Original Research Article

Assessment of Electrocardiogram among Adult Nigerians: High Blood Pressure versus Normal Blood Pressure

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ABSTRACT

Aims: This study assessed the electrocardiogram (ECG) variables of apparently healthy adult Nigerians (≥18 years) who presented for medical screening to determine the effects of high blood pressure (HBP) on the heart's electrical activities.
Study design: This was a descriptive retrospective study.
Place and Duration of Study: This study was conducted at the Department of Physiological Sciences ECG library contains archives of ECG collected throughout the 10 years.
Methodology: ECGs obtained from the participants through a standard protocol from 2014 to 2015 were selected, sorted, and stratified into two categories (A and B) based on the blood pressure level. Group A contained 250 ECGs of individuals with high blood pressure (SBP ≥130mmHg and/or DBP ≥80mmHg) while Group B contained 250 ECGs of age-and-sex-matched individuals with normal blood pressure (SBP <130mmHg and/or DBP<80mmHg). Variables extracted from each ECG include age, gender, height, weight, blood pressure, ECG variables, and patterns.

Results: HBP did not significantly alter P wave variables except for morphology ($\chi 2=16.65$, P=.005). Across the left lateral leads, QRS voltage(mm) was significantly higher among Group A than Group B; I (8.99 ± 3.54, 7.54±3.00; t = 4.89, $P < .001$), aVL (5.07± 3.97, 3.83± 3.07; t=3.91, $P<.001$), V5 (19.18±7.18,16.98±6.45; t=3.60, $P <.001$) and V6(16.14±5.95, 14.10±5.23; t =4.07, $P<.001$). The ventricular rate in bpm (77.46 ±14, 70.26 ± 12.48; t=5.99, P =.001) and QTc in ms (424.56±29.24,409.16 ± 22.23; t=0.56, $P<.001$) were significantly higher in Group A than Group B respectively.
Conclusion: In conclusion, HBP significantly altered cardiac electrical activities and the changes are detectable through routine ECG screening of asymptomatic adults. ECG is recommended as a routine test for adult Nigerians with HBP.

Keywords: Blood Pressure, Routine, Medical Screening, Electrocardiogram, Adults, Nigeria

1. INTRODUCTION

Persistent high blood pressure (HBP) affects individuals of all ages globally [1]. The increasing burden of HBP in underdeveloped countries has led to heightened cardiovascular mortality [1,2]. This warrants early diagnosis and prevention. Medical interventions include screening and early detection of hypertension using blood pressure monitoring devices [3]. An electrocardiogram (ECG) is an important investigation for diagnosing and monitoring HBP and its complications. It is the graphical record of cardiac electrical activities of the heart obtained from the body surface. The most widely used form of ECG is the standard 12-lead ECG, which is typically performed during routine medical visits. ECG recording depicts the generation and propagation of the heart's electrical signals made recordable by placing 4 limb and 6 chest electrodes at specific locations on the body's surface [4]. This non-invasive investigation is

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effective in detecting the risk associated with cardiovascular disorders and the effects of cardiovascular diseases on the heart [4-6].

Electrocardiographic variables and interpretations such as P-wave, QRS complex, T-wave, PR interval, QT interval, amplitude, duration, and cardiac rotation can be used to trace cardiovascular abnormalities [5]. Cardiac rotation is classified based on the location of the transition zone in the chest leads; normal transition (transition zone is located at V3 to V4), early transition/counterclockwise rotation (transition zone is located before V3), and late transition/clockwise rotation (transition zone is located after V4) [5,7].

2. MATERIAL AND METHODS

This was a retrospective study carried out over five weeks at the ECG library located in the Department of Physiological Sciences at Obafemi Awolowo University, Ile-Ife. Ethical Clearance was obtained from the Health Research Ethic Committee, Institute of Public Health in the University. All studied ECGs were recorded from apparently healthy adults (members of staff and their relatives) who presented for medical screening as a form of general medical check-up or pre-employment test. The archived ECG recordings were collected over three years (2013 – 2015). The previously obtained ECG data allowed for performing a retrospective study within a brief period. Participants' age, gender, height, and weight were documented. Their systolic blood pressure (SBP) and diastolic blood pressure (DBP) measured with a digital blood pressure monitor (OMRON) as a precondition for participating in the ECG procedure were documented. The Nihon Kohden Cardiofax ECG machine was utilized for the acquisition of the ECG according to standard procedure. Body Mass Index (BMI) was estimated from the recorded weight (Kg) and height in meters (m) using the Quetelex formula (BMI=Weight divided by the square of height. Body surface area was calculated from the weight and height using the Mosteller formula (BSA = square root of the height (cm) multiplied by the weight (kg) divided by 3600).

