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A study of vector electrocardiography: The normal Q,R,S,T, and P vectors, ventricular gradient and QRS-T angle in frontal plane in young Korean adults

Isaack Sohn* Sung-Yul Lim†

*Korean Medical Association,

†Korean Medical Association,

A study of vector electrocardiography: The normal Q,R,S,T, and P vectors, ventricular gradient and QRS-T angle in frontal plane in young Korean adults*

Isaack Sohn and Sung-Yul Lim

Abstract

The vector electrocardiographic method was applied on 126 healthy young Korean adults without any evidence of cardiac diseases. The range of the age of the subjects were between 19 and 34. The normal values of the magnitude and direction of the mean QRS, T, P vectors, ventricular gradient and QRS-T angle in frontal plane were presented and discussed in comparison with those previously reported in the literature. Considering the age of the subjects under study, our results were in general agreement with those previously reported by other authors.

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A STUDY OF VECTOR ELECTROCARDIOGRAPHY: THE NORMAL Q, R, S, T, AND P VECTORS, VENTRICULAR GRADIENT AND QRS-T ANGLE IN FRONTAL PLANE IN YOUNG KOREAN ADULTS[1,2]

Isaack SOHN, and Sung-Yul LIM

Lt. Col., MC, and Capt., MC, ROK Army, Seoul, Korea

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In recent years, there has been an increasing trend in the medical literature to analyze the magnitude and direction of the cardiac vectors either on the frontal plane or in space by various methods in addition to the conventional, scalar electrocardiographic study[1,2]. Two methods are available for studying the cardiac vectors. In the method of vector electrocardiography, the direction of the electrical forces responsible for the conventional electrocardiographic waves are visualized in space and are represented as vectors. Vectorcardiography, on the other hand, uses different equipment and different electrode attachment. This method, utilizing an oscilloscope, actually records the direction and magnitude of the instantaneous electrical forces of the heart and allows one to study the QRS—T, and P loops[3].

In our present study, we applied the vector electrocardiographic method on 126 healthy young adults without any evidence of cardiac diseases. The purpose of this study was to obtain the normal value of the magnitude and direction of the mean QRS—T, P vectors, ventricular gradient and QRS—T angle in young Koreans on the frontal plane, and the results thus obtained by this method were compared with those previously reported in America and Japan.

MATERIAL AND METHOD

Our observations have been carried out on 126 normal young Korean adults, 66 males and 60 females. All subjects underwent complete physical examination including chest-X ray and were found to have no evidence of cardiac diseases. The females were mostly student nurses and the males were army officres. The range of the age was between 22 and 34 in male and 19 and 34 in female. The distribution of age is shown in Table 1 and the electrical heart positions of

1. The outline of this study was presented at the Annual Session of The Korean Medical Association, Pusan, Korea, October, 1959.

2. This study was supported by a grant from The Special Treatment and Research Program, Surgeon General's Office, ROK Army.

these subjects are classified in Table 2.

Table 1. The age distribution of subjects.

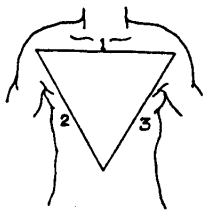
age	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Total
♂				1	5	3	4	11	13	7	11	4	2	2	2	1	66
♀	10	16	13	6	2	3	1	5	3							1	60
Total	10	16	13	7	7	6	5	16	16	7	11	4	2	2	2	2	126

Table 2. The classification of electrical heart position in 126 subjects.

	Vertical	Semivertical	Semihori-zontal	Intermediate	Indetermi-nate	Total
♂	17	39	2	4	4	66
♀	12	23	4	19	2	60
Total	29	62	6	23	6	126
%	23.0	49.2	4.8	18.2	4.8	

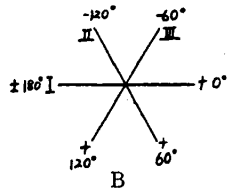
The electrocardiograms were taken with a Sanborn Cardiette electrocardiograph. The standard triaxial reference system of Bailey was used for plotting the derived frontal plane axes (Fig. 1). The areas of corrected electrocardiographic potentials were measured in standard leads. The value from each lead, expressed as Ashman unit[4,5,6], were adequately plotted on Baily's triaxial reference system and the direction and magnitude of the area vectors were calculated (Fig. 2).

Fig. 1. The reference systems.



A

The Equilateral Triangle of Einthoven



B

The Triaxial Reference System of Bailey

The ventricular gradient in this study was obtained by simple method of plotting the mean QRS and T vectors in their proper directions and magnitudes in the frontal plane and treating these as the two sides of the parallelogram. As shown in Fig. 3. the ventricular gradient is the diagonal of the parallelogram.

Fig. 2. Drawing off cardiac mean vectors. A. Measurement of vectors from the electrocardiographic deflections in the limb leads by Ashman unit. B. Drawing of cardiac mean vectors on Bailey's triaxial reference system.

