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Normal frank electrocardiogram in athletic and nonathletic adolescent males

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THE NORMAL FRANK ELECTROCARDIOGRAM IN ATHLETIC AND NONATHLETIC ADOLESCENT MALES

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INTRODUCTION

The Normal Electrocardiogram in the Adolescent.

Since the initial communication of Lewis and Gilder[1] on the normal electrocardiogram appeared in 1912, there have been many attempts to establish normal limits for electrocardiographic data. Ziegler's[52] monograph in 1951, almost forty years later, was the beginning for investigation of the normal electrocardiogram in the pediatric age group. Although Ziegler studied normal populations up to age sixteen, he presented data from children ages twelve to sixteen as a single group. Since Ziegler's original work, many authors have investigated the normal electrocardiogram in the pediatric age group. These studies have either failed to include adolescents in the group, have combined adolescents of many ages into a single group, have neglected to determine the limits from the standard deviation or have failed to group populations by sex.

Simonson[41] has discussed the advantages of statistical analysis by standard deviation and the significant influence of age and sex upon the normal electrocardiogram in adult populations. The significant influence of age and sex upon the electrocardiogram in adolescence as well has been discussed by Walker[46] in a study of the importance of age, sex and body habitus in the diagnosis of left ventricular hypertrophy from the precordial electrocardiogram in a group of 849 children and adolescents. In this study, the sum of the voltages in millimeters for the value SV_2+RV_5 was calculated for each of the 849 patients, and after the mean values had been calculated for each year of age from one through sixteen, the difference between the sexes in each age group was subjected to statistical analysis with the t^2 test. Although no significant relationship was found between voltage and general body habitus, the study demonstrated marked differences in the two sexes after eleven years of age. Furthermore, the author concluded that because of the finding of values considerably in excess of those usually quoted to exist in this age group, it was unwise to rely on precordial voltage alone as an index of left ventricular hypertrophy unless the SV_2+RV_5 value was greater than 60 mm in children less than eleven years old, or greater than 55 mm in females and 65 mm in males past eleven years of age.

Unfortunately large voltages in the precordial leads are not the only unusual findings in the adolescent electrocardiogram. The finding of inverted T waves in the precordial leads of the adult electrocardiogram has usually been considered a cause for concern, although this finding has occasionally been reported in normal adult Negroes and Caucasians. The fact remains that this pattern is often associated with acute myocardial disease in the adult. On the other hand, inversion of the T waves in leads V_1 through V_4 have been found so frequently in normal children, that it has been called "the normal juvenile pattern". This pattern has also been reported in normal adolescents by Blackman[6] who discovered that abnormal appearing negative precordial T waves, accompanied in some instances by "cove-laned" ST segments, became quite normal in appearance when the subjects took a maximum held inspiration. It was theorized that in some adolescents the precordial electrodes lie in close proximity to the heart, much like an epicardial electrode. It has been demonstrated that the epicardial electrode tends to show isolated areas of precordial T wave negativity. However, deep inspiration interposes aereated lung tissue between the electrode and the heart, thus making the electrodes "distant" and reverting the negative T wave to its normally upright position. Since anatomic changes in heart-lung relationships occur with growth and maturity, and since these changes are charceteristically associated with adolescence, it seems reasonable to assume that the incidence of normal precordial T wave inversion in adolescence differs from that found in either childhood or adulthood.

This discussion of a few differences observed in adolescent electrocardiograms as compared with either adult or childhood electrocardiograms is not intended to emphasize what is known about adolescent electrocardiography, but rather to illustrate the need for establishing normal values for this age group.

GENERAL CONSIDERATIONS OF NORMAL AND ABNORMAL

The first and most important step in electrocardiographic interpretation is the differentiation between "normal" and "abnormal". The second step is the differentiation between the various abnormal conditions and their relationship to disease. It is quite likely that the disparity in knowledge between what actually is normal and what basically is abnormal has resulted in the present dilemma of the so-called borderline electrocardiogram and the many instances in electrocardiography of "false positives" and "false negatives".

It would appear then that the objective of any study of normality is to more clearly define what is usual or common among persons presently classified as clinically healthy and thus produce a more accurate probability of an individual finding being related to either health or disease.