A total of 1200 ECG recordings were screened and a sample size of 500 ECGs were selected for the study. The inclusion criteria included the age of 18 years. ECGs were stratified into groups A and B, based on blood pressure. Group A included 250 ECGs of individuals with high blood pressure (SBP≥130mmHg and/or DBP≥80mmHg) and group B included 250 ECGs of age-and-sex-matched adults with normal blood pressure (SBP<130mmHg and DBP<80mmHg). The 250 ECGs in Group A were obtained first by screening 700 ECGs out of the 1200. Then, 250 ECGs in group B were selected by screening all the 1200 ECGs to achieve the age-and-sex-matched participants. Both groups were selected via convenient sampling.

To analyze the data, the population was stratified by age, gender, BMI, BSA, and blood pressure. BMI was obtained through Excel using the Quetelet formula. BSA was calculated in Excel using the Mosteller formula. Blood pressure was categorized as a continuous variable. From each ECG recording, the following variables were obtained: rhythm, ventricular heart rate, PR interval, P-wave analysis (axis, duration, voltage, morphology), QRS analysis (axis, voltages, duration), T-wave axis, QT interval, and QTc. A magnifying lens was utilized to enhance the visual appreciation of ECG waves on the background of the gridlines. SPSS version 4.6.1 was used to analyze the data. Descriptive statistics utilized include frequency and mean with standard deviation. Comparison between grouped data was done using Chi-

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square while the means of continuous data were compared using the Student t-test. A p-value of .05 was considered a significant statistical difference.

3. RESULTS

The mean ages of Group A and Group B were 40.84 ± 14.11 years and 40.59 ± 13.11 years (t = 0.194, *P* = .84), respectively. There was no significant difference in the mean height of the two groups. However, significant differences were observed in weight (Group A: 74.19 ± 13.73 kg, Group B: 69.27 ± 14.40 kg, *P* <.001), BMI (Group A: 25.98 ± 4.84 kg/m², Group B: 24.59 ± 5.18 kg/m², P = .002), BSA (Group A: 1.86 ± 0.19 m², Group B: 1.79 ± 0.19 m², *P* < .001), SBP (Group A: 143.04 ± 15.88 mmHg, Group B: 116.82 ± 8.67 mmHg, *P* < .001), and DBP (Group A: 81.36 ± 11.00 mmHg, Group B: 65.68 ± 7.67 mmHg, *P* < .001) (Table 1).

Table 2 shows the relationship between anthropometric parameters and selected cardiovascular indices (BP and ventricular rate). Height, weight, BMI, and BSA were associated with blood pressure. Weight, BMI, and BSA were positively correlated with systolic BP (r = 0.198, r = 0.173, and r = 0.197, respectively; *P* < .001). Height was negatively correlated with diastolic BP (r = -0.032; *P* = 0.48) and ventricular rate (r = -0.097*; P* = 0.03). Weight, BMI, and BSA were positively correlated with both diastolic BP (r = 0.206, r = 0.216, and r = 0.185, respectively; *P* < .001) and ventricular rate (r = 0.077, *P* = .087; r = 0.118, p = .008; and r = 0.042, *P* = .35, respectively).

The mean P-wave duration of HBP individuals (93.3 ms) was not statistically significantly different from that of NBP individuals (91.6 ms). The mean P-wave amplitude of HBP individuals (1.58 mm) was less than that of NBP individuals (1.63 mm); there was no significant difference. The mean P-wave axis of HBP individuals (53.33 degrees) was less than that of NBP individuals (52.86 degrees); there was no statistically significant difference (Table 3). P-wave morphology was classified into five groups: upright with rounded contour, peaked, bifid, inverted, and flattened. More HBP individuals (68.4%) had P-waves with upright and rounded contour morphology compared to NBP individuals (55.2%). In contrast, more NBP individuals (32.4% and 9.6%, respectively) had P-waves with peaked and bifid morphologies compared to HBP individuals (26.8% and 8.4%).

Individuals with HBP had a significantly greater QRS voltage (SV1 and RV5) compared with individuals with NBP (*P* < .001 and t = 3.902) (Fig. 1). Individuals with HBP had a higher QRS duration (89.54 ms) compared to individuals with NBP (87.40 ms). This difference was statistically significant (*P* = .02). However, individuals with HBP had a lower axis (38.74 degrees) than individuals with NBP (42.34 degrees). This was not statistically significant (*P* = .19) (Table 4). R-wave amplitude varied significantly between both groups in the left lateral leads. R1 in HBP was 8.99 mm compared to NBP at 7.54 mm. RaVL in HBP was 5.07 mm compared to NBP at 3.83 mm. In the other limb leads (II, III, aVR, and aVF), the means of R-wave amplitude did not show a significant statistical difference between both groups (Table 5).

