Ethnic differences in electrocardiographic amplitude measurements

Ishak A. Mansi, MD*; Ira S. Nash, MD, FACC†

BACKGROUND: There is controversy regarding ethnic differences in electrocardiographic (ECG) patterns because of potentially confounding socioeconomic, nutritional, environmental and occupational factors.

METHODS: We reviewed the first 1000 medical files of a multi-ethnic community, where all individuals shared similar living conditions. Only healthy adults age 15 to 60 years were included. Wave amplitudes were measured manually from the standard 12 lead ECG. Minnesota coding was used.

RESULTS: ECGs from 597 subjects were included in the study: 350 Saudi Arabians, 95 Indians, 39 Jordanians, 17 Sri-Lankans, 39 Filipinos, and 57 Caucasians; 349 were men. The mean±SD of Sokolow-Lyon voltage (SLV) in men was significantly different among ethnic groups (2.9 ± 0.86, 2.64 ± 0.79, 2.73 ± 0.72, 3.23 ± 0.61, 2.94 ± 0.6, 2.58 ± 0.79 mV; *P*=0.0006, for Saudis, Indians, Jordanians, Filipinos, Sri-Lankans, and Caucasians, respectively). SLV was similar among ethnic groups in women. The prevalence of early transition patterns was also different among ethnic groups in men but not women (15.8%, 34.6%, 17.9%, 21.7%, 35.3%, 26.8% in Saudi, Indian, Jordanian, Filipino, Sri-Lankan, and Caucasian men, respectively, *P*=0.037). T wave amplitude was significantly different among ethnic groups in selected leads.

CONCLUSIONS: ECG wave amplitude differs with ethnic origin even when other factors are similar. Using SLV of 3.5 mV as a criterion may overestimate the incidence of left ventricular hypertrophy in some ethnic groups. The pattern of high R wave in lead V1 is common in healthy adults in certain ethnic groups. T wave height differs with ethnic origin and sex.

KEYWORDS: Electrocardiography, ethnicity, left ventricular hypertrophy, T wave

*From the *Department of Medicine, School of Medicine in Shreveport, Louisiana State University Health Sciences Center; and †Mount Sinai School of Medicine, New York.*

Correspondence to:
Dr. Ishak Mansi
Section of General Internal Medicine
Louisiana State University - Health Science Center
School of Medicine in Shreveport
1501 Kings Highway, Shreveport, LA 71130

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Electrocardiography (ECG) plays a pivotal role in clinical decision making. Several studies indicate that T wave inversion, ST segment depression, ST segment elevation, peaked tall T wave and the early repolarization pattern are more prevalent in some ethnic groups.[1-4] Controversy over the occurrence of such inter-ethnic differences exists[1,5,6] as it is difficult to adjust for socioeconomic, environmental, nutritional and occupational factors that may independently affect the ECG.[1,7] In addition, most studies have examined random cross-sections of populations so that the observed ECG differences reflected both potential inter-ethnic variations in the ECG and the different prevalence of cardiovascular diseases in these groups.[1,8-10] Moreover, though ECG differences between black and white populations have been studied extensively,[5,6] few studies are available in other ethnic groups.[11,12]

We compared ECG wave amplitudes in a group of healthy adults from different ethnic groups with similar socioeconomic, nutritional, environmental and occupational conditions. Interval and axes measurements were analyzed separately.[13,14]

Methods

The ECG files of employees of a company in the Eastern Province of the Kingdom of Saudi Arabia and their dependents were reviewed. Employees and dependents lived in the company's residential complex, which included recreational facilities, schools, shops and health care facilities. They had similar socioeconomic and nutritional standards. Permission was obtained to access and collect data from the central medical records room.

The first consecutive thousand ECG files in the record room were reviewed retrospectively. Files were arranged according to employee numbers in the firm. Only ECGs of healthy adult subjects, aged 15 to 60 years, were included in the study. Subjects were excluded if they had hypertension, diabetes mellitus, chronic airway disease, chronic anemia, connective tissue disease or chronic use of any medication. All ECGs were performed in the course of routine preventive medicine, pre-operative evaluation, or trivial illness. If an ECG was reported by the automated analysis as "abnormal", the patient underwent echocardiography and stress ECG as a matter of routine. Only those individuals with normal findings on both were included in the study.