The problems inherent in determining normality are complex and multiple. In general, one is first confronted with the difficulty of selecting a sample representative of an average healthy population. More specifically, Simonson[41] recommends that the following conditions should be eliminated from a sample considered representative of a healthy population:

1. Coronary heart disease
2. Gross electrocardiographic deviations
3. Arterial hypertension
4. Renal disease
5. Any type of heart disease
6. Acute infectious diseases
7. Endocrine disorders
8. Active gallbladder disease
9. Peptic ulcer
10. Pulmonary disease
11. Diseases of the central nervous system
12. Anemia
13. Metabolic and toxic disorders

Regardless of all precautions, it is probable that any large healthy group will include some individuals with latent disease. However, the following criteria are considered by Simonson to be essential:

1. The sample should be drawn from a population representative of the average population.

2. All conditions (diseases) which might directly or indirectly affect the electrocardiogram should be eliminated from the sample.

3. Certain well established electrocardiographic patterns of abnormality, such as infarct, should be excluded, even with negative clinical findings.

4. The sample should be large enough for statistical evaluation.

5. The electrocardiographic technique should be the same as that used in present clinical electrocardiography, and all leads should be evaluated in the same sample.

6. For determination of the criteria, statistical evaluation by means of percentile distribution is preferable.

7. Statistical breakdown is necessary for the constitutional factors which have a significant effect on the electrocardiogram (age, relative body weight, and sex).

It should be emphasized that there are many variables besides these listed above. Simonson has discussed factors of technical variability with regard to leads, instruments, electrodes and error of measurement, as well as patient related factors of position, exercise, meals, malnutrition, dietary fat, respiratory position, high altitude, blood pressure, chest configuration and race. The most important factors appear to be technical methods of measurement which are uniformly consistent and the biologic factors of age and sex. The effect of relative body weight on the electrocardiogram shows no significant trend in young men, although it becomes considerably more important in those over 45 years of age.

Although there as yet does not seem to be an abundance of information in the literature concerning the chronic effects of exercise on the electrocardiogram, Hugenholtz[22] refers to the physiologic hypertrophy found in athletes and Rautaharju[37] found significant differences in spatial vectors between skiers of international merit and average Finnish populations. The magnitude of the QRS spatial vector was greater and the angle between the QRS and T vectors was smaller in the athletes. One might logcally conclude from this that athletes may form a distinct group by virtue of greater QRS deflections. Although the exact significance of this variable is undetermined at present, there may be some merit in comparing normal values of populations engaged in various degress of physical activity.

Why Study Normal Adolescents with the Frank Lead System?

Despite the apparent simplicity of the differentiation of murmurs, Zaver[51] has emphasized that significant and even severe aortic stenosis can exist in this age group with normal electrocardiograms and without cardiomegaly.

He has also stated that vector cardiography in certain instances may help to indicate signs of left ventricular hypertrophy in those cases in which the electrocardiogram is within the upper limits of normal. Hugenholtz[22, 23, 24] has demonstrated the superior performance of the Frank vector cardiogram in the assessment of congenital aortic stenosis when compared with the performance of standard scalar and exercise electrocardiograms. In so doing, he has also demonstrated that the Frank system may be used in pediatric age groups and is more accurate and reliable in vectorcardiographic analysis than the older cube system.

Hugenholtz and Gamboa[22] have demonstrated high correlation between left and right ventricular hypertrophy and the maximum spatial voltages with the Frank system. They have also demonstrated that maximum .01 and .02 second vectors bear a linear relationship to the magnitude of peak ventricular pressures, and found no overlap with normals when peak left ventricular pressures exceeded 160 mm. Hg. Yano and Pipberger[50] have demonstrated that the Frank system is capable of scalar interpretation also. They achieved a recognition rate of 76 per cent and no false positives using only QRS criteria in the diagnosis of left ventricular overload established by x-ray.

The Frank system has also been demonstrated by Taymor[45] to be of value in the diagnosis of mitral stenosis, and Abildskov[1] found upright or diphasic p waves in lead z only in those patients with left atrial enlargement. In addition, Benchimol and Lucena[5] have published a study of the typical qualitative vectorcardiographic findings that are seen in most of the common congenital heart diseases when studied with the Frank lead system. Also quantitative values for normal adults and children have already been published by Bristow[7], Draper[10], Forkner[12] and Hugenholtz[24] with a striking similarity in results for all four studies.