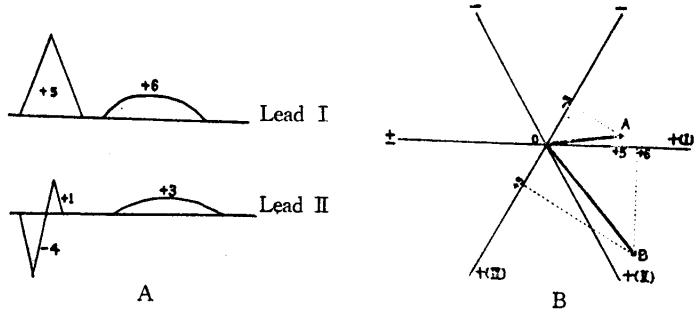
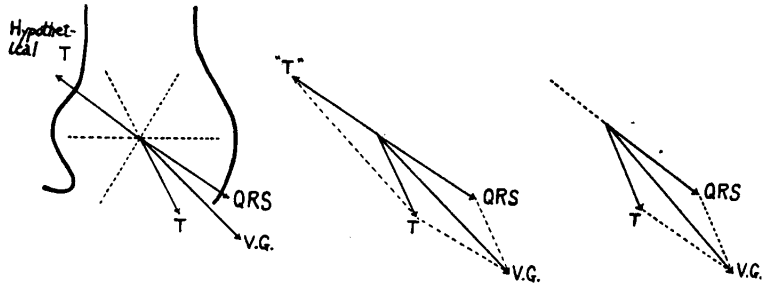


Fig. 3. Method of obtaining ventricular gradient.



Ventricular Gradient

RESULTS

The incidence in the various directions and magnitudes of QRS, T, P vectors, ventricular gradient and QRS—T angle are summarized in Table 3 and 4.

The directions and magnitudes of mean QRS—T, P vectors, ventricular gradient and QRS—T angle in various heart positions in male and female are illustrated in Tables 5, 6, 7 and 8.

The average mean QRS vector was directed toward +50.6 degrees (minimum +7 degrees, maximum +90 degrees) in male and +57.6 degrees (minimum +18 degrees, maximum +92 degrees) in female. The average of mean QRS vector was 7.2 Ashman units (minimum 1.7 Ashman units, maximum 19.5 Ashman units) in male and 5.5 Ashman units (minimum 2.5 Ashman units, maximum 15 Ashman units) in female.

The average mean T vector was directed toward +34.1 degrees (minimum +5 degrees, maximum +82 degrees) in male and +42 degrees (minimum +20 degrees, maximum +63 degrees) in female. The average magnitude of mean T vector was 6.6 Ashman units (minimum 3.5 Ashman units, maximum

Table 3. Incidence of direction of mean QRS, T, P vectors, ventricular gradient and QRS—T angle.

angle	AQRS	AT	AP	G	QRS—T
0~10°	1	2	7	1	47
11~20°	2	3	6		35
21~30°	3	8	8	6	22
31~40°	9	25	14	12	16
41~50°	14	46	19	29	5
51~60°	28	31	31	33	1
61~70°	30	9	26	31	
71~80°	24	1	10	13	
81~90°	14		2	1	
91~100°	1	1			
101~110°					
0~−10°			1		
−11~−20°			1		
−51~−60°			1		
Total	126	126	126	126	126

20.1 Ashman units) in male and 4.9 Ashman units (minimum 1.0 Ashman units, maximum 9.5 Ashman units) in female.

The average direction of mean P vector was +47.3 degrees (minimum −60 degrees, maximum +84 degrees) in male and +40.4 degrees (minimum 0 degree, maximum +78 degrees) in female. The average magnitude of mean P vector was 1.1 Ashman units (minimum 0.5 Ashman unit, maximum 26 Ashman units) in male and 0.9 Ashman unit (minimum 0.2 Ashman unit, maximum 1.7 Ashman units) in female.

The average direction of ventricular gradient was +44.2 degrees (minimum +6 degrees, maximum +82.5 degrees) in male and +51.6 degrees (minimum +22 degrees, maximum +75 degrees) in female. The average magnitude of ventricular gradient was 12.9 Ashman units (minimum 7.2 Ashman units, maximum 28.2 Ashman units) in male and 10 Ashman units (minimum 4.5 Ashman units, maximum 17.7 Ashman units) in female.

The average angle formed by the mean QRS and T vectors was 15.7 degrees (minimum 0 degree, maximum 52 degrees) in male and 18 degrees (mi-

Table 4. Incidence of magnitude of mean QRS, T, P vectors, and ventricular gradient.

Ashman unit	AQRS	AT	AP	G
0.5			20	
1		3	100	
2	1	2	6	1
3	16	11		
4	11	25		
5	9	26		4
6	21	21		2
7	20	12		5
8	14	10		6
9	9	10		14
10	9			11
11	4	2		11
12	3			8
13	5	1		17
14	1	1		10
15	2			7
16		1		4
17				11
18				4
19				1
20	1	1		3
21				1
24				2
25				1
28				1
30				
31				1

Table 5. Direction of mean QRS, T, P vectors, ventricular gradient, and QRS—T angle in male.

