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Normal Limits of Electrocardiogram and Cut-Off Values for Left Ventricular Hypertrophy in Young Adult Nigerians

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Summary: This study assessed healthy young adults to determine the normal limits for electrocardiographic variables and cut-off values for left ventricular hypertrophy. It was a cross sectional descriptive study in which the participants were evaluated clinically by standard 12-lead resting electrocardiogram (ECG) at 25mm/s during quiet respiration. The heart rate, P wave duration, axis and amplitude, PR and QT intervals, QRS duration, axis and amplitude and T wave axis were assessed. Three hundred and twenty four (324) volunteers comprising of 175 males and 149 females aged 20 to 30 years (mean, 23.01±2.88years) participated in the study. The normal limits for heart rate, P wave duration, amplitude and axis in lead II, QRS duration and axis, T wave axis, PR interval, QT interval and QTc respectively were; 61-93beats per minute,0.08-0.12s,1.00-2.00mm,22.00-79.00^0,78.00-106.00ms,15.50-81.00^0, 24.25-69.00^0,0.12-0.19s, 0.32-0.40s and 0.36-0.44s. The cut-off values for Sokolow-Lyon, Cornell and Araoye criteria for assessment of left ventricular hypertrophy (LVH) were higher than those previously in use in medical practice. Gender difference exists in some cut-off values for LVH. This study defined the normal limits for electrocardiographic variables for young adult Nigerians. Racial factor should be taken into consideration in interpretation of ECG.

Keywords*:* Normal limits, Electrocardiogram, Cut-off values, Left ventricular hypertrophy, Young Adults

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INTRODUCTION

Electrocardiogram (ECG) is a very important non-invasive cardiac investigation (Zipes, 2000). It had been established that age, gender and racial/ethnic differences exist with regards to ECG measurements (Rautaharju *et al*.1994, Macfarlane *et al*.1994, Vitelli *et al*.1998, Ogunlade *et al*. 2012).Therefore, age, gender and race/ethnicity should be considered in defining normal limits that will assists in accurate interpretation of ECG for a particular population. However, such reference data are not available especially for young adults. Most of the reference range data available in adults were established for middle aged population mainly of Caucasian extraction. Only very few studies exist with regards to ECG normal patterns of young adult of Yoruba population in the South-Western Nigeria (Araoye, 1984, Ogunlade *et al*.2012).This study aimed at defining the normal limits of important ECG variables and measurement for population of healthy young adults of Yoruba ethnic group. It also aimed at establishing the cut-off values for a few previously used ECG criteria for the diagnosis of left ventricular hypertrophy (LVH).

MATERIALS AND METHODS

This was a cross-sectional descriptive study. The target population was young adults between the ages of 20 and 30 years. Three hundred and twenty four (175 males and 149 females) healthy non-athletic young adults who participated in the study were recruited from Obafemi Awolowo University, Ile-Ife over a period of one year. For each candidate, weight and height measurement were carried out using a weighing scale(ZT-120 health scale).Body mass index(BMI) was estimated from the weight and height(BMI=weight/height^2) while blood pressure (BP) measurement was done using digital sphygmamometer (lumiscope) after five minutes of rest. Fasting blood glucose assessment was done using a glucometer with a drop of blood obtained from the fingertip with a sterile lancet. Inclusion criteria include; normal blood pressure (< 140/90mmHg), body mass index < 30kg/m^2, fasting blood glucose <7.0mmol/l and absence of symptomatic systemic diseases. Ethical clearance was obtained from the Ethics and Research Committee of the Obafemi Awolowo University Teaching Hospitals

Complex (OAUTHC), Ile-Ife (Ethical review reference no: 0005422).

The participants were educated about ECG procedure and written informed consent obtained from them. The chest and the limbs were exposed for electrode placement.With a three channel electrocardiograph (Dongjiang ECG-32A), the standard 12-lead ECG was recorded from the body surface by the attachment of 10 electrodes at the specific locations on the body according to internationally approved protocol (Kligfield *et al*. 2007).The chest leads(V1-V6) were recorded by the attachment of 6 electrodes to the precordium according to the conventional method;V1 at 4th intercostal space right sternal edge, V2 at 4th intercostal space left sternal edge, V3 at the point mid-way betweenV2 and V4, V4 at 5th intercostal space left midclavicular line, V5 at 5th intercostal space left anterior axillary line and V6 at 5th intercostal space left mid-axillary line.

The six limb leads (I, II, III, aVF, aVL and aVR) were recorded using four electrodes. An electrode was attached to the distal end of each limb according to the standard protocol for limb electrode placement. The standard 12-lead ECGs were recorded in supine position during quiet respiration at a speed of 25mm/s and calibration signal of 10mm/mV. The ECGs were printed out for detailed interpretation by a cardiologist. The QT interval was corrected for the heart rate using Bazett's formula (Bazzet, 1920).