Resting ECGs were recorded in the supine position by trained and licensed technicians using a 3-channel machine (Hewlett-Packard, Pagewriter XLi-Model M1700A). From this recording, integrated analysis software performed the interpretation. All ECGs were reviewed and wave amplitudes were measured manually by one of the authors (I.M.) using the Minnesota Codes definitions and standard of measurements (Addendum).[15] The mean T wave amplitude in the inferior leads (II, III, aVF) for each individual was calculated as a single value. Similarly, the T wave amplitude in each of the pairs of leads (I, aVL), (V3-V4), and (V5-V6) was also calculated as a single value for each pair, to limit the number of variables. T wave amplitudes were approximated to the closest 0.25 mm. (based on calibration of 1 mV=10mm). The T wave was considered diphasic when the negative phase was > 1mm (Figure 1). The Sokolow-Lyon voltage (the sum of the amplitude of the S wave in lead V1 and the amplitude of the R wave in lead V5 or V6, whichever is greater) was measured.[16] Early transition was defined as in Minnesota Code 9.4.1: QRS transition zone at V3 or to the right of V3 on the chest (Figure 2). A high amplitude R wave in the right precordial leads was defined by Minnesota coding 3.2[15,17]: R amplitude ≥5.0 mm and R amplitude ≥ S amplitude in the majority of beats in lead V1, when S amplitude is > R amplitude somewhere to the left on the chest of V1 (Figure 3).

Analysis of results for male and female subjects was done separately for each group. One-way analysis of variance (ANOVA) was used to test for differences between the means of various measurements. Tukey's analysis was performed if ANOVA indicated the presence of a significant difference. The Kruskal-Wallis test was used for comparing ranks of T wave amplitudes. The Chi-square test was used to test the differences in the prevalence of dichotomous factors among groups.

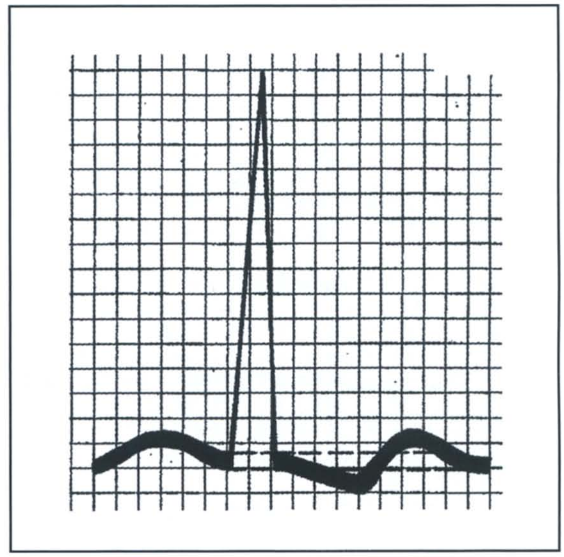

Figure 1. Diphasic T wave.

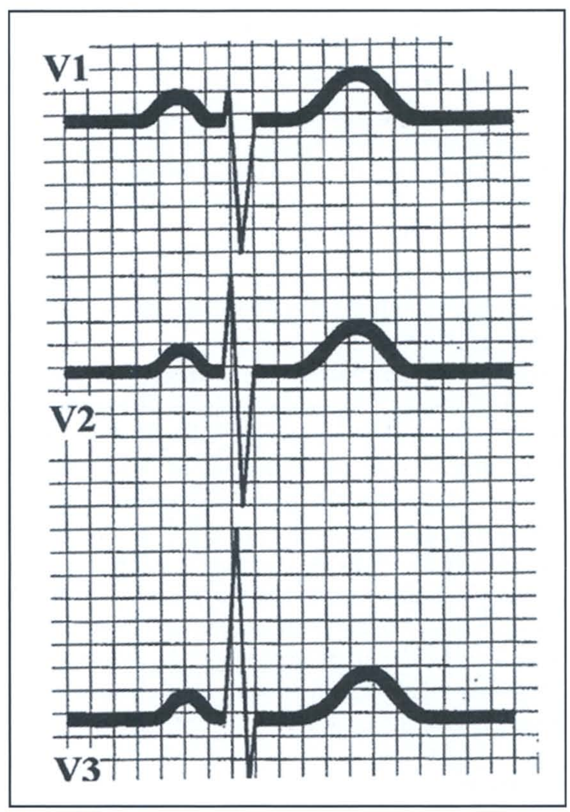

Figure 2. Early transition pattern as defined in Minnesota Coding (Code 9.4.1).