	AQRS			AT			AP			G			AQRS—T angle		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Vertical	+55	+86	+78	+37	+77	+54	−60	+80	+54.9	+43	+82.5	+65.6	+3	+41	+21.1
Semivertical	+22	+90	+68	+11	+82	+32.1	−17	+84	+52.2	+40	+79	+60.8	0	+52	+18.7
Semihorizontal	+ 7	+28	+17.5	+ 5	+21	+13	−10	+56	+23	+ 6	+24	+15	+2	+ 7	+4.5
Intermediate	+34	+56	+40.4	+13	+55	+39.7	+47	+69	+59	+24	+55.5	+41.5	+1	+47	+17.5
Indeterminated	+37	+61	+48.7	+ 8	+55	+31.7	+36	+55	+47.7	+26	+58	+38.5	+4	+29	+17
Total	+ 7	+90	+50.6	+ 5	+82	+34.1	−60	+81	+47.3	+ 6	+82.5	+41.2	0	+52	+15.7

Table 6. Direction of mean QRS, T, P vectors, ventricular gradient, and QRS—T angle in female.

	AQRS			AT			AP			G			AQRS—T angle		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Vertical	+59	+92	+73.5	+38	+63	+49.5	0	+72	+44.3	+47	+75	+63.4	9	50	22.7
Semivertical	+49	+79	+63.2	+27	+55	+42.3	0	+78	+38.4	+40	+68	+57.7	4	40	32.5
Semihorizontal	+18	+69	+39.7	+37	+50	+41	+17	+57	+34.5	+26	+68	+41.7	3	19	11
Intermediate	+21	+58	+50.2	+20	+62	+37	+13	+61	+44.2	+20	+60	+43.5	1	21	7.1
Indeterminated	+61	+67	+63.5	+41	+45	+43	+20	+62	+41	+51	+53	+51.5	20	22	21
Total	+18	+92	+57.6	+20	+63	+42.5	0	+78	+40.4	+20	+75	+51.6	1	50	18.9

Table 7. Magnitude of mean QRS, T, P vectors, ventricular gradient in male. (Ashman unit)

	AQRS			AT			AP			G		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Vertical	3.1	19.5	8.7	4.5	16.5	7.4	0.5	2.6	1.2	8.8	28.2	15.6
Semivertical	2.5	15.3	8.0	3.5	20.1	7.0	0.5	2.2	1.2	7.4	25.1	14.1
Semihorizontal	5.7	8.7	7.2	4	5	4.5	0.6	1	0.8	7.2	9.7	8.5
Intermediate	3.2	8.7	5.0	4.5	6.2	5.1	0.6	1.2	0.9	9.0	14.5	10.1
Indeterminated	1.7	10	7.2	4.8	13.7	8.4	0.5	1.5	1.3	10.0	24.0	16.5
Total	1.7	19.5	7.2	3.5	20.1	6.6	0.5	2.6	1.1	7.2	28.2	12.9

nimum 1 degree, maximum 50 degrees) in female.

The variation in positions of mean QRS vectors in various heart positions

Table 8. Magnitude of mean QRS, T, P vectors and ventricular gradient in female.

	AQRS			AT			AP			G		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Vertical	3.0	15.0	6.7	3.0	8.8	3.8	0.5	1.2	0.9	7.2	24	10.8
Semivertical	3.5	10.7	6.8	2.2	9.5	5.5	0.3	1.5	0.9	6.2	17.7	12.3
Semihorizontal	2.5	6.1	3.8	1.0	4.5	3.4	0.4	1.0	0.6	4.5	10.7	7.2
Intermediate	3.2	6.5	4.9	5.2	5.7	5.4	1.6	1.7	1.6	8.5	12.2	10.3
Indeterminated	2.5	6.7	5.1	1.7	7.5	5.3	0.2	1.2	0.7	4.6	14.2	10.2
Total	2.5	15.0	5.5	1.0	9.5	4.9	0.2	1.7	0.9	4.5	17.7	10.1

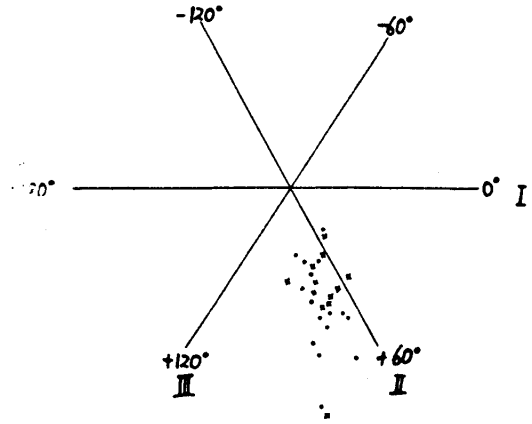
are illustrated in Fig. 4, A through F, in which the magnitudes and directions of mean QRS vectors in the frontal plane were plotted in each heart position and in entire cases. According to these illustrations, it is quite clear that the positions of mean QRS vectors distinctively differ in accordance with each different heart position. In the vertical heart position, the position of mean QRS vectors are mainly located in the 5th sextant, whereas in the semihorizontal and intermediate heart positions they are mostly found in the 6th sextant. In the semivertical heart position, the mean QRS vectors are found equally in both 5th and 6th sextants.