Statistical Analysis

Values of ECG variables were presented as Mean ± SD. The lower and upper limits of normal were determined at 5th and 95th percentiles respectively. The cut-off values for the voltage LVH criteria were determined at 95th percentile. The data were analyzed with the aids of SPSS version16.0 software using descriptive statistics.

RESULTS

Three hundred and twenty four (324) young adults participated in the study. One hundred and seventy five (54.01%) were males while one hundred and forty nine (45.99%) were females. All participants were in sinus rhythm. The mean ± standard deviation (SD) for age(years), weight(kg), height(m), body mass index(kg/m^2), systolic blood pressure(mmHg) and diastolic blood pressure (mmHg) for both sexes were 23.01±2.88, 60.89 ±8.99, 1.67 ± 0.08, 21.70 ± 2.86, 119.77 ±11.37 and 72.27 ± 8.37 respectively.

The mean ± SD and normal limits of heart rate (beats per minute), P wave duration in lead II(s), P wave amplitude in lead II(mm), P wave axis (^{0}), QRS duration(ms), QRS axis(^{0}), T wave axis(^{0}), PR interval(s), QT interval(s) and QTc for the 324 young adults were 74 ± 9 (61-93), 0.09 ± 0.01(0.08-0.12), 1.28 ± 0.41(1.00-2.00), 56.99 ± 18.60 (22.00-79.00), 89.80 ± 9.48 (78.00-106.00), 54.31±19.82 (15.50-81.00), 49.74 ±13.11(24.25-69.00), 0.15 ± 0.02(0.12-0.19), 0.36 ± 0.02(0.32-0.40) and 0.40 ± 0.02 (0.36-0.44) respectively.

Table 1.Demographic characteristics and blood pressure according to gender

Parameters	**Male (n=175)**	**Female (n=149)**
Age(yrs)	23.71 ±2.91	22.18±2.54
Wt(kg)	63.02 ±8.59	58.38±8.84
Ht(m)	1.72 ±0.07	1.62±0.07
BMI(kg/ m^2)	21.30 ± 2.55	22.16±3.14
SBP(mmHg)	123.00 ±11.65	115.99±9.81
DBP(mmHg)	72.99 ±8.59	71.44±8.05

SBP-systolic blood pressure, DBP-diastolic blood pressure

Table 2. Gender-specific normal limits of heart rate, P wave, QRS complex, T wave, PR and QT intervals

ECG Variables	**Male (n=175)**	**Female (n=149)**
Heart rate(bpm)	61-88	61-94
P duration (s)	0.08-0.12	0.08-0.10
P amplitude (mm)	1.00 -2.00	1.00-2.00
P axis(^{0})	27.40-81.20	11.50-75.50
QRS duration(ms)	80.00-108.00	75.50-101.00
QRS axis(^{0})	11.00-82.20	23.00-77.00
T wave axis(^{0})	23.80-71.40	26.00-64.50
PR interval(s)	0.12-0.19	0.13-0.19
QTinterval(s)	0.32-0.39	0.36-0.40
QTc(s)	0.35-0.43	0.37-0.46

bpm- beats per minute, SBP-systolic blood pressure, DBP-diastolic blood pressure, QTc-corrected QT interval, s-second

Table 3. Normal limits for amplitude (mm) of R wave in limb and chest leads

Lead	Male (n=175)	Female (n=149)
I	3-11	3-13
II	6-19	6-19
III	2-13	1-14
aVL	0-6	0-5
aVF	4-15	3-16
V1	1-9	1-5
V2	2-15	2-12
V3	4-28	4-20
V4	10-33	8-25
V5	9-29	7-21
V6	6-20	6-18

Table 4. .Normal limits for depth (mm) of S wave in limb and chest leads

Lead	Male (n=175)	Female (n=149)
I	0-3	0-2
II	0-4	0-2
III	0-4	0-3
aVL	0-5	0-5
aVF	0-5	0-2
V1	5-23	3-17
V2	5-30	2-17
V3	0-19	0-9
V4	0-11	0-6
V5	0-6	0-3
V6	0-3	0-1

Table 5. Cut-off values for voltage left ventricular (LVH) hypertrophy in young adults.