In the S-wave of the limb leads, SIII and SaVR varied significantly between both groups. SIII in HBP individuals was 3.43 mm compared to NBP individuals at 2.43 mm. SaVR in HBP individuals was 9.93 mm compared to NBP individuals at 9.27 mm. S depth in leads I, II, aVL, and aVF was not statistically significant (Table 6). Similar to the R-wave in limb leads, R-wave amplitude varied significantly between both groups in left lateral leads I, aVL, V5, and V6. RV5 in HBP individuals was 19.18 mm, greater than in NBP individuals at 16.98 mm. RV6 in HBP individuals was 16.14 mm, greater than in NBP individuals at 14.10 mm. Fig. 3 illustrates the increase in QRS voltage in a woman with HBP (SV1 + RV5 > 35 mm). R-wave amplitude in leads V1 to V3 was not statistically significant between both groups (Table 7). The means of S-wave depth in the chest leads between HBP and NBP groups were significantly different in

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most leads except for SV3 and SV6 (Table 8). As shown in Table 9, more HBP individuals (47.6%) had normal transitions compared to NBP individuals (26.4%). In contrast, more NBP individuals (64.8%) had early transition compared to HBP individuals (48%). Therefore, individuals with HBP tended to have a more normal transition compared to individuals with NBP. Furthermore, individuals with NBP tended to have more early transitions compared to individuals with HBP. The results showed that there was no significant difference in PR interval and QT interval, but the ventricular rate and QTc were significantly higher in the HBP group than in the NBP group (Table 10).

4. DISCUSSION

In this study, as expected, overweight and/or obese individuals were more likely to develop hypertension. There was a strong association between the anthropometric data (Height, BMI, BSA) and HBP (Tables 1 and 2). Body size has been documented to predict cardiovascular disease [8]. Body mass index (BMI) is associated with increased vascular resistance and stroke volume; these result in an increase in cardiac output [8]. Interestingly, our study revealed an association between BMI, height, and BP (Table 2). However, a study carried out among teenagers living in Limpopo, South Africa, showed that body surface area (BSA) is moderately associated with systolic blood pressure (SBP) but weakly associated with diastolic blood pressure (DBP) in those in the prehypertensive stage (BP=130/85 mmHg) [8-10]. Similarly, our study observed a strong association between SBP and DBP (Table 1). Moreover, increased body fat reduces the transmission of electrical impulses from the heart to the body surface, thus reflecting a reduced QRS voltage on the ECG. Therefore, the QRS voltage of an obese individual might underestimate the cardiac size assessed using ECG.

Left atrial enlargement is a marker of left ventricular pressure and volume overload [11]. It is an early sign of hypertensive heart disease and is usually reported in the ECG of patients with moderate and severe hypertension [12]. Left atrial enlargement abnormality is assessed electrocardiographically by the presence of a bifid P wave with duration ≥0.12s in lead II or a biphasic P wave with P-terminal force ≥0.04s in V1. Right atrial abnormality is assessed when the P wave is peaked and its amplitude is ≥2.5mm in the lead II. The presence of atrial abnormalities predisposes to embolic events and arrhythmogenesis especially atrial flutter and atrial fibrillation. On the ECG, the P wave denotes atrial depolarization; it reflects the electrical activity through the atrium and thus helps to identify atrial abnormalities [14-16]. In this study, there were insignificant changes in P-wave duration and amplitude (Table 3) in those with HBP compared to NBP. This suggests that the ECG may not suffice for the early detection of atrial abnormalities in cases of mildly elevated blood pressure.

However, the QRS analysis pinpoints ventricular depolarization in the cardiac cycle during the spread of electrical activity within the ventricles [18]. Leads are classified based on the heart region where they depict changes. For instance, inferior leads (II, III, and aVF) depict changes in the inferior wall of the heart, left lateral leads (1, aVL, V5 & V6) depict changes in the lateral wall of the left ventricle, and anterior leads(V1-V6) depict changes in the anterior wall of the heart. The increase in QRS duration and QRS voltage in the left lateral leads reflects the increase in left ventricular mass [18-19]. An abnormal QRS value is a good indicator of left ventricular hypertrophy. However, high left ventricular voltage (amplitude > 3.0 mV) may be a normal finding in people less than 45 years old with high blood pressure. High QRS voltage in the left lateral leads was observed among the participants with HBP, which is suggestive of an enlargement or hypertrophy of the left ventricle (Fig.1 and 2). In a retrospective study by Domain et al. (2021) [17], they documented that there was a proportional relationship between QRS duration and left ventricular hypertrophy (LVH). An Ethiopian study by Kinfe et al. (2020) [18] found a significant association between LVH and BP in a population of 223 hypertensive individuals. Similarly, this study revealed significantly higher QRS duration and voltage in left lateral leads among the participants with HBP than those with NBP. On the chest leads our