The variations in positions of mean T vectors in various electrical heart positions and entire cases are illustrated in Fig. 5, A through F, in which the magnitudes and directions of mean T vectors in frontal plane were plotted in each heart position and in entire cases. With only a few exceptions, almost all mean T vectors are located in the 6th sextant, although the mean T vectors in the vertical and semivertical electrical heart positions were located closer to the boarder of the 5th and 6th sextants and T vectors in the intermediated and semihorizontal electrical heart positions closer to the boarder of the 6th and lst sextants.

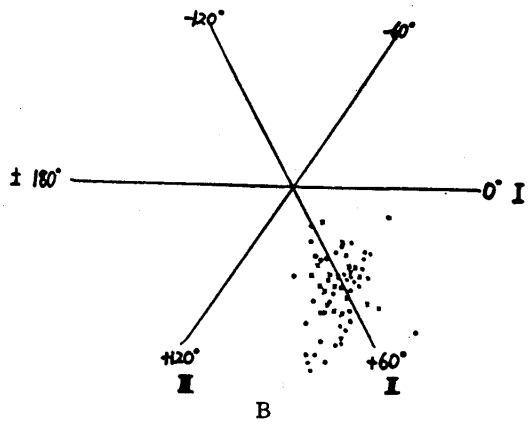
The variations in positions of mean P vectors in various electrical heart positions and entire cases are illustrated in Fig. 6, A through F, in which the magnitudes and directions of mean P vectors in frontal plane were plotted in each heart position and in entire cases. Majority of the mean P vectors are located in the 6th sextant and the extremes were −60 degrees and +84 degrees.

The variations in orientations of ventricular gradient are illustrated in Fig. 7, A through F, in which the magnitudes and directions of ventricular gradients in frontal plane were plotted in each electrical heart position and in entire cases. According to these illustrations, the positions of ventricular gradients in

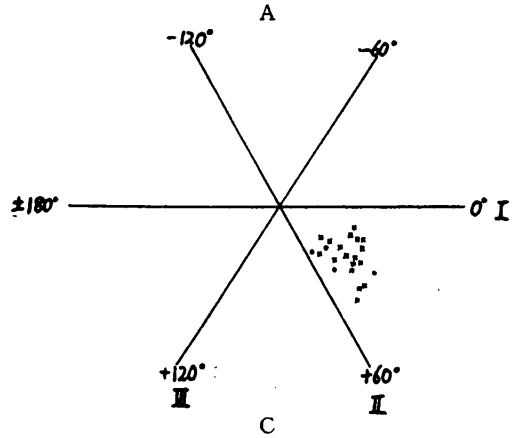
Fig. 4. Magnitudes and directions of mean QRS vectors in the frontal plane in the various heart positions. A. Vertical, B. Semivertical, C. Intermediate, D. Semihorizontal, E. Indeterminate, F. Entire cases. . male, × female.



A



B



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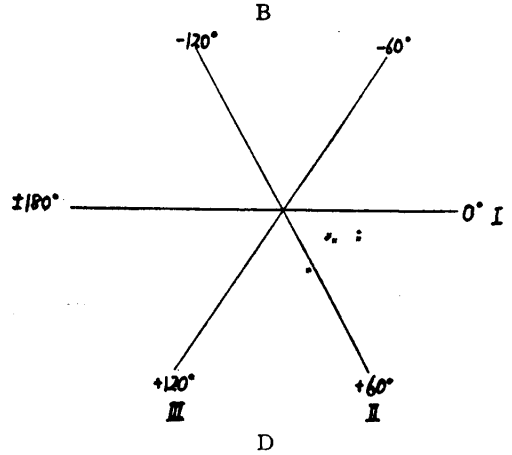

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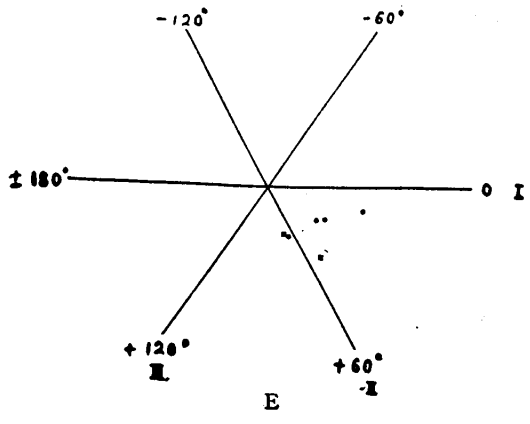

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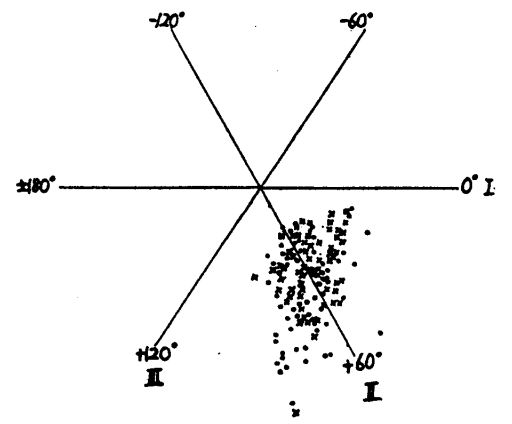


F

Fig. 5. Magnitudes and directions of mean T vectors in the frontal plane in the various heart positions. A. Vertical, B. Semivertical, C. Intermediate, D. Semihorizontal, E. Indeterminate, F. Entire cases. . male, × female.