Results

Out of one thousand ECG files reviewed, 597 ECGs were included. The most common causes for exclusion were age less than 15 years or greater than 60 years, diabetes, hypertension, and ischemic heart disease. The study population belonged to six ethnic groups: 350 Saudi Arabian, 95 Indian, 39 Jordanian, 17 Sri-Lankan, 39 Filipino and 57 Caucasian; 349 were males and 248 were females.

For males, ages were similar across all ethnic groups. For the QRS complex, there was a statistically significant difference in Sokolow-Lyon voltage among different ethnic groups. Filipino males had the highest voltage, whereas Caucasians and Indians had the lowest voltage (Table 1). There was no statistically significant difference in the incidence of late transition patterns. There was a statistically significant difference in the incidence of the early transition pattern, which was least common among Saudis and Jordanians (Table 2). There were statistically significant inter-ethnic differences in T wave amplitude in leads I, aVL, and V6, as well as in leads V2-V5. Diphasic T waves were

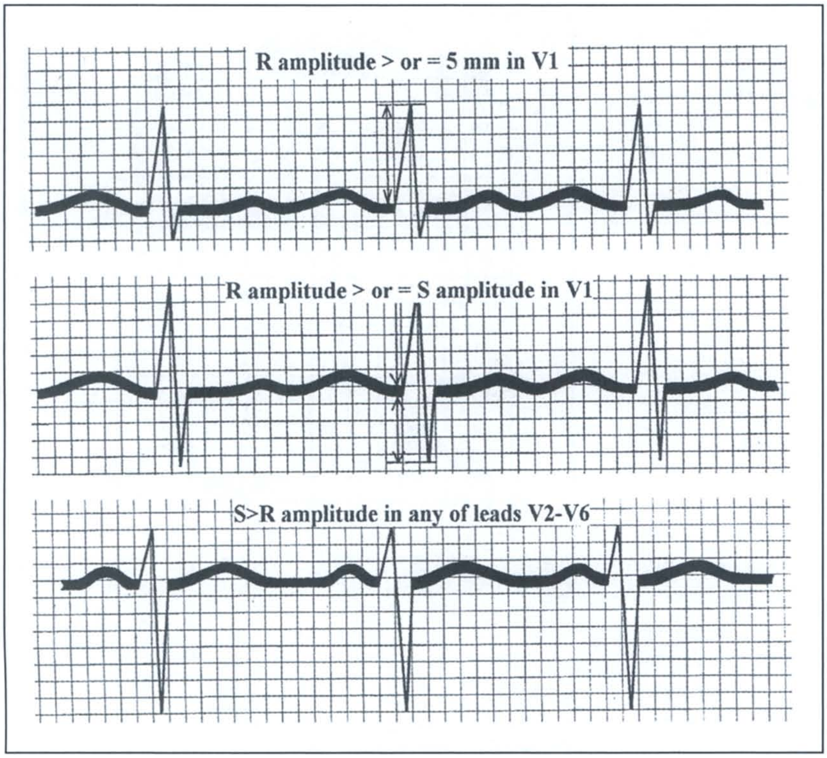

Figure 3. High amplitude R wave in the right precordial leads (code 3.2): R amplitude ≥ 5.0 mm, R amplitude ≥ S amplitude in the majority of beats in lead V1, and S amplitude is > R amplitude somewhere to the left on the chest of V1.

present in 12 men in lead V1, in 4 men in lead V2, and in one in each of leads V3 and V4. There were no ethnic differences (Table 3).