Voltage Criteria	Description	Male	Female
Sokolow-Lyon	SV1 + RV5	>52mm	>38mm
	SV1 + RV6	>43mm	>35mm
Cornell	SV3 + RaVL	>25mm	>14mm
Araoye	SV2 + RV6	>50mm	>35mm
Ogunlade	(RI+RV5)/2	>20mm	>17mm
Gubner-Ungerleider	RI+SIII	>15mm	>16mm

The mean and normal limits of amplitude (mm) of R wave for leads I, II, III, aVL, aVF, V1,V2,V3,V4, V5 and V6 for 324 young adults were: 6.25 ± 2.60 (3-12), 11.92 ± 3.79 (3-19), 6.44 ± 3.84 (1-13), 2.06 ± 1.87 (0-5), 8.97 ± 3.67(4-16), 3.46 ± 2.19 (1-8), 7.35 ± 3.72 (2-14), 12.68 ± 5.91 (4-24), 18.66 ± 6.80(9-30), 15.63 ± 5.39(8-26) and 11.82 ± 3.97(6-18) respectively. The mean and normal limits of depth (mm) of S wave for leads I, II, III, aVL, aVF,V1,V2,V3,V4,V5 and V6 for the 324 young adults were: 0.48 ± 0.86(0-2), 0.82 ±1.23(0-3), 0.98 ±1.53(0-4), 1.31±1.78(0-5), 0.98 ± 1.71(0-4), 11.05 ± 5.91(3-22), 12.53 ± 7.99(2-28), 6.59 ± 5.71(0-18), 3.30 ± 3.26 (0-10), 1.39 ± 1.83 (0-5) and 0.73 ± 1.57(0-2) respectively. Table 1 showed the demographic characteristics and blood pressure of participants according to gender. Tables 2-4 showed gender specific normal limits for various ECG variables such as heart rate, P wave, PR interval, QRS axis, R wave amplitude, depth of S wave and QT interval. Table 5 showed the cut-off values for Sokolow-Lyon, Cornell, Ogunlade and Gubner-Ungerleider voltage criteria as determined at the 95th percentile of the ECG measurements for the age group.

DISCUSSION

This study provides a comprehensive description of normal limits for the ECG variables of young adults in a Negro population. This is important because data are sparse with regards to the characteristics and normal limits of ECG variable in this population. Moreover, most of the standards for interpretation of ECG utilized in Nigeria are derived from data/criteria obtained from White population such as Minnesota code (Blackburn, 1969).

This study showed that the upper normal limit for heart rate was 88 beats per minute in male and 94 beats per minutes in female. The upper limits for the heart rate for both genders were lower than the universally defined upper limit of 100beats per minute (Spodick , *et al.* 1992).Similar findings of upper limit below 100beats per minute (95 beats per minute) even at 98th percentile had been described in a Chinese population (Wu *et al* . 2003). In a study of apparently healthy young adults in the age group 20-39 years (92 males, 89 females) in the South-Western Nigeria in 1984, Araoye reported mean value of 68 ±13 beats per minutes and 79 ±11 beats per minutes for males and females respectively. By these, the upper limits for heart rate for young adults population studied were lower than 100 beats per minute.

The upper limits for P wave duration and amplitude are used as criteria for evaluation of left atrial and right atrial abnormalities respectively. Left atrial abnormality is assessed when the P wave duration in lead II is greater than 0.12s and right atrial abnormality is assessed when the P wave amplitude in lead II is greater than 2.5mm for both males and females (Mirvis and Goldberger, 2008). The upper limits for P wave duration was 0.12s in male and 0.10s in female while the upper limits for P wave amplitudes were 2mm in both sexes. These suggested that upper limits for P wave duration and amplitude need adjustment for the study population.

The normal limits for PR intervals in males (0.12-0.19s) and females (0.13-0.19s) in this study were comparable to that of the Caucasians (Mirvis and Goldberger, 2008).Similar findings were also described in a Chinese population (Wu *et al*.2003).

The upper limits for corrected QT intervals (QTc) were higher in females than males but the result was consistent with findings in other races. The upper limits for QRS duration were higher in males. However, the upper limits of QRS duration in this study were lower than the reference values defined for broad QRS complex (>120ms) for Caucasian population (Mirvis and Goldberger, 2008).This established that the QRS duration is narrower in the young adult population.

The upper limits of amplitude of R waves and depth of S waves across the limb and chest leads for the age group in the study were higher than previously recorded values. The commonly used diagnostic criteria for left ventricular hypertrophy were based on measurements of QRS voltages. Most of the criteria for the prediction of left ventricular hypertrophy such as Sokolow-Lyon criteria, Cornell criteria, Araoye code system and Ogunlade criterion were derived from the addition of two or more of the upper limits of R wave amplitude and or S wave depth in limb and or chest leads (Sokolow and Lyon 1949, Casale *et al.*1985, Araoye 1996, Hancock *et al.*, 2009, Ogunlade 2010). A few others were derived from the summation of points of some selected criteria and the outcome were given cut-off values (Romhilt and Estes,1968).These criteria were derived from studies conducted among individuals who were mostly greater than 35years in age. The standards for the 16 to 35year age group are not well established

(Hancock *et al*.2009). This study reassessed the existing criteria with a view to defining cut-off values for the most commonly used voltage criteria. It was discovered that for most of the voltage criteria assessed, the upper limits for cut-off values were higher than those previously established for middle age population (table 5).