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study showed that specific R waves (RV4, RV5, and RV6) and S waves (SV1, SV2, SV4, SV5) were significantly increased in those with HBP compared to the control group (NBP) (Tables 5). Using the Sokolow-Lyon criteria for the assessment of left ventricle hypertrophy (Fig. 3), the findings showed that blood pressure has a greater impact on left ventricular hypertrophy. This study is the first to document the relationship between cardiac rotation and BP; we discovered that counterclockwise rotation is strongly associated with normal blood pressure, while normal transition is strongly associated with high blood pressure. Notably, counterclockwise rotation was prevalent among our study population (Nigerians). The rotation may be due to age and sex variation [20,21]. In a study by Patel et al. (2017) [5], participants with counterclockwise rotation demonstrated the lowest risk of cardiovascular disease and mortality, while those with normal blood pressure and clockwise rotation were associated with the highest risk of heart failure. Participants with counterclockwise rotation were mainly Black and had a higher BMI. Similarly, our population had similar characteristics. Further research is needed to understand the association between counterclockwise rotation and BMI. Therefore, a comprehensive review to fully understand the association between cardiac rotation and cardiovascular risk factors in different age groups and races is necessary. This would contribute to the understanding of cardiovascular pathophysiology.

Table 1. – Age, weight, height and blood pressure of the participants

Variable	Group A (HBP) n = 250	Group B (NBP) n = 250	t	P-value
Age (years)	40.84 ± 14.11	40.59 ± 13.10	0.194	.85
Height (m)	169.24 ± 8.86	168.02 ± 7.79	1.640	.10
Weight (kg)	74.19 ± 13.73	69.27 ± 14.40	3.910	<.001
BMI (kg/m^2)	25.98 ± 4.84	24.59 ± 5.18	3.088	.002
BSA (m^2)	1.86 ± 0.19	1.79 ± 0.19	4.126	<.001
SBP (mm Hg)	143.04 ± 15.88	116.82 ± 8.67	22.906	<.001
DBP (mm Hg)	81.36 ± 11.00	65.68 ± 7.67	18.476	<.001

BMI – Body Mass Index; BSA – Body Surface Area; HBP – High Blood Pressure; NBP-Normal Blood Pressure, SBP – Systolic Blood Pressure; DBP – Diastolic Blood Pressure

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Table 2: Relationship between anthropometric parameters and selected cardiovascular indices

Parameters	Systolic BP		Diastolic BP		Ventricular Rate	
	r	p-value	r	*P*-value	r	*P*-value
Height (cm)	0.047	0.296	-0.032	.48	-0.097	.031
Weight (kg)	0.198	<0.001	0.206	<0.001	0.077	.087
BMI (kg/m^2)	0.173	<0.001	0.216	<0.001	0.118	.008
BSA (m^2)	0.197	<0.001	0.185	<0.001	0.042	.347

BMI – Body Mass Index; BSA – Body Surface Area; BP – Blood Pressure; SBP – Systolic Blood Pressure.; DBP – Diastolic Blood Pressure.

Table 3: Association between the P-wave duration, amplitude, axis, and blood pressure

Variable	High BP (n = 250)	Normal BP (n = 250)	t	*P*-value
P-wave duration (ms)	93.3 ± 26.71	91.6 ± 24.89	0.766	.44
P-wave amplitude (mm)	1.58 ± 0.61	1.63 ± 0.62	-0.877	.38
P-wave axis (degrees)	53.33 ± 17.60	52.86 ± 19.25	0.289	.77

BP – Blood pressure

Table 4: Association between QRS duration and axis of the participants and blood pressure

Variable	High BP (n = 250)	Normal BP (n = 250)	t	p-value
QRS duration (ms)	89.54 ± 11.22	87.40 ± 9.77	2.27	.02
QRS axis (degrees)	38.74 ± 31.86	42.34 ± 29.92	- 1.30	.19

BP – Blood pressure

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Table 5: Amplitude of R waves in Limb Leads