For females, ages were similar among ethnic groups. For the QRS complex, there was no statistically significant difference in Sokolow-Lyon voltage (Table 1). There was also no statistically significant difference in incidence of early transition or late transition patterns. There were differences in T wave amplitudes in leads II, III, aVF, and V2-V6. T wave amplitudes were similar among ethnic groups in leads I and aVL. Filipino females had the highest median T wave in leads V3-V4, and V5-V6. Saudis and Indians had the lowest T wave amplitude in leads II, III, aVF, V2, V3-V4 and V5-V6 (Table 4). There were no diphasic T waves in females in any ethnic group.

Discussion

Normal reference values in ECG parameters have been largely derived from Caucasian populations. Controversy regarding inter-ethnic differences in ECG patterns makes extrapolating these parameters to other ethnic groups problematic.[1,18] Our study addresses the issue of inter-ethnic difference in amplitude measurements of ECG waves.

We found that Sokolow-Lyon voltage differs among different ethnic origin in men but not in women. Difference in QRS voltage among ethnic groups has been reported previously. This was best described in black Americans versus white Americans.[6,12,19-21] Ethnic difference in QRS voltage has also been described among other ethnic groups, including Japanese,[22] Chinese,[11] and Hispanics.[12] The cause of this ethnic difference in QRS voltage may be related to anthropomorphic factors. The Sokolow-Lyon voltage may be affected by body mass index.[12,18,19,23] Some studies reported that African-Americans have smaller thoracic diameters than whites.[24,25] As thoracic diameter decreases, precordial ECG voltage may increase. The Sokolow-Lyon voltage is also related to age.[1,2,16,18] In our study, age was similar across ethnic groups. The relationship between QRS voltage and ethnicity is confounded by differences in the prevalence of diseases, such as hypertension, that may affect QRS voltage. This factor varied in different studies according to their selection criteria. In our study this factor should have been minimal as we included only normotensive individuals.

A prominent R wave in lead V1 may simulate a prior posterior wall myocardial infarction. Few studies, to our knowledge, have compared this pattern among ethnic groups. We found that the incidence of early transition pattern and a high R wave in lead V1 were different among ethnic groups. Sri-Lankan and Indian men had highest prevalence of such patterns, while Saudis had the lowest.

The incidence of T wave changes varies among different ethnic groups.[1,4,27] The incidence of inter-ethnic differences in T wave changes is higher in younger age groups.[1] In our study, T wave amplitude was different among ethnic groups. Differences in T wave patterns among ethnic groups are usually reported according to the Minnesota Codes. However, the lead in which T wave abnormalities appear is not represented in the coding system. Also, all anterior leads (V1-V5) were grouped together. In our study, racial differences in T wave amplitude were present in the inferior leads (II, III, aVF) in females, in the lateral leads (I and aVL) in males, in leads V2-V6 in both males and females, but were not found in lead V1. Walker and Walker also noticed no ethnic differences in T wave height in lead V1.[1] Describing ethnic differences through single Minnesota Code for all leads may not be sufficiently descriptive.

Table 1. ECG parameters in males and females.

Variable	Saudi	Indian	Jordanian	Filipino	Sri-Lankan	Caucasian	
Total (Male)	350 (190)	95 (52)	39 (28)	39 (23)	17 (17)	57 (41)	
Age-Male	43.0 ± 12.1	45.5 ± 8.6	43.7 ± 8.3	39.7 ± 5.8	42.4 ± 5.1	46.8 ± 4.9	NS
HR-Male	**71 ± 14**	**72 ± 12**	69 ± 11	70 ± 12	66 ± 9	*61 ± 8*	*P*<0.001
S-L, Male	**2.9 ± 8.6**	*2.6 ± 7.9*	2.7 ± 7.2	**3.2 ± 6.1**	2.9 ± 6.0	*2.6 ± 7.9*	*P*<0.001
Age-Female	38.5 ± 11.1	39.9 ± 8.5	39.0 ± 6.0	36.4 ± 4.4		44.3 ± 5.3	NS
HR-Female	**80 ± 14**	76 ± 13	77 ± 16	77 ± 16		*71 ± 11*	*P*=0.057
S-L, Female	2.2 ± 0.7	2.1 ± 0.70	2.2 ± 1.0	2.6 ± 1.1		2.5 ± 0.8	NS

Age in years, HR = heart rate in beat per minute, S-L = Sokolow-Lyon Voltage in mV, NS= no statistical significance. Figures written in bold or italic represent values that significantly differed among each other, the bold figures represent significantly higher, and the italic figures represent significantly lower values.