On a theoretical basis, the Frank lead system is advantageous because of its orthogonal representation of electrical forces.[13, 14] Practically, it has the advantage of simple and easy application and has been shown to possess greater reproducibility, constancy of lead axis, narrower and more uniform ranges of normality, greater accuracy of recording and superior performance in the assessment of ventricular enlargement.

On the other hand, a brief review of the literature by Allenstein[2], Griep[16], Heine[19], Hugenholtz[23], Kilty,[25] Kossman[26], Lasser[27], Myers[29], Parkin[21], Rosenfeld[38], Scott[39], Selzer[40], Soloff[43], Walker[46] and Wolff[49] will reveal that the assessment of ventricular hypertrophy from standard electrocardiograms has been somewhat disappointing with large discrepancies in results and much confusion over the sensitivity and specificity of the various criteria employed.

Two reasons for these discrepancies may be the lack of established normal ranges until quite recently, and the fact that there are certain inherent limitations to a nonorthogonal method of quantitative measurement.

In summary, then, the Frank system was preferred for this study of normal adolescents because:

1. The wide overlap between normal and pathologic is obviously undesirable, and the orthogonal lead system has a smaller range for normal values without loss of sensitivity for abnormal values.

2. A sizable number of independent investigations have already been published, with strikingly similar results, thus indicating the reliability, reproducibility and probable future popularity of the Frank system.

3. The system has been proven superior in evaluating patients with ventricular hypertrophy, a primary consideration in adolescent heart disease.

4. The system requires only seven electrodes and, therefore, is clinically practical.

5. Statistical analysis is less cumbersome because all necessary data is obtained using only three leads.

MATERIALS AND METHODS

Selection of Subjects

Letters explaining the purpose of the study, questionnaires designed to screen for possible heart disease, and forms for parental consent were distributed to approximately four hundred male students enrolled in the athletic and R.O.T.C. programs of Omaha North High School. Approximately 25% of the student population enrolled in the above mentioned programs volunteered for the study. From this group 61 subjects were finally selected to participate on the basis of entirely negative histories and predominately athletic or nonathletic activities. All athletes were in active training at the time and had received physical examinations by their private physicians during the past year.

These 61 subjects were further screened by physical examinations at the University of Nebraska College of Medicine prior to the recording of the Frank electrocardiogram. Physical examination consisted of recording the blood pressure in the right arm in the supine position and examining the chest, heart and neck for any signs suggestive of cardiovascular disease. No subject with a blood pressure greater than 140 mm Hg systolic or 90 mm Hg diastolic was accepted. All subjects were examined by the author in the erect, supine and left lateral recumbent positions, and in all phases of respiration. Auscultation following exercise was not done routinely, but was employed whenever there was some doubt about a particular physical finding.

Murmurs were considered innocent or essentially without pathologic significance only if they had the following characteristics:

1. Midsystolic or systolic ejection type murmurs of grade II or less intensity based on a grading system of VI.

2. Best heard at the upper left sternal border in the supine position and showing obvious variation with positional changes.

3. No palpable or visible thrill.

4. No abnormal widening, fixed splitting or paradoxical splitting of the second heart sound.

5. No increased intensity of the first or second heart sound.

6. No ejection click or opening snap.

7. No protodiastolic, middiastolic or presystolic component to the murmur.

8. No radiation to the back, axilla or radiation to the neck in the erect position.

9. No parasternal lift.

10. No increase in intensity of the murmur with inspiration.

11. Apical point of maximum impulse medical to the midclavicular line.

Any subject with a systolic murmur failing to meet all of the above criteria, as well as any diastolic murmur was referred to a board-certified pediatric cardiologist for further evaluation. If, in the opinion of the cardiologist, the murmur was innocent, the subject was included in the study group. Physical examination resulted in the additional exclusion of three athletes from the prospective study group because of physical findings which could not confidently be regarded as normal. Although they were not included in the normal population, Frank electrocardiograms were obtained on these three individuals for future comparison with their clinically normal peers.

Because all subjects were young, active, apparently healthy, had no past histories suggestive of acquired or congenital heart disease and had no significant abnormalities by physical examination, the routine procedures of chest x-rays and standard electrocardiograms were omitted. Although the addition of these two procedures might have enhanced the validity of assuming all subjects were normal, the procedures are costly and probably inferior to the gross inspection of the vector loop as a means of detecting heart disease in an asymptomatic group of apparently healthy adolescents.

