.15 (1-24)	6.77 (0.5-20)	5.070	0.000*
V_3	10.81 (8-20)	9.11 (4-26)	5.165	0.000*
V_4	16.21 (3-38)	13.86 (3-50)	5.129	0.000*
V_5	14.43 (1-40)	16.50 (4-46)	4.873	0.000*
V_6	10.30 (4-26)	11.37 (4-22)	2.786	0.005*
I	5.82 (1.5-18)	5.66 (1-11)	0.998	0.318
II	12.45 (2-26)	11.73 (2-22)	2.629	0.009*
III	7.55 (1-26)	6.94 (2-27)	2.296	0.022*
AVF	9.49 (3-24)	8.97 (3-28)	2.011	0.045*
AVL	1.75 (0.4-10)	1.72 (0.2-10)	0.281	0.779
AVR	0.46 (0.2-6)	0.49 (0.2-12)	-0.352	0.725

**Statistically significant*

Table 12. R wave amplitude (mm) according to sex (mean, range)

Leads	R wave Sex	Amplitude (mm)	T-test	P-value
	Male	**Female**		
V_1	4.50 (1-21)	3.13 (1-11)	7.767	0.000*
V_2	8.37 (1-24)	6.04 (1-24)	8.655	0.000*
V_3	11.22 (4-26)	7.99 (1-22)	9.977	0.000*
V_4	17.25 (3-50)	11.64 (3-32)	12.840	0.000*
V_5	17.44 (1-46)	12.44 (0.5-26)	13.307	0.000*
V_6	11.60 (4-26)	9.65 (4-24)	5.720	0.000*
I	5.69 (1-18)	5.80 (0.2-19)	-0.668	0.504
II	12.36 (2-26)	11.65 (0.2-22)	2.620	0.009*
III	7.70 (1-27)	6.53 (0.8-18)	4.357	0.000*
AVF	9.54 (3-28)	8.74 (2-20)	3.019	0.003*
AVL	1.74 (0.2-10)	1.73 (0.2-7.5)	0.040	0.968
AVR	0.56 (0.2-12)	0.35 (0.2-11)	2.172	0.030*

**Statistically significant*

3.5.3.4 R wave amplitude according to sex

Table 12 illustrates that the R wave amplitude was substantially higher in the male students than the females in almost all the leads. The differences were significant (p = 0.000 – 0.030).

3.5.3.5 S wave amplitude according to age group

S wave showed a similar but inverse pattern to the R wave amplitude. Table 13 shows that there was an increase in S wave amplitude in V_1 and

V_2 with increasing age and a concomitant decrease in leads V_5 and V_6. There was a significant difference in leads V_2 and V_3.

3.5.3.6 S wave amplitude according to sex

In all the leads (except AVR), the S wave amplitude was significantly higher in the male students than the females. This is shown in Table 14 (p=0.000).

R/S ratio:

In Table 15, the R/S ratio is shown for the precordial leads. It decreases with increasing age in leads V1 and V2 and increases with increasing age in leads V_5 and V_6.

3.6 Comparison of ECG Parameters in the Study Population with Those of Caucasian Adolescents

The mean values of the ECG parameters among students in the study population are comparable to the values obtained in similar ages by Davignon [14] in Quebec, Canada and Rijnbeek [16] in Rotterdam, Netherlands. There were some variations in the specific values of the Q wave, R wave and S wave amplitudes compared to those of the Caucasian adolescents. The mean R/S ratio in V_6 was comparatively higher in the study population. This is illustrated in Table 16.

Table 13. S wave amplitude (mm) according to age group (mean, range)

Leads	S-wave	Amplitude (mm)	T-test	P-value
	Age group			
	10-14 years	15-19 years		
V_1	11.49 (2-36)	11.84 (3-40)	1.000	0.317
V_2	14.01 (3-40)	15.30 (3-38)	2.884	0.004*
V_3	12.71 (0.1-30)	11.64 (0.2-40)	2.536	0.011*
V_4	7.40 (0.2-24)	7.18 (0.5-26)	0.708	0.479
V_5	2.72 (0.1-17)	2.48 (0.1-18)	1.378	0.169
V_6	0.63 (0.1-14)	0.57 (0.1-12)	0.735	0.463
I	0.64 (0.1-11)	0.50 (0.1-4)	2.270	0.023*
II	1.03 (0.1-14)	1.10 (0.1-11)	-0.697	0.486
III	1.07 (0.1-14)	1.22 (0.1-12)	-1.310	0.191
AVF	0.92 (0.1-4.5)	1.06 (0.1-10)	-1.398	0.162
AVL	2.29 (0.1-14)	2.00 (0.1-13)	1.991	0.047*
AVR	8.79 (3-16)	8.49 (3-20)	1.680	0.093