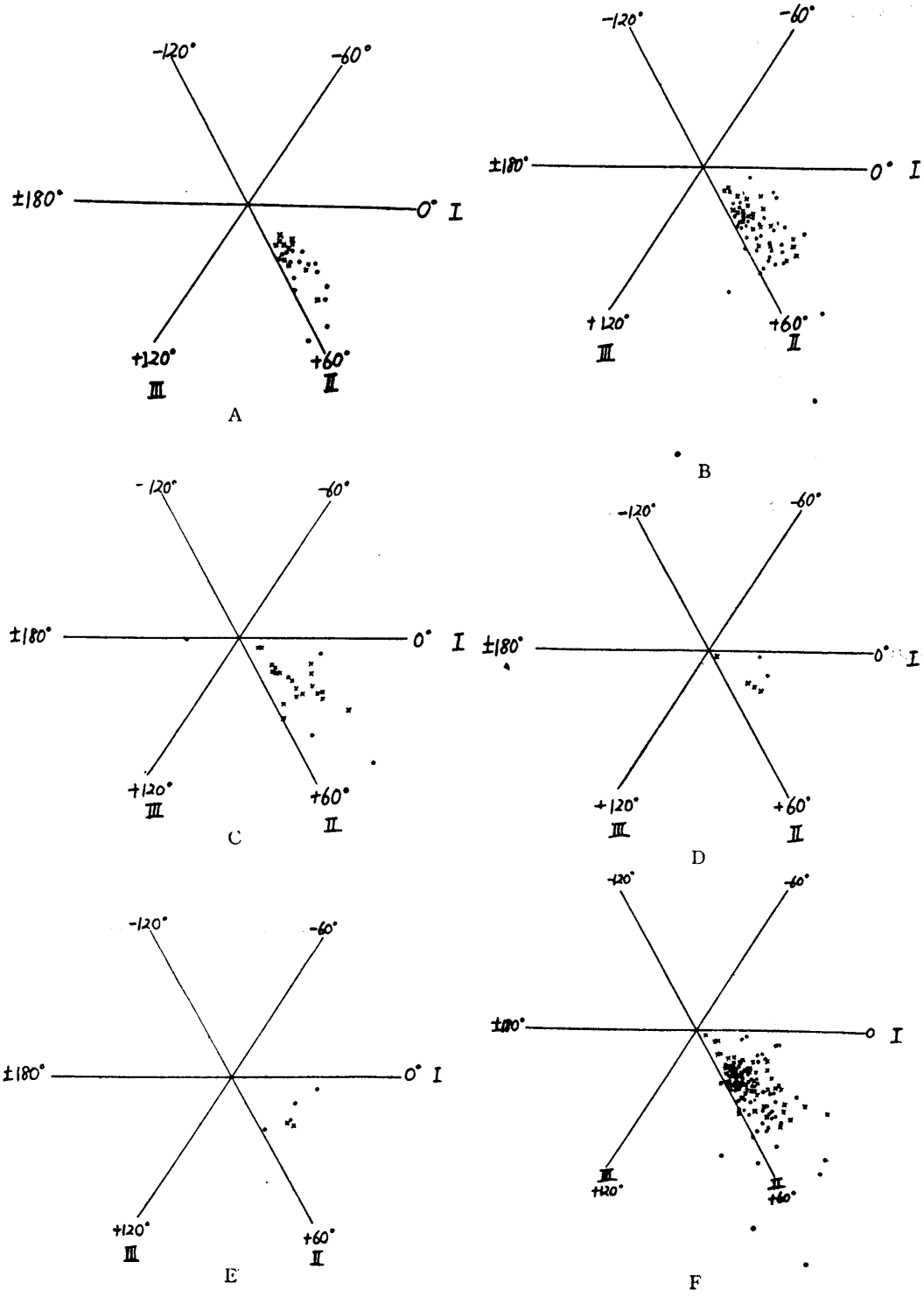


Fig. 6. Magnitudes and directions of mean P vectors in the frontal plane in the various heart positions. A. Vertical, B. Semivertical, C. Intermediate, D. Semihorizontal, E. Indeterminate, F. Entire cases. . male, × female.