Data regarding individual age, type of activity, ponderal index*, blood pressure and clinical findings are presented in Tables IA and IB.

METHOD OF STUDY

The placement of electrodes and the lead resistance network employed were as proposed by Frank[13]. The fifth intercostal space at the sternal border was used in all cases as the level for the chest leads. Frank's point C, located 45 degrees between the anatomic axes of points A and E, was found by inspection. The examination was performed with the subject seated comfortably.

Standard Welsh precordial electrodes with a diameter of 3 cms. were used. preamplification was via a Tektronix 122 low level preamplifier set at 1000 approximate voltage gain, 1K.C. high frequency and 0.2 low frequency response. Adjustment to base line for each of the three scalar leads was performed prior to the actual recording and all three scalar leads were simultaneously monitored on a Textronix RM561A

Ref. 28 A nomogram based on the formula Ponderal Index = $\text{height}/\sqrt[3]{\text{weight}}$ was used. Values are based on weight to the nearest 5 pounds, height to the nearest inch and index to the nearest 0.5 unit.

oscilloscope during the process of recording onto magnetic tape. A Sanborn 2107 FM Record/Reproduce mode tape recorder, having three FM channels for simultaneous recording of the orthogonal leads together with one direct channel for verbal identification of the subjects was employed. All data was recorded at a speed of 3 3/4 h.p.s, at which rate the recorder has a band width of 0-625 c.p.s, frequency response of ±1 d.b. and total harmonic distortion of 1.5%. A 1MV square wave standardization was recorded at the beginning and termination of the study.

After accumulation of the data on electromagnetic tape, the ECG information was played back into a Sanborn Model 67-1200 three channel direct writer with three separate D.C. amplifiers set at x20 attenuation. Recordings were made at a paper speed of 50mm/sec. after each stylus had been set at a sensitivity such that 10 mm equaled 1mv on the writing paper. Each ECG was then read and values recorded for rate, PR and QRS intervals and maximum deflections of Q, R and S waves in leads X, Y and Z.

Total duration of the QRS was determined by the earliest onset of the Q waves in any one lead and the latest termination of the S wave in either of the other two leads. While this method of calculating the QRS duration varies somewhat from that used in clinical electrocardiography, it must be remembered that all leads are recorded simultaneously with an orthogonal lead system and maximum deflections for each wave differ in time. It was, therefore felt that the total time of depolarization could more accurately be measured by the above mentioned method. Draper[10] has used this method for his study of the Frank ECG in normal men.

Because most clinicians consider a QRS duration of .10 sec. or longer indicative of a ventricular conduction defect, all subjects with QRS intervals .10 sec. or greater were excluded.

RESULTS OF THE STUDY

As illustrated in Tables IA and IB, 13 of the original 28 subjects, or approximately 45% of the athletic group possessed heart murmurs. Three students in this group, one with a diastolic murmur, were excluded because of findings on physical examination. It was found that 10 of the 33 nonathletic subjects had heart murmurs; however, all were considered to be innocent murmurs and none of these subjects were excluded.

Additional subjects were excluded because of a QRS of .10 sec. duration or greater. Only one athlete had a prolonged QRS, and this was subject 59, already excluded on clinical grounds. Interestingly, four subjects from the nonthletic group were excluded because of prolonged QRS duration, subject 20 having a QRS of .14 sec. Subjects 60, 46 and 21 all had QRS durations of .10 seconds. Subjects 36 and 41 were excluded because of a technical defect encountered during the recording period.

Findings for the remaining subjects using the Frank electrocardiogram are given in Tables IIA and IIB. Levels of significance for the difference between the means of parameters measured for athletes and nonathletes are given in Table IIB as determined by the t-test for nonpaired samples.