Table 2. Incidence of early and late transition; number (percentage).

Variables	Saudi	Indian	Jordanian	Filipino	Sri-Lankan	Caucasian	
Early transition and high R wave in V1 in males	30 (15.8)	18 (34.6)	5 (17.9)	5 (21.7)	6 (35.3)	11 (26.8)	*P*=0.037
Late transition in males	1 (0.53)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2.4)	NS
Early transition in females	28 (17.5)	12 (27.9)	3 (23.1)	3 (18.8%)	5 (31.2)	N/A	NS

NS = Non-significant statistically.

Table 3. Median value for T wave height in mm in males.

T wave height	Saudi	Indian	Jordanian	Filipino	Sri-Lankan	Caucasian	
Average in II, III, VF	1.00	1.5	1.5	1.3	2.0	1.5	NS
Average in I, aVL	*1.5*	1.5	1.75	**2.0**	1.5	1.5	*P*=0.001
V1	0.0	0.0	0.25	0.0	0.0	0.0	NS
V2	5.0	*5.0*	5.0	**7.0**	6.0	6.0	*P*=0.005
Average in V3-V4	*4.0*	5.0	4.5	**6.0**	6.0	5.0	*P*=0.01
Average in V5-V6	*3.0*	*3.0*	3.0	**4.0**	3.0	3.0	*P*=0.001

NS= no statistical significance. Figures written in bolds or Italics represent values that significantly differed among each other, the bold figures represent significantly higher, and the italic figures represent significantly lower values

Table 4. Median value for T wave height in mm in females.

T wave height in mm	Saudis	Indians	Jordanians	Filipinos	Caucasians	
Number	160	43	13	16	16	
Average in II, III, aVF	*1.0*	*1.0*	1.0	1.25	**1.5**	*P*=<0.005
Average in I, aVL	1.0	1.0	1.5	1.5	1.25	NS
V1	0.1	0.0	0.1	0.1	0.1	NS
V2	*2.0*	*2.0*	3.0	3.0	**3.5**	*P*=0.05
Average in V3-V4	*2.5*	*2.0*	3.0	**3.0**	**3.0**	*P*=<0.005
Average in V5-V6	*2.0*	*2.0*	3.0	**3.5**	2.75	*P*=<0.005

Figures written in bold or italic represent values that significantly differed among each other, the bold figures represent significantly higher, and the italic figures represent significantly lower values. NS= no statistical significance.

Filipinos had the highest median T wave amplitude in leads V2-V6, and Saudis or Indians had the lowest T wave amplitude. Lower median T wave amplitude may increase the likelihood of having flat or inverted T waves. Many studies used such T wave changes as markers for coronary artery disease in Caucasian populations.[10,28] This finding was then applied to other ethnic groups.[8] Our observation suggests that minor T wave changes cannot be applied to other ethnic groups in whom the incidence of low T wave amplitude is common in normal healthy adults. A diphasic T wave, however, was an uncommon finding in males in leads V1 and V2, and rare in leads V3 and V4 (only 2 ECGs), with no ethnic predilection. A diphasic T wave was not found in females.

There are clear ethnic differences in QRS voltage among the ethnic groups studied. Filipinos had higher Sokolow-Lyon voltage, and many of the normal Filipinos in our study would meet the voltage criteria for left ventricular hypertrophy of 35 mm. Inter-ethnic anthropomorphic differences, which can contribute to ECG amplitude differences, include differences in fat distribution,[29] differences in height, body size, and weight- stature ratios.[30]

The limitations of the study included a small number of subjects in some ethnic groups, which may have limited our ability to detect differences among ethnic groups. The small sample size also did not allow stratifying participants by age, which may have yielded more reliable comparisons, even though the mean age was similar in all groups.