**Statistically significant*

Table 14. S wave amplitude (mm) according to sex (mean, range)

	S wave amplitude (mm)		T-test	P-value
Leads	Sex			
	Male	Female		
V_1	12.18 (3-40)	10.89 (2-30)	3.680	0.000*
V_2	16.17 (3-40)	12.35 (2-26)	8.701	0.000*
V_3	15.15 (0.1-40)	7.74 (0.1-24)	20.483	0.000*
V_4	8.78 (0.2-26)	5.10 (0.1-12)	12.514	0.000*
V_5	3.08 (0.1-18)	1.88 (0.1-17)	6.992	0.000*
V_6	0.74 (0.1-14)	0.39 (0.1-11)	4.160	0.000*
I	0.67 (0.1-14)	0.41 (0.1-11)	4.135	0.000*
II	1.32 (0.1-14)	0.69 (0.1-13)	5.921	0.000*
III	1.36 (0.1-14)	0.85 (0.1-7)	4.431	0.000*
AVF	1.22 (0.1-10)	0.67 (0.1-5.5)	5.736	0.000*
AVL	2.35 (0.1-14)	1.83 (0.1-12)	3.616	0.000*
AVR	8.72 (3-20)	8.50 (3-16)	1.198	0.231

**Statistically significant*

Table 15. R/S ratio in precordial leads

Leads	Age groups	
	10-14 years	**15-19 years**
V_1	0.38	0.28
V_2	0.58	0.44
V_3	0.85	0.78
V_4	2.19	1.93
V_5	5.31	6.65
V_6	16.35	19.95

4. DISCUSSION

This study showed that most adolescents in Port Harcourt, Southern Nigeria have comparatively normal ECG parameters, pattern and subgroup variations. Specifically, values for the mean ECG heart rate was 82 bpm (range 50 to 142 bpm) in the 10-14-year age group and decreased with age to a mean value of 80bpm (range 45 to 132 bpm) in the 15-19-year age group. This is similar to the findings of Davignon et al. [12] and Rijnbeek et al. [13] and possibly relates to increase in stroke volume with age (probably due to increasing left ventricular dominance) such that at lower heart rate, cardiac output is still met [20]. The mean heart rate was also noticed to be higher among the female than the male students agreeing with findings by Aliyu et al. [19] Davignon et al. [12] and Rijnbeek et al. [13].

The P-wave duration and PR interval of the study population increased with age, as has been observed in other studies [19,14,21,22,23]. The mean P-wave duration was 0.08 seconds, while the PR interval was 0.15 seconds. Kolawole et al. [19] obtained similar findings in a study in Ilorin, Western Nigeria. These values were however different from that obtained by Rijnbeek et al. [13] among Caucasian children, who noted a longer P-wave duration of 0.10 seconds and slightly lower PR interval of 0.14 seconds. The possible reason for these differences may be due racial factors.

The mean QRS duration in the index study population (measured across all leads) was 0.08 seconds. This agrees with observations made by Rijnbeek et al. [13] in their study of adolescents in The Netherlands; but slightly lower than the 0.07 seconds obtained by Kolawole et al. [19] in Ilorin. Although the Kolawole et al. [19] study was done among children in the western region of Nigeria, the mean QRS duration in their study was obtained from only lead II, while the present study calculated the mean QRS from all leads. This may have accounted for the slight differences in value obtained. On the other hand, it may suggest that children in the Western Region of Nigeria have a shorter ventricular depolarization time compared to those in the Niger-Delta region of Southern Nigeria. Further investigation to determine the significance of this may be warranted in future studies.

The mean QTc interval of 0.42 ± 0.02 seconds was comparable with that obtained by Semizel et al. [24] Rijnbeek [13] and Davignon et al. [12] in Caucasian adolescents. As with these studies, QT_c was higher in the females at 0.43 ± 0.02 than the male students (0.41 ± 0.02), which in literature has been attributed to the androgen hormone effect which shortens QTc in males [25].

The QRS axis in the study was 57.0 ± 20.8° in the 15-19 years' age group, increasing to 59.18 ± 20.86° in the younger 10-14 years' age group. This is possibly due to rotation of the axis from right to left as a result of increasing electrical preponderance of the left ventricle compared to the right ventricle as children grow. Similar observations were also documented by Aliyu et al. [14] Rijnbeek et al. [13] and Semizel et al. [24] The mean QRS axis was higher among the male students, which is similar to the findings of Aliyu et al. [14] in Kano, Nigeria. It however contrasts with the findings of Semizel et al. [24] where the mean QRS axis was higher amongst female subjects. The reason for the variations in the QRS axis is unclear.