Since QX, SX, QY and SY were not present in all tracings, the occurrence for each observation is recorded. The number present was used as n in the calculation of the standard deviation (S.D.) and two standard deviations were added and subtracted from the mean to obtain the five and ninety-five percentile limits. For Table IIA the formula $SD = \sqrt{\Sigma(Y-Y)^2/n-1}$ was used. For Table IIB the formula $SD = \sqrt{\Sigma Y^2 - \frac{(\Sigma Y)^2}{n}/n-1}$ was used where ΣY^2 sybolizes the sum of the squares of each of the original values of Y and the quantity $\frac{(\Sigma Y)^2}{n}$ is the square of the total divided by the number of entries in the series. For the t-test, the formula $t = \bar{Y}_1 - \bar{Y}_2 / \sqrt{s_1^2/n_1 + s_2^2/n_2}$ was used where Y, S^2 and n are the respective means, variances and individuals of the two series and t is based on 50 degrees of freedom.

Table IIC provides the results of Draper's study[10] for 510 normal men ranging in age from 19 to 84, the majority being 30 to 50 years of age. This table is presented for comparison, however the reader should be reminded that values were obtained for a much larger series using a computer with a sampling rate of 1000 per second for each lead. Nevertheless Draper's study provides the reader with an idea of values obtained with the Frank system using highly accurate methods and, therefore serves as a baseline for orientation. Draper's values were originally reported in mV's of amplitude, however all values have been multiplied by 10 to convert to millemeters to aid the reader in comparison.

DISCUSSION

As mentioned previously, there exists a multitude of difficulties in attempting to select a "normal" sample from the general population. In this investigation, as in most other investigations of this type, "normal" means essentially free from overt heart disease past or present and the validity of the study can therefore be no better than the accuracy of methods employed in eliminating those subjects with heart disease.

Although standard ECG's and chest films were not used in the present study, several other methods were employed which the author feels lend some confidence to the assertion that the individuals in the group are normal. In contra-distinction to many studies of "normal" subjects hospitalized for a "non-cardiac" illness, all subjects in the present study were overtly well, many functioning satisfactorily in strenuous athletic programs. There is also an advantage in studying the adolescent in that he is usually too young for the ravages of degenerative heart disease and too old to be asymptomatic if he has severe congenital heart disease. Thus it would appear that the chances of selecting a "normal" sample from an adolescent population are quite good. While it is probably true that most adolescents are free from heart disease and its occurrence is relatively rare, we are still faced with a number of subtle and difficult diagnostic problems in this age group.

The small septal defects may cause no symptoms and produce only a rather innocent sounding systolic murmur. This age group is considered more prone to rheumatic heart disease than either the young child or the adult usually and a history of rheumatic fever is sometimes almost impossible to obtain; nor is the low frequency rumble of mitral stenosis easily detectable. The investigator of this age group is also faced with the problems of diagnosing viral myocarditis, familial cardiomyopathies and idiopathic hypertrophic subaortic stenosis. Yet it is probably safe to assume that history and physical examination related to the cardiorespiratory and musculoskeletal systems will screen out most of those individuals suspected of having overt heart disease and the yield of additional significant findings contributed by chest film and ECG would be of relatively minor importance.

Additional safeguards introduced into the study are the exclusion of all subjects with a QRS duration greater than .10 sec. and the use of statistical analysis to better define ranges of normality. To obtain a relatively narrow range for normal values an orthogonal lead system was employed which has demonstrated consistent performance in the past and has shown a good sensitivity and specificity in the detection of ventricular hypertrophy, an important area in adolescent cardiology and an area in which the standard ECG has been somewhat disappointing.

The results of the 52 normal adolescent males ages 13 to 18 are given in Tables IIA and IIB and are rather straightforward and self-explanatory. Although one cannot state the statistical significance of differences, there appears to be a remarkable similarity between values obtained in this study and in Draper's study.

One advantage of the orthogonal lead system over conventional bipolar and unipolar lead systems has been the narrower ranges of normality obtained with the former. Leads X, Y and Z have approximately the same orientation as leads I, AVF and V_2 with positive deflections directed toward the left shoulder, feet and back respectively. When ranges for the orthogonal leads are compared with their theoretical counterparts in standard electrocardiography[52]; one sees that there is a marked decrease in size of normal ranges for the orthogonal leads in this study.