Variable	High BP n = 250	Normal BP n = 250	t	p-value
R I (mm)	8.99 ± 3.54	7.54 ± 3.00	4.891	<.001
R II (mm)	11.47 ± 5.01	11.13 ± 4.63	0.793	.43
R III (mm)	5.39 ± 4.89	5.44 ± 4.59	-0.113	.91
R aVR (mm)	0.14 ± 0.54	0.31 ± 1.36	-1.81	.07
R aVL (mm)	5.07 ± 3.97	3.83 ± 3.07	3.94	<0.001
R aVF (mm)	7.95 ± 5.28	7.95 ± 4.69	-0.013	0.989

BP – Blood pressure

Table 6: Depth of S waves in Limb Leads

Variable	High BP n = 250	Normal BP n = 250	t	p-value
S I (mm)	0.80 ± 1.25	0.66 ± 0.94	1.535	.126
S II (mm)	1.31 ± 1.87	1.32 ± 2.07	-0.045	.964
S III (mm)	3.43 ± 4.42	2.43 ± 3.27	2.846	.005
S aVR (mm)	9.93 ± 3.14	9.27 ± 2.95	2.400	.017
S aVL (mm)	1.74 ± 2.41	1.53 ± 2.15	0.988	.324
S aVF (mm)	1.95 ± 2.86	1.52 ± 2.45	1.798	.073

BP – Blood pressure

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Table 7: R wave amplitude in chest leads

Variable	High BP (n = 250)	Normal BP (n = 250)	t	p-value
RV1 (mm)	3.57 ± 3.19	3.41 ± 2.78	0.590	.278
RV2 (mm)	8.02 ± 4.67	8.20 ± 4.77	-0.417	.339
RV3 (mm)	14.92 ± 7.95	14.42 ± 7.32	0.720	.236
RV4 (mm)	20.50 ± 8.93	18.59 ± 7.88	2.534	.006*
RV5 (mm)	19.18 ± 7.18	16.98 ± 6.45	3.602	<0.001*
RV6 (mm)	16.14 ± 5.95	14.10 ± 5.23	4.070	<0.001*

BP – Blood pressure, * means p < 0.05 (significant value).

Table 8: S wave depth in chest leads (S)

Variable	High BP n = 250	Normal BP n = 250	t	P-value
SV1 (mm)	14.00 ± 7.24	12.54 ± 5.78	2.481	.01*
SV2 (mm)	16.59 ± 9.10	14.99 ± 7.23	2.183	.03*
SV3 (mm)	7.76 ± 5.20	7.07 ± 4.99	1.500	.13
SV4 (mm)	5.24 ± 3.95	4.51 ± 3.29	2.251	.03*
SV5 (mm)	2.95 ± 2.92	2.32 ± 2.19	2.719	.01*
SV6 (mm)	1.52 ± 1.98	1.27 ± 1.69	1.530	.13

BP – Blood pressure; * means p < 0.05 (significant value).

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Table 9: Cardiac rotation among the participants

QRS Rotation	High BP n = 250	Normal BP n = 250	Total	χ2	p-value
Normal Transition	119 (47.6%)	66 (26.4%)	185 (37%)	25.106	<.001
Late Transition	11 (4.4%)	22 (8.8%)	33 (6.6%)		
Early Transition	120 (48%)	162 (64.8%)	282 (56.4%)		
Total	250	250	500		

BP – Blood Pressure.

Table 10: Ventricular Rate and ECG Intervals

Variable	High BP	Normal BP	t	p-value
Ventricular Rate	77.46 ± 14.34	70.26 ± 12.48	5.99	.001
PR Interval	161.86 ± 24.62	163.29 ± 23.11	-0.67	.51
QT Interval	376.30 ± 30.4	380.70 ± 29.03	-1.65	.10
QT Corrected	424.56 ± 29.24	409.16 ± 22.83	6.56	<0.001