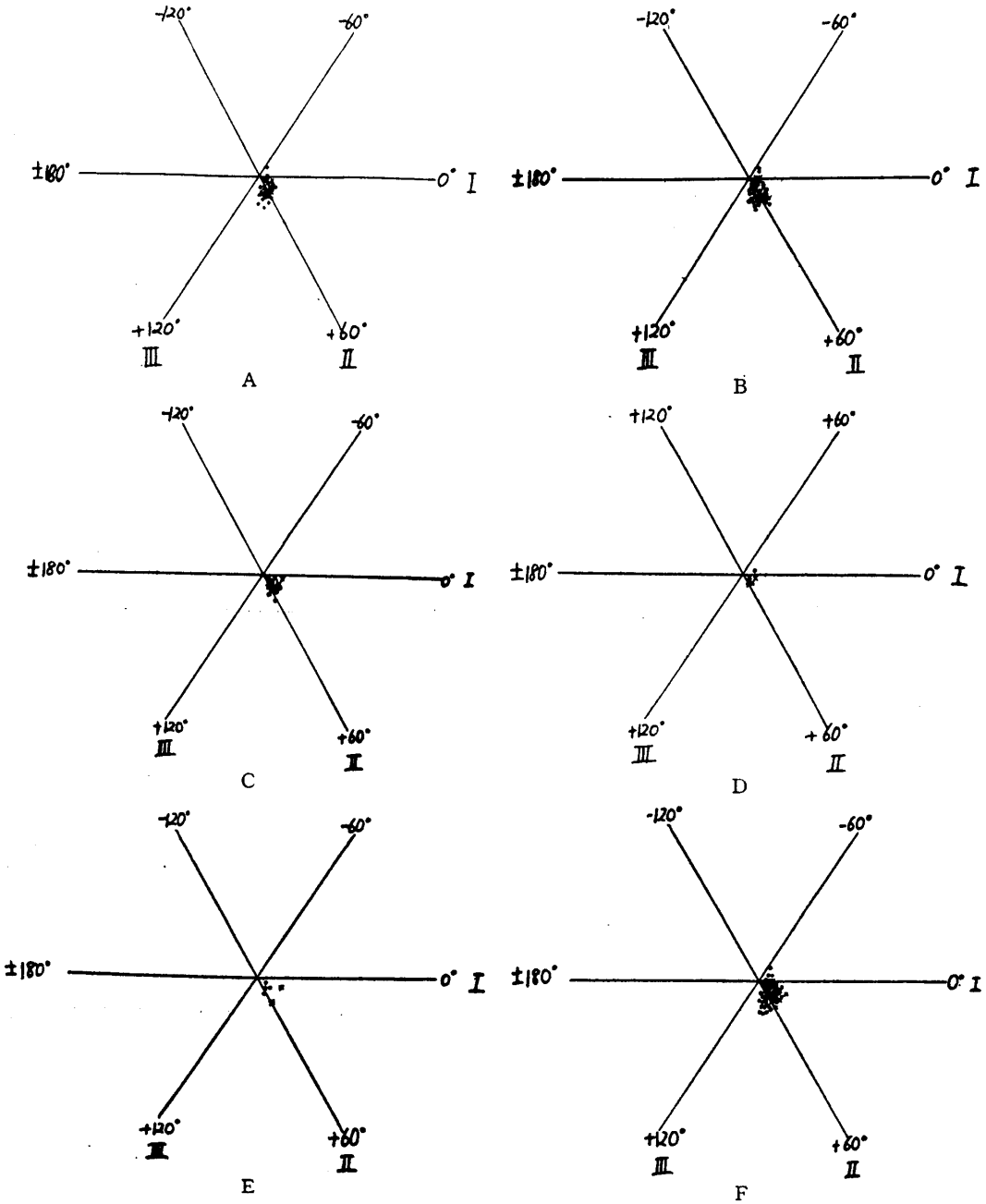
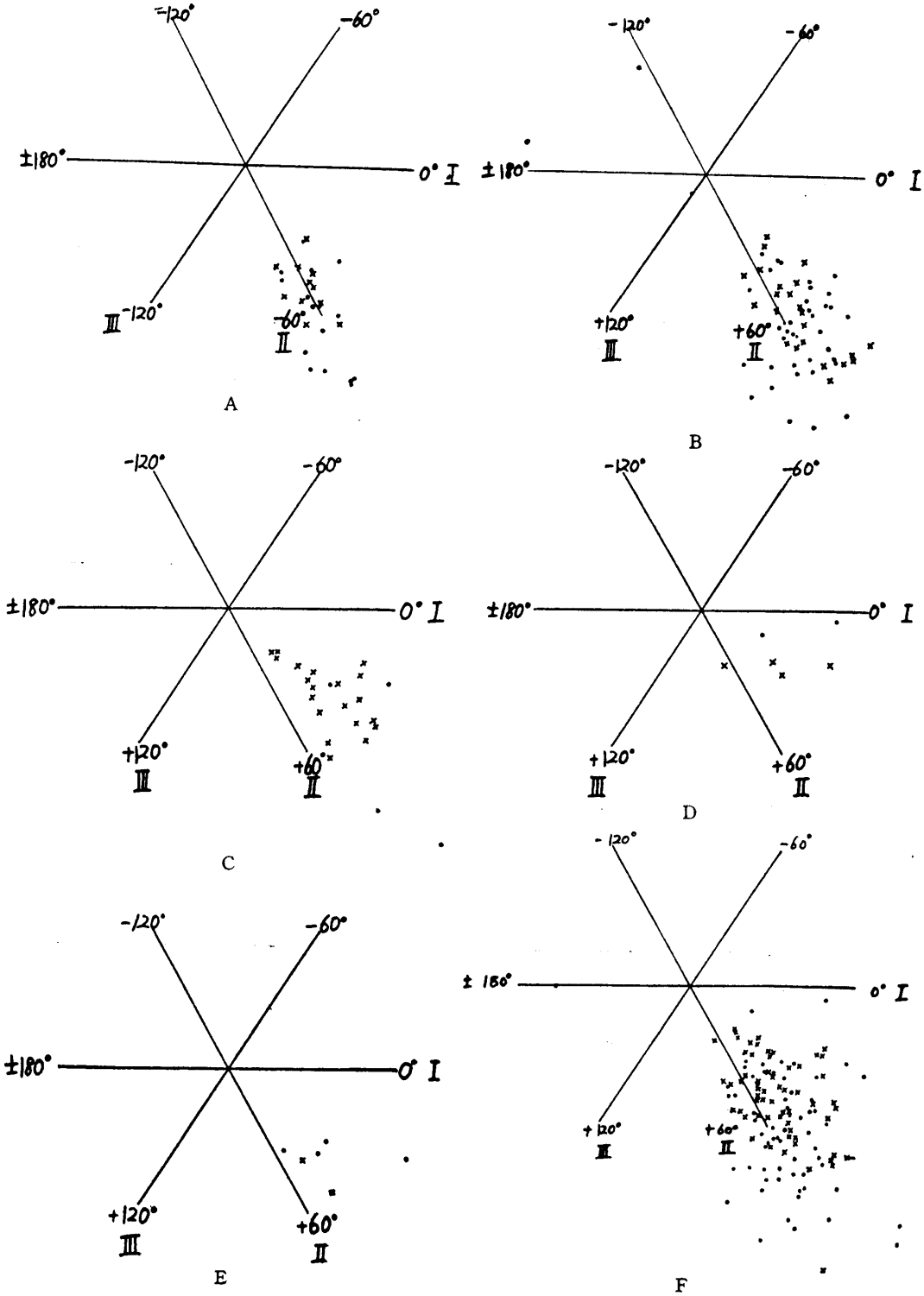