Perhaps the most interesting aspect of the study, however, is the comparison of athletes and nonathletes found in Table IIB. As mentioned in the introduction, Simonson[41] has discussed the influence of age, sex, body habitus and a variety of other factors which are considered under the general term of "biologic variables". Although chronic exercise programs are advocated as healthy and are thought to influence the heart, there is no general agreement as to the exact influence it has on the heart nor whether the ECG of the athlete differs significantly from that of the nonathlete. Rautebarju[37] found greater maximum spatial vectors for athletes but these were skiers of international merit. Hugenholtz[22] describes the so-called "athletes heart" as a physiologic left ventricular hypertrophy, whereas Smith[42] found right ventricular hypertrophy in marathon runners competing in the British Commonwealth Games. It is general knowledge that athletes have slower heart rates; but when does a person become an athlete with an athlete's heart rate? A comparison of the mean heart rates of the two groups given in Table IIB indicates that even during adolescence when all boys are supposedly young, healthy and active there is a highly significant difference in the mean heart rates of the two groups.

An additional observation, perhaps more intriguing though statistically less significant, is the difference in the mean Rz between athletes and nonathletes. Since an R wave in lead Z indicates posteriorly directed forces, one would expect athletes with the so-called "athletes heart" and physiologic left ventricular hypertrophy to have posteriorly directed forces of greater magnitude than those of their nonathletic peers. This does not appear to be the case in this study however, because the athletes actually have a mean Rz which is smaller than their peers. One might consider Smith's[42] finding of right ventricular hypertrophy more reasonable, especially since the mean values for Qx and Sx appear greater in athletes, indicating greater rightward initial and terminal forces in the process of depolarization. However, the differences of the means Qx and Sx are significant at the 10% level only, which is not significant at all. We are, therefore, left with only a few conclusions from this study:

1. The Frank orthogonal electrocardiogram has been used successfully in the study of both children and adults and has resulted in narrower ranges for normal than are commonly published data obtained from conventional bipolar and unipolar leads. Narrower ranges for normal values were also observed in the present study of adolescent males.

2. Bristow[7], Draper[10], Forkner[12] and Hugenholtz[32] have noted a remarkable similarity in findings when studying different populations with orthogonal leads. Although statistical analysis was not attempted to compare values found in this study with the results of Draper's study, there again appears to be a remarkable similarity in results obtained.

3. There is a statistically significant difference between the heart rates of athletes and nonathletes even in adolescence.

4. Examination of maximum Q, R, and S waves of the Frank orthogonal ECG fails to reveal any statistically significant difference between those deflections in athletes and in nonathletes. The finding of a difference between the two groups for Rz significant at the 5% level is only of borderline significance at best and leaves the question of ventricular hypertrophy in athletes an open issue.

It is the author's opinion that further study of the group employing analysis of instantaneous vectors may provide worthwhile additional information.

SUMMARY AND CONCLUSIONS

A total of 52 normal adolescent males ranging from 13 to 18 years of age were studied with the Frank orthogonal ECG in an effort to establish normal limits for electrocardiographic measurements for this age group and sex. All subjects were obtained from the athletic and R.O.T.C. programs of a local high school and were classified on the basis of activities as either "athletic" or "nonathletic". Electrocardiographic data for the QRS complex, PR interval and heart rate was analyzed statistically for each group and the statistically significance of differences between the two groups was ascertained.

The Frank orthogonal ECG was found to yield narrower ranges in this age group than are normally found with conventional bipolar and unipolar leads and yielded values remarkably similar to those found in other studies using the Frank system. Comparison of heart rates between athletes and nonathletes revealed a statistically significant difference and a difference of borderline significance was found between the two groups for the R wave in lead Z, suggesting a difference in posteriorly directed forces of depolarization for the two groups. Theories concerning the development of physiologic ventricular hypertrophy in athletes were mentioned briefly and it was suggested the vectorcardiographic analysis of the group might yield additional worthwhile information.

ADDENDUM

It was intended at the beginning of this study that all electrocardiographic data would be analyzed by a computer. From studies by Abildskov[1] and Pipberger[34], it is evident that all information found in the conventional 12 lead ECG is present in the 3 lead Frank System. Nevertheless, somewhere between seven and ten per cent of significant diagnostic features of the standard 12 lead ECG cannot be recovered in scalar orthogonal 3 lead records when examined clinically. This apparently serious drawback to the Frank system is actually insignificant when a computer is used because all clinical information can be recovered from the 3 lead system by resolution of the 3 basic orthogonal components and/or vector loop representation, which are rather simple functions for a large computer. This indicates that the clinical information is contained in the 3 lead ECG but cannot be recognized without transformation of data.