In conclusion, gender difference exists in some cut-off values for LVH. This study defined the normal limits for electrocardiographic variables for young adult Nigerians. Therefore, among adult population, age, gender and racial factor should be taken into consideration in interpretation of ECG.

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REFERENCES

Araoye, M.A.(1984).The 12-lead electrocardiogram (ECG) healthy adult Nigerians; an investigation of a Yoruba group. A thesis submitted to College of Medicine, University of Lagos, Nigeria:1-248

Araoye, M.A.(1996). Left ventricular hypertrophy by electrocardiography: A code system applicable to Negroes. Nigerian Postgraduate Medical Journal. 3: 92-97.

Bazzet, H.C. (1920). An analysis of the time-relations of electrocardiogram. *Heart*.7: 353-70.

Blackburn, H. (1969). Classification of the electrocardiogram for population studies: Minnesota code. Journal of Electrocardiology. 2, 305-310

Casale, P.N., Devereux, R.B., Kligfied, P.,Eisenberg,R.R., Miller,D.H.,Chaudhary,B.S and M.C.Phillips.(1985).Electrocardiographic detection of the left ventricular hypertrophy: development and prospective validation of improved criteria. *Journal of American College of Cardiology*.6:572-580.

Hancock, E.W., Deal, B. J., Mirvis, D. M., Okin, P., Kligfield, P and Gettes, L.S.(2009). AHA/ACCF/HRS Recommendations for the standardization and interpretation of the electrocardiogram: Part V: Electrocardiographic changes associated with cardiac chamber hypertrophy: 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 of Computerized electrocardiology.Circulation.119: e251-e261.

Kligfield, P., Gettes, L. S., Bailey, J.J., Childers, R., Deal, B.J., Hancock, W., van Herpen, G., Kors, J. A., Macfarlane, P., Mirvis, D.M., Pahlm, O., Rautaharju, P and Wagner,G.S. (2007). 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. Circulation.115, 1306-1324.

Macfarlane, P.M., Mclaughlin, S.C., Devine, B., andYang, T.F.(1994). Effects of age, sex, and race on ECG interval measurements. *Journal of Electrocardiology*. 27:14-19.

Mirvis, D. M and Goldberger, A.L. (2008). Electrocardiography. In: Libby, P.,Bonow, R.O.,Mann, D. L., Zipes, D.P. and Braunwald, E.(eds). Braunwald's heart disease: a textbook of cardiovascular medicine. 8th Ed. Saunders Elsevier:149-193.

Ogunlade,O.,(2010). Prediction of LVH from average of R-wave amplitude in leads I and V5 among adult Nigerians with hypertension. *Nigerian Journal of Postgraduate Medicine*.3(1):5-14

Ogunlade,O.,Ayoka,A.O.,Akintomide,A.O.,Ajayi,O.E., Ukponmwan,O. E and Ogunlade, O.B. (2012). Gender differences in electrocardiogram of young adults in South-Western Nigeria. *European Journal of Scientific Research*.81(1):26-32.

Ogunlade,O., Ukponmwan, O.E., Ayoka, A.O., Akintomide, A.O. and Ogunlade, O.B., (2012). Standard 12-lead electrocardiogram in healthy young adults in South-Western Nigeria. *Acta Cardiologica*. 67(6):665-673.

Rautaharju, P.M., Zhou,S.H., and Calhoun H.P.(1994).Ethnic differences in ECG amplitudes in North American white,black, and Hispanic men and women. *Journal of Electrocardiology*.27: 20-31.

Romhilt, D.W and J.R. Estes. (1968). A point score system for the diagnosis of left ventricular hypertrophy.*American Heart Journal*.75:752-758.

Sokolow, M and T.P. Lyon.(1949).The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial leads. *American Heart Journal*.37:161-186.

Spodick, D.H., Raju R., Bishop, R.L.,Rifkin, R.D.(1992).Operational definition of normal sinus heart rate. *American Journal of Cardiology*.69:1245-1246.

Wu, J.,Kors,J.A., Rijnbeek ,P.R., Herpen,G., Lu, Z., and Xu,C.(2003).Normal limits of the electro-cardiogram in Chinese subjects. *International Journal of Cardiology*.87: 37-51.

Vitelli, L.L., Crow, R.S., Shahar, E., Hutchinson, R.G., Rautaharju, P.M., and Folsom, A.R.(1998). Electrocardiographic findings in a healthy biracial population. *American Journal of Cardiology*, 81:453-459.

Zipes, D.P (2000). Clinical application of electrocar-diogram. *Journal of American College of Cardiology*.36 (6)1746-1748.