Fig. 7. Magnitudes and directions of vetricular gradients in the frontal plane in the various heart positions. A. Vertical, B. Semivertical, C. Inntermediate, D. Semihorizontal, E. Indeterminate, F. Entire cases. . male, × female.



the vertical and semivertical heart positions are mainly located around the boarder of the 5th and 6th sextants, whereas in the intermediate and semihorizontal electrical heart positions they are found in the middle zone of the 6th sextant.

Table 9 shows the relationship of the mean T vector to the mean QRS vector in the frontal plane in various heart positions. It is clear from this Table 9 that with the exception of semihorizontal heart position the mean T vectors are in the majority of the cases located to the left of the mean QRS vectors in each heart position.

Table 9. Relationship of the mean T vector to the mean QRS vector in the frontal plane in various heart position.

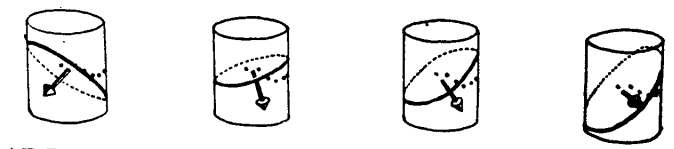
	AT to the Left of AQRS			AT to the Right of AQRS			Same Direction
	Male	Female	Total	Male	Female	Total	Male
Vertical	17	12	29	0	0	0	0
Semi-vertical	32	23	55	5	0	5	2
Semi-Horizontal	2	1	3	2	3	5	0
Intermediate	4	14	18	0	5	5	0
Indeterminate	4	2	6	0	0	0	0

DISCUSSION

The mean QRS, T, P vectors, ventricular gradient and QRS—T angle in the frontal plane obtained with vector electrocardiographic method were described for 126 healthy young Korean adults who apparently did not show any evidence of cardiac diseases. In general, the results obtained in this study were in agreement with those of Americans and Japanese previously reported in the literature.

The mean QRS vector varies greatly with age and electrical heart position in normal individual (Fig. 8). According to Sodi-Pallares[7] the mean QRS vector is placed around +60 degrees in adults of average body build. In obese people it is frequently located between +30 degrees and −30 degrees and in tall, thin individual, the mean QRS vector is frequently found at +90 degrees. Burch[8] found the average mean QRS vector in the frontal plane at +53 degrees +66

Fig. 8. Direction of the mean QRS vectors in various age groups.



degrees. In our study, the mean QRS vector varied greatly with the electrical heart position as shown in Fig. 4. The minimum of the direction of the QRS vector was found at +7 degrees in male with semihorizontal heart position and the maximum was +92 degrees in female with vertical heart position. The average was +50.6 degrees in male and +57.6 degrees in female. In Zao's study[9,10,11], the QRS vector had the maximum incidence at +45 degrees and this difference seems to come from the difference in age in two groups.