BP – Blood Pressure

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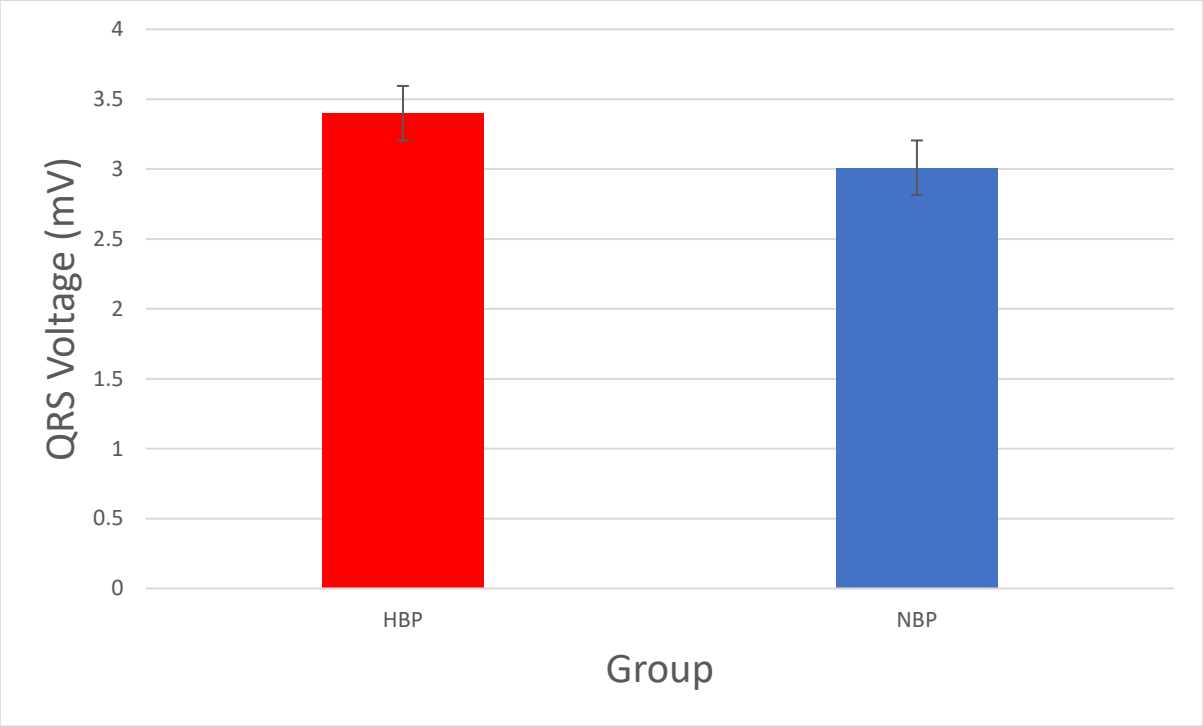

Fig 1: **QRS Voltage Assessment (SV1 +RV5); HBP versus NBP.**

HBP – High Blood Pressure. NBP – Normal Blood Pressure

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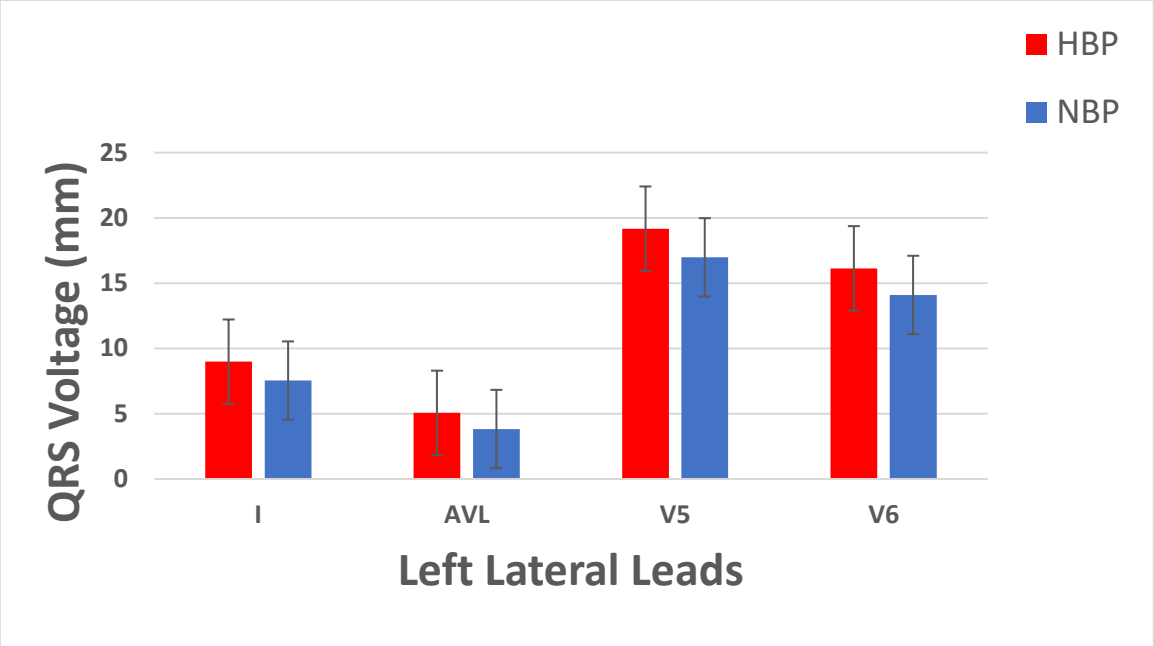