A program of orthogonal lead computer analysis has been in operation at the Mayo Clinic for some time and an attempt was made there to analyze the data recorded on electromagnetic tape at University of Nebraska College of Medicine. Unfortunately, a difference in tape recording machines at the two institutions made it impossible to accurately convert analog to digital information. After several unsuccessful attempts at correcting the system incompatability, the tape was returned.

The University of Nebraska College of Medicine Department of Biomedical Engineering has quite recently received a copy of the program presently in operation at the Mayo Clinic and now possesses all the equipment necessary for electrocardiographic computer analysis. Work on this program should begin within the next few weeks and the system is expected to be operational before mid-July, 1966. Once this program is operational, further investigation employing analysis of instantaneous spatial vectors is planned.

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Table I-A

Clinical Data on Athletic Group of Subjects

Case Number	Age	Ponderal Index	Blood Pressure	Comments
9	13	13.5	122/60	Innocent murmur
3	14	13	120/70	
54	14	14	110/74	Innocent murmur
57	14	13.5	130/70	Innocent murmur
1	15	12.5	110/60	
6	15	13	120/80	Innocent murmur
10	15	13	140/84	Possible A.S.D.
39	15	13	128/70	
50	15	13	130/70	
58	15	13	110/70	Innocent murmur
59	15	13	120/60	Possible A.S.
4	16	12.5	120/70	Innocent murmur
5	16	13.5	126/74	
11	16	13	110/70	
22	16	13	130/74	
40	16	13.5	120/60	Innocent murmur
49	16	14	98/70	
52	16	14	134/80	
53	16	13.0	110/60	Innocent murmur
55	16	12.5	132/70	Innocent murmur

Table I-A

Clinical Data on Athletic Group of Subjects

Case Number	Age	Ponderal Index	Blood Pressure	Comments
56	16	13.0	120/60	
61	16	13	110/70	
2	17	12	120/80	
7	17	12	110/56	Innocent murmur
8	17	13	110/70	
43	17	13	128/72	
51	17	13	120/60	
13	18	13.5	130/70	Possible A.I.

Table I-B

Clinical Data on Nonathletic Group of Subjects

Case Number	Age	Ponderal Index	Blood Pressure	Comments
16	14		130/76	
20	14	13	114/68	
38	14	13.5	112/70	
60	14	13.5	130/60	
15	15	14	100/50	
23	15	13.5	130/72	Innocent murmur
24	15	13.5	112/72	Venous hum
28	15		120/60	Innocent murmur, venous hum
29	15	14.5	100/60	
37	15		114/70	
46	15	13.5	118/60	Innocent murmur
48	15	12.5	138/80	Innocent murmur
12	16	14	132/70	
17	16	13.5	130/76	
21	16	13	120/70	Occasional premature beats
31	16	13.5	120/60	
32	16	14	120/72	
34	16	13	120/60	
36	16		136/70	

Table I-B

Clinical Data on Nonathletic Group of Subjects

Case Number	Age	Ponderal Index	Blood Pressure	Comments
41	16	13	130/74	Innocent murmur
42	16	13	120/50	Innocent murmur
44	16	13.5	138/80	Innocent murmur
47	16	12.5	130/74	
14	17	13	110/60	
18	17	14	120/70	Innocent murmur
25	17	13	120/70	
26	17	13	122/84	
27	17	12.5	110/72	
33	17	13.5	96/52	
35	17	13	120/74	
45	17	14	134/68	Innocent murmur
19	18	12	110/60	
30	18	13.5	126/76	