The average magnitude of mean QRS vectors in male and female in our study were 7.2 and 5.5 Ashman units respectively and they are in general agreement with those of Ashman's report of 6.7 Ashman units in male and 5.9 Ashman units in female. However, it is interesting to note that the maximum magnitude in male was 19.5 Ashman units and 15 Ashman units in female, which were far greater than 11.0—12.0 Ashman units reported in Ashman's study. We could not find any evidence of cardiac abnormality in these persons except for the great magnitude of mean QRS vectors.

The average mean T vectors in our study in male and female were +34.1 degrees and +42 degrees respectively, which were smaller than those of direction of the mean QRS vector. According to Burch and Zao the average mean T vector in the frontal plane was +45 degrees and Jackson reported that the mean T vector was found at +38 degrees.

The average mean P vector in frontal plane in our study found at +47.3 degrees in male and +40.4 degrees in female, which was generally in agreement with the previous reports of Spodick[12,13], Zuckerman[14] and Gross[15]. Spodick reported that in most normal adults, the mean manifest frontal P vector was generally considered to vary within the narrow Zone of +45 degrees and +64 degrees.

The ventricular gradient lay between +6 degrees and +82.5 degrees in male and between +20 degrees and +75 degrees in female. The average was +44.2 degrees in male and +51.6 degrees in female. According to Ashman the extreme positions of ventricular gradient in normal heart were −17 degrees and +86 degrees. Takubo[16,17] reported that the ventricular gradient in 100 normal Japanese adults between the age of 20 and 30 were found at between +9 degrees and +79 degrees (average +53.6 degrees) in male and between +9 degrees and +66 degrees (average +44.9 degrees) in female.

The mean amplitude of ventricular gradient in our study was 12.9 Ashman units (7.2—28.2 units) in male and 10.0 Ashman units (4.5—17.7 Ashman units) in female, which was almost identical with the report of Ashman. Nimura reported that in Japanese the amplitude of ventricular gradient were between 3.5 Ashman units and 14.25 Ashman units (average 7.78 Ashman units) in male and between 2.67 Ashman units and 9.6 Ashman units (average 6.43 Ashman

units) in female, which were considerably smaller than those reported by Ashman and by us in this study.

The relation of positions of QRS and T vector varies greatly with age and various electrical heart positions (Fig. 9 and 10). In vertical heart and young age the T vector is located to the left of the QRS vector and consequently the direction of the T vector is smaller than that of QRS vector. The results of the analysis of relationship of QRS and T vectors in our study were summarized in Table 9 and it is quite clear that our results are almost same as those previous reported by other authers.

Fig. 9. QRS—T relations in various age groups.

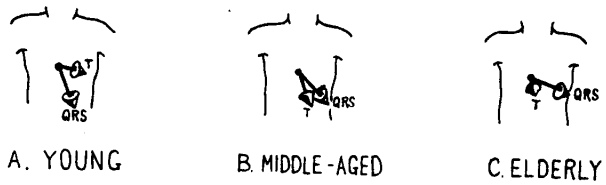
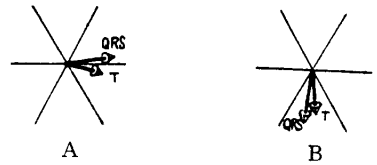


Fig. 10. QRS—T relations in various heart positions.



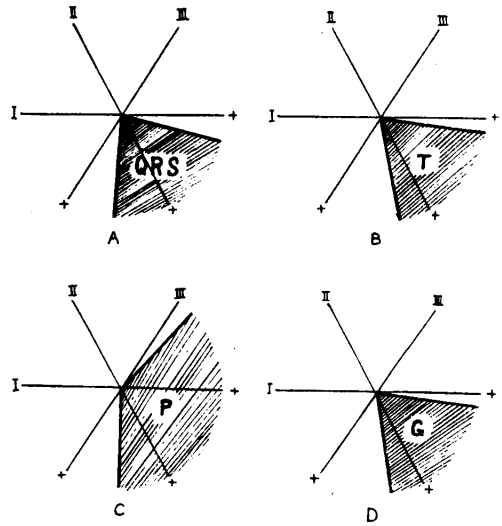
QRS—T Relations in various heart positions
A. Horizontal electrical heart position
B. Vertical electrical heart position

Fig. 11 shows that the mean QRS, T, P vectors and ventricular gradient in young Korean adults are found within the wide limits of the shaded area.

SUMMARY

The vector electrocardiographic method was applied on 126 healthy young Korean adults without any evidence of cardiac diseases. The range of the age of the subjects were between 19 and 34. The normal values of the magnitude and direction of the mean QRS, T, P vectors, ventricular gradient and QRS—T angle in frontal plane were presented and discussed in comparison with those previously reported in the literature. Considering the age of the subjects under study, our results were in general agreement with those previously reported by other authors.

Fig. 11. The normal range of mean QRS, T, and P vectors and ventricular gradient in normal young Koreans.



A. Mean QRS Vectors. B. Mean T vectors.
C. Mean P vectors. D. Ventricular gradient.

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