Fig 2: R wave voltage assessment in left lateral leads

HBP – high blood pressure. NBP – normal blood pressure

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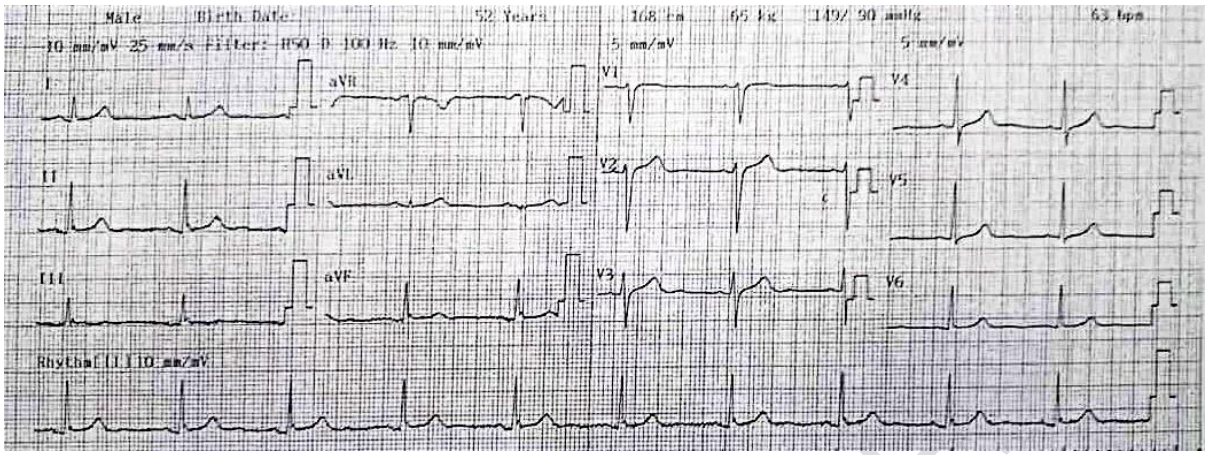

Fig 3: **ECG of a 52-year-old woman with high blood pressure and left ventricular hypertrophy (SV1 + RV5 >35mm)**

4. LIMITATIONS OF THE STUDY

The retrospective design of the study limited the control over confounding factors, such as lifestyle choices, which may have influenced the data. Additionally, the use of a convenient sampling method to recruit the initial pool of participants restricts the generalizability of the findings.

5. CONCLUSION

High blood pressure significantly alters cardiac electrical activity, and these changes can be effectively detected through routine ECG screenings, even in asymptomatic adults. This study underscores the importance of early detection, as ECG abnormalities may indicate underlying cardiovascular issues that, if left unnoticed, could lead to more serious complications. Regular ECG screening is particularly valuable for hypertensive patients in Nigeria, given the prevalence of hypertension and the potential for undiagnosed cardiac arrhythmias in this population. Therefore, we recommend the integration of ECG as a routine diagnostic tool for adult Nigerians with HBP to enable early detection and timely intervention.

Further research should explore the long-term benefits of routine ECG screening in hypertensive populations, including its potential to prevent adverse cardiac events. Prospective studies should be conducted to assess the cost-effectiveness of widespread ECG implementation in healthcare settings across Nigeria. Additionally, research into the predictive value of ECG abnormalities about different stages of hypertension could provide deeper insights into how cardiac electrical changes correlate with disease progression. Longitudinal studies are also needed to examine the impact of lifestyle interventions on ECG abnormalities in hypertensive individuals.

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Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCES

1. Zhou B, Carrillo-Larco RM, Danaei G, Riley LM, Paciorek CJ, Stevens GA et al. Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019: a pooled analysis of 1201 population-representative studies with 104 million participants. The Lancet, 2021, 398 (10304), 957-980.

2. Ayogu RNB, Ezeh MG, Okafor AM. Prevalence and predictors of different patterns of hypertension among adults aged 20 - 60 years in rural communities of Southeast Nigeria: a cross-sectional study. Archives of Public Health, 2021: 79 (1). https://doi.org/10.1186/s13690-021-00724-y.

3. Carey RM, Moran AE, Whelton PK. Treatment of hypertension. JAMA, 2022: 328(18), 1849. https://doi.org/10.1001/jama.2022.19590.

4. Lyon A, Mincholé A, Martínez JCV, Laguna, Rodriguez B. Computational techniques for ECG analysis and interpretation in light of their contribution to medical advances. Journal of the Royal Society Interface, 2018: 15(138), 20170821. https://doi.org/10.1098/rsif.2017.0821.