In conclusion, QRS voltage varies significantly among ethnic groups. These differences should be considered in defining ECG criteria for left ventricular hypertrophy.The pattern of high R wave in lead V1, which may be occasionally confused with posterior myocardial infarction, may be more common in certain ethnic groups. T wave patterns differ among ethnic groups. Minnesota coding is not descriptive enough for comparing ethnic differences in normal patterns of ECG patterns. A diphasic T wave is not found in normal women and is uncommon in normal men.

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Addendum

Minnesota coding of electrocardiographic findings and measurements is a compilation of standard methods of performing ECG, standard procedures for measurement of wave patterns, and classification of ECG abnormalities. Minnesota coding of ECG was initially started by Perineas et al to be used in their own laboratory. Their attempt was, thereafter, highly quoted, but acquired its international spread when the World Health Organization monograph series included it in its Cardiovascular Surgery Methods, published in 1969. Since then, the Code has been expanded and updated to classify end-points of clinical trial. The Minnesota Code was later published as a manual.[15]

The Minnesota Code manual include details of ECG methodology (as it is commonly performed in many laboratories), detailed methods of measurement of each wave, and coding system for "abnormal" patterns. It must be emphasized that Minnesota Code provides a standardized method for measurement of ECG, but codes only abnormal wave pattern. Accordingly, a perfectly normal ECG will carry no code. A pathologic or non-specific change in the ECG will have a code. This methodology makes the Code popular in comparing cross-sectional large populations, since it enables comparing "abnormal" findings. The coding system is composed of 3 or 2 digits. The first digit is wave specific, for example QRS abnormalities start with 1, and T wave abnormalities start with 5. The second digit refers to the significance of the changes, so as if the second digit is 1 it carries more significance than 2. The third digit, if present, is pattern specific. Lead descriptions is usually grouped and coded into 3 groups: inferior leads (II, III, and aVF), anterolateral leads (I, aVL, V6), and anterior leads (V1-V5). The definitions of the same code differ for each group of leads. For example, code 1.1.1 in anterolateral leads describes an abnormal QRS complex in which Q/R amplitude is ≥1/3 plus a Q duration ≥0.03 second in lead I or V6 whereas, code 1.1.1 in inferior leads describes Q/R amplitude is ≥1/3 plus a Q duration (0.03 second in lead II, but not in III or aVF. Code 5.1 for anterolateral leads describes abnormal T wave in which T amplitude is negative 5 mm or more in either of leads I, V6, or lead aVL when R amplitude is (5.0mm), whereas code 5.1 for inferior leads describes abnormal T wave in which T amplitude is negative 5 mm or more in lead II, or lead aVF when QRS is mainly upright.

Some Minnesota Coding of methods of measurements as used in this article:

Definition of QRS complex: the earliest positive deflection in a QRS complex is the R-wave. Any negative deflection that precedes the R wave is a Q wave. Any negative deflection that follows the R wave is an S wave. The manual contains many illustrative examples of different types of QRS complexes, and how to names waves.

Amplitude measurement of QRS complex: amplitude of the R wave is measured from the upper margin of the preceding P-R baseline and the Q wave amplitude is measured from the lower margin.

High right ventricular R wave (Minnesota Code 3.2): requires all of the 3 following patterns: R amplitude ≥5.0 mm in V1, R amplitude ≥S amplitude in the majority of beats in lead V1, and S amplitude is > R amplitude somewhere to the left on the chest of V1.

Early transition pattern (Code 9.4.1): QRS transition zone at V3 or to the right of V3 on the chest.

Late transition pattern (Code 9.4.2): QRS transition zone at V4 or to the right of V4 on the chest.

T wave negativity measurement: the presence of a negative T-wave is determined by its relation to the top of the preceding P-R segment, but the degree of negativity is measured from the bottom of the ensuing TP interval. The Minnesota Manual of coding includes many examples of how to define J point, ST segment, and the beginning of T wave from an ST segment.

Diphasic T wave: T wave is considered diphasic when the negative phase was > 1mm.