There was an increase in the R wave amplitude from V_1 to V_6 in this study, and a concomitant decrease in the S wave amplitude towards V_6 in both the male and female students across the age groups. Also, the amplitude of the R and S waves were higher for the males than females in most of the leads. This higher amplitude in the males may be due to the fact that adolescent males have more cardiac muscle bulk than females. Breast tissue development has been postulated in some studies [26,27] as a reason for the differences in the R and S amplitude between males and females probably due to damping of the electrical activity by the adipose tissue causing an increased distance between the recording electrode and the myocardium. These observations agree with findings by Rijnbeek et al. [13] Semizel et al. [24] and Davignon et al. [12].

Table 16. Comparison of ECG parameters of subjects with that of Caucasian adolescents [15,16]

ECG parameters	Index study	Davignon study	Rijnbeek study
Heart rate (bpm)	81.6	80	74.5
PR Interval (sec)	0.15	0.14	0.14
P Wave Duration (sec)	0.08	0.09	0.09
QRS axis (^{o})	57.7	59	65.5
QRS Duration (sec)	0.08	0.07	0.08
QT Interval (sec)	0.42	0.41	0.41
P wave amplitude, II (mm)	1.5	1.4	1.4
Q wave amplitude, III (mm)	0.2	0.5	1.0
Q wave amplitude, V_6 (mm)	0.6	0.6	0.9
R wave amplitude, V_1 (mm)	4.06	4	4.2
R wave amplitude, V_6 (mm)	10.68	14	18.4
S wave amplitude, V_1 (mm)	11.44	11	12.3
S wave amplitude, V_6 (mm)	0.56	1	3.4
R/S ratio, V_1	0.33	0.36	0.35
R/S ratio, V_6	19	14	5.45

The mean R and S wave amplitude obtained in this study contrasted with that obtained by Aliyu et al. [14] in Kano, Northern Nigeria. For instance, the R wave amplitude in V_1 among the males aged 10-14 years was 4.50 mm which is lower than the 8 mm obtained in a similar age group by Aliyu et al. [14]. Also, the mean S wave amplitude of 12.18 mm in lead V_1 in this study was lower than the 18 mm in the Kano study [14]. Aliyu et al. [14] also observed that the R and S wave amplitudes recorded across all the age groups in their study of children in Northern Nigerian was higher than that obtained in similar age groups by Davignon et al. [12] in Quebec, Canada and Rijnbeek et al. [13] in Rotterdam, Netherlands. Similar findings were obtained by Kolawole et al. [19] among children in Ilorin, Western Nigeria, who had comparatively higher R and S wave amplitudes than Caucasian children [12,13]. Reiley et al. [27] in a study on 114 adolescents aged 11 to 17 years showed that race had an influence on the ECG of adolescents. The R-wave and S-wave amplitude among the black teenagers studied were significantly higher than in their Caucasian counterparts. Some authors attribute the differences in the R and S voltage to a difference in the pattern of ventricular activation between blacks and whites [28]. In this study however, the R-wave and S-wave amplitude was comparable to those found in the Caucasian adolescent population [12,13] contrasting with those of Nigeria children done in the Western and Northern region of the country. This finding should be interpreted with caution as it is difficult to explain why the values obtained was lower than that obtained in other Nigerian studies [19,14]; but it suggests that ethnic variations even amongst the same racial group may also play a role in ventricular activation pattern. However further studies are necessitated. It may also be possible that the subjects in this study were bigger than those in Kano [14] as obesity has been shown to result in low R and S wave amplitudes. Unfortunately, the BMI was not documented in the study by Aliyu et al. [14] in Kano for comparison.

Comparisons of all the ECG parameters between the adolescents in this study and Caucasian adolescents in Canada [13] and The Netherlands [12] shows minimal variations for most of the values except in the S Wave amplitude in V_1 which was much lower in the index study population. As a result, the R/S ratio in V_6 was much higher in the present study compared to those of the Caucasian adolescents. This finding is important because it may suggest a “different” higher criteria value for R/S ratio as an indicator of left ventricular hypertrophy in adolescents in Port Harcourt, Southern Nigeria. As such, this information should be taken into consideration before making an ECG interpretation of left ventricular hypertrophy based on the R/S ratio alone in adolescents in this region.

5. CONCLUSION

The ECG parameters of adolescents in the Niger Delta Region of Southern Nigeria (Port Harcourt) is similar to those found in adolescents in Northern and Western Nigeria in most parameters except the R-wave and S-wave amplitudes which was lower in adolescents in

Port Harcourt. The parameters are also comparable to those of Caucasian adolescents in the Netherland and Canada except in the R/S ratio in V_6 which was much higher in the study population, suggesting a higher R/S ratio criteria value for the determination of left ventricular hypertrophy in adolescents in the sub-region.

CONSENT

As per international standard or university standard written patient consent has been collected and preserved by the authors.

ETHICAL APPROVAL

As per international standard or university standard written ethical permission has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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