5. Patel SM, Kwak L, Agarwal SK, Tereshchenko LG, Coresh J, Soliman EZ, Matsushita K. Counterclockwise and clockwise rotation of QRS transitional zone: prospective correlates of change and time-varying associations with cardiovascular. outcomes. Journal of the American Heart Association, 2017: 6(11). https://doi.org/10.1161/jaha.117.006281.

6. Adeoye OA, Adekunle AO, Bolaji OO. Prevalence and electrocardiographic patterns of left ventricular hypertrophy in hypertensive patients in a Nigerian tertiary hospital. Ethiop J Health Sci 2020; 30(4):541-548.

7. Bradford N, Shah AJ, Usoro AO, Haisty WK, Soliman E. Z. (2014). Abnormal electrocardiographic QRS transition zone and risk of mortality in individuals free of cardiovasculardisease. Europace, 2014:17(1),131-136. https://doi.org/10.1093/europace/euu149.

8. Ewah PA, Oyeyemi AY. Relation between derived cardiovascular indices, body surface area, and blood pressure/heart rate recovery among active and inactive Nigerian student. Bull Fac Phys Ther 27, 34 (2022). https://doi.org/10.1186/s43161-022-00094-8.

9. Evans JM, Wang S, Greb C, Kostas V, Knapp CF, Zhang Q et al. Body Size Predicts Cardiac and Vascular Resistance Effects on Men's and Women's Blood Pressure. Frontiers in physiology, 2017: 8, 561.

10. Raphadu TT. Staden MV, Dibakwane WM, Monyeki KD. A Non-Invasive Investigation into the Prevalence of Higher-than-Normal Blood Pressure, Hypertension and the

.

Association between Blood Pressure and Body Weight in Male and Female Adolescents in the Polokwane Local Municipality, Limpopo-South Africa: A Cross-Sectional Study. Children 2020, 7, 18. https://doi.org/10.3390/children7030018.

11. Reule S, Drawz PE. Heart rate and blood pressure: any possible implications for management of hypertension? Curr Hypertens Rep. 2012 Dec;14(6):478-84. doi: 10.1007/s11906-012-0306-3. PMID: 22972532; PMCID: PMC3491126.

12. Maheshwari A, Norby FL, Soliman EZ, Alonso A, Sotoodehnia N, Chen LX. Association of P-wave abnormalities with sudden cardiac and cardiovascular death. Circulation-arrhythmia and Electrophysiology, 2021:14(2).

13. Su G, Cao H, Xu S, Lu Y, Shuai X, Sun Y et al. Left atrial enlargement in the early stage of hypertensive heart disease: a common but ignored condition. J Clin Hypertens.. 2014; 16(3):192-7. doi: 10.1111/jch.12282.

14. Eshoo S, David L. Ross, Thomas L. Impact of Mild Hypertension on Left Atrial Size and Function. Cardiovascular Imaging. 2009; 2:93–99.

15. Chen LX, Ribeiro ALP, Platonov PG, Cygankiewicz, I., Soliman EZ, Gorenek B, Ikeda T et al. P Wave Parameters and Indices: A Critical Appraisal of Clinical Utility, Challenges, and Future Research-A Consensus Document Endorsed by the International Society of Electrocardiology and the International Society for Holter and Noninvasive Electrocardiology. PubMed, 2022:15(4),e010435. https://doi.org/10.1161/circep.121.01043.

16. Kabutoya T, Kario K. P-wave changes as an index of hypertensive organ damage and a predictor of cardiovascular events: can the P wave be used to assess atrial reverse remodeling? Hypertension Research, 2022: 45(8), 1400 1403.

17. Domain G, Chouquet C, Reant P, Bongard V, Vedis T, Rollin A et al. Relationships between left ventricular mass and QRS duration in diverse types of left ventricular hypertrophy. European Journal of Echocardiography, 2021: 23(4), 560–568.

18. Kinfe DG, Berhe G, Gidey K, Demoz GT. Blood Pressure Control, Left Ventricular Hypertrophy and Treatment Practice Among Hypertensive Patients in Ethiopia.

.

International Journal of General Medicine, 2020:13, 903–916. https://doi.org/10.2147/ijgm.s273668

19. Giamouzis G, Dimos A, Xanthopoulos A, Skoularigis J, Triposkiadis F. Left ventricular hypertrophy and sudden cardiac death. Heart Failure Reviews, 2021: 27(2), 711–724.

20. Araoye MA. Electrical axis of the heart in healthy adult Nigerians. African journal of medicine and medical sciences, 1984: 13 (1-2), 85-91.

21. Lawal M, Enikuomehin A, Otubogun FM. The diagnostic yield of routine electrocardiography in hypertension and implications for care in a Southwestern Nigerian practice. International Journal of General Medicine, 2021: 14, 1421–1427.

.