Table IIA

QRS Amplitudes of Adolescent Males 13 to 18

Total Number	9	9	16	18
Parameter	Ath 13-15	Nonath 13-15	Ath 16-18	Nonath 16-18
Qx present	2	8	6	9
Mean	1	.88	1.58	.67
SD	0	.51	1.75	0.5
5→95 percentile	-	0→1.90	0→5.08	0.33→1.67
Range	1-1	0.5-2.0	0.5-5.0	0.5-2.0
Rx present	9	9	16	18
Mean	9.8	11.20	10.94	9.89
SD	4	2.37	3.43	4.31
5→95 percentile	1.8→17.8	6.46→15.94	4.08→17.8	1.27→18.51
Range	3-15.5	8-16.5	3-15	2.5-21.0
Sx present	8	8	14	17
Mean	4.38	2.44	3.54	2.74
SD	4.15	1.16	2.13	1.6
5→95 percentile	0→12.68	0.12→2.32	0→7.8	0→5.94
Range	1-13	0.5-4.0	0.5-7.0	0.5-6.0
Qy present	5	5	6	9
Mean	0.70	1.40	1.00	1.06
SD	.087	.76	0.55	0.62
5→95 percentile	0→.874	0→2.92	0→2.10	0→2.3
Range	0.5-1.0	0.5-2.5	0.5-1.5	0.5-2.0
Ry present	9	9	16	18
Mean	12.6	11.22	11.0	11.17
SD	5.2	4.3	5.14	4.60
5→95 percentile	1.9→23.0	2.62→19.82	0.8→21.28	1.97→20.37
Range	1-17.5	5-18	1-19	1.5-18.0
Sy present	6	4	9	9
Mean	1.58	2.13	2.56	2.61
SD	1.28	1.25	1.89	.31
5→95 percentile	0→4.14	0→4.63	0→6.34	1.99→3.23
Range	0.5-4	0.5-3.5	1-6	1.5-4.0
Qz present	9	9	16	18
Mean	3.2	3.5	3.50	2.61
SD	1.23	2.06	1.12	1.23
5→95 percentile	0.74→5.66	1.44→5.56	1.26→5.74	0.15→5.07
Range	1.5-4.5	2-4.5	2.0-6.0	0.5-4.0
Rz present	9	9	16	18
Mean	8.4	10.40	8.90	9.92
SD	3.4	.74	3.05	1.46
5→95 percentile	1.6→15.2	8.92→11.88	2.8→15	7→12.84
Range	3.0-11.5	9-11.5	4-11.5	7-11.5

All values given in mm. amplitude

Table IIB

Maximal QRS Amplitudes Ages 13 to 18

Parameter	Athlete	Nonathlete	t Test Significant Level (N.S. = Not Significant)
Total Number	25	27	
Qx present	8	16	
Mean	1.44	.81	10%
5→95 percentile	0→3.98	.72→.90	
Rx present	25	27	
Mean	10.54	10.34	N.S.
5→95 percentile	8.24→12.84	5.98→14.70	
Sx present	22	25	
Mean	3.84	2.64	10%
5→95 percentile	0→9.76	0→5.36	
Qy present	8	13	
Mean	1.19	1.27	N.S.
5→95 percentile	0→2.75	1.03→1.51	
Ry present	25	27	
Mean	11.56	11.19	N.S.
5→95 percentile	1.50→21.62	2.37→20.01	
Sy present	15	13	
Mean	2.17	2.46	N.S.
5→95 percentile	0→5.73	0.36→4.56	
Qz present	25	27	
Mean	3.38	2.91	N.S.
5→95 percentile	1.34→5.42	2.13→3.69	
Rz present	25	27	
Mean	8.74	10.07	5%
5→95 percentile	2.50→14.98	7.57→12.57	
PR. (sec)			
Mean	.124	.119	N.S.
5→95 percentile	.079→.169	.091→.148	
QRS (sec)			
Mean	.08	.08	N.S.
5→95 percentile	.080→.081	.069→.092	
Rate (per min.)			
Mean	71.2	81.85	0.1%
5→95 percentile	40.9→91.5	56.45→107.25	

All values given in mm. amplitude unless otherwise stated

Table IIC

Study of 510 Normal Men QRS Amplitudes

Item	Results
Qx present	306
Mean	1.0
SD	0.5
96% limits	0.3→2.5
Rx present	510
Mean	11.7
SD	3.7
96% limits	5.1→19.7
Sx present	407
Mean	2.7
SD	1.5
96% limits	0.6→6.8
Qy present	333
Mean	1.0
SD	0.7
96% limits	0.1→2.9
Ry present	510
Mean	10.3
SD	4.1
96% limits	3.5→19.5
Sy present	274
Mean	1.8
SD	1.2
96% limits	0.3→4.9
Qz present	510
Mean	4.1
SD	2.1
96% limits	0.9→9.3
Rz present	510
Mean	9.3
SD	3.5
96% limits	3.6→17.9

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