Computer Analysis of Frank Vectorcardiograms in Normal Children
— Maximal Spatial QRS Vector —

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Frank vectorcardiograms recorded on magnetic tape were analyzed by a computer. The study population was 835 normal children aged from 6 to 16. Magnitudes, angles (azimuth, elevation) of the maximal spatial QRS vector and QRS duration were calculated. The magnitude of maximal spatial QRS vector increased significantly in males compared to those in females at ages 9–10, 11–12 (p < 0.01) and 15–16 (p < 0.001). Though there was no significant difference of elevation in either sex, azimuth tended to move more anteriorly in females than in males. QRS duration in males became longer with increasing age, while in females at age 15–16, it decreased (p < 0.001).

Several reports about the spatial QRS vector in children have been done by Liebman1 Kan2 and Guller3. However, in this country, to our knowledge, such information has not yet been available except for Ichikawa’s4,5 and Yamada’s6 analysis of adults.

Therefore, we attempted to disclose the characteristics of spatial QRS vector in children. Healthy 835 primary, junior and senior high school students were selected by routine health examinations. Using a computer, Frank vectorcardiograms recorded from them were analyzed. Particular attention was paid to the analysis of the maximal spatial QRS vector to ascertain to what extent it was influenced by sex and age.

MATERIAL AND METHOD
Population of this study consisted of 835 healthy children with ages from 6 to 16 (Table I). Heart diseases were excluded by thorough examinations. Laboratory data obtained were as follows: blood pressure, hemoglobin, urinalysis,

![Diagram of computer analysis system of vectorcardiogram.](image)

Key Words:
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TABLE I MAGNITUDE, ANGLE (ELEVATION, AZIMUTH), DURATION OF MAXIMAL SPATIAL QRS VECTOR AMONG VARIOUS AGES AND SEXES

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Number of subjects</th>
<th>Magnitude (mV)</th>
<th>Angle</th>
<th>Duration (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6–7</td>
<td>m</td>
<td>126</td>
<td>2.01 ± 0.38</td>
<td>37.8 ± 9.5</td>
<td>18.9 ± 7.4</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>123</td>
<td>1.97 ± 0.38</td>
<td>39.9 ± 10.9</td>
<td>10.7 ± 20.9</td>
</tr>
<tr>
<td>9–10</td>
<td>m</td>
<td>123</td>
<td>2.11 ± 0.37</td>
<td>38.3 ± 9.6</td>
<td>15.6 ± 17.0</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>104</td>
<td>1.95 ± 0.34</td>
<td>38.6 ± 11.3</td>
<td>10.4 ± 20.0</td>
</tr>
<tr>
<td>12–13</td>
<td>m</td>
<td>112</td>
<td>2.12 ± 0.41</td>
<td>38.1 ± 11.6</td>
<td>11.8 ± 27.1</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>146</td>
<td>1.97 ± 0.39</td>
<td>46.6 ± 10.6</td>
<td>-4.2 ± 20.6</td>
</tr>
<tr>
<td>15–16</td>
<td>m</td>
<td>50</td>
<td>2.22 ± 0.33</td>
<td>42.6 ± 8.9</td>
<td>-9.6 ± 18.7</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>51</td>
<td>1.82 ± 0.37</td>
<td>45.9 ± 9.8</td>
<td>+3.9 ± 19.7</td>
</tr>
<tr>
<td>Total</td>
<td>m</td>
<td>411</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>424</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation

Fig.2. Distribution of the magnitude of the maximal spatial QRS vector according to age and sex.

anthropometric measurements (body weight, height, upper arm circumference, triceps, skin hold thickness), EEC, M-mode echocardiography and Frank vectorcardiograms.

Vectorcardiograms were recorded by a Fukuda Denshi SDC-30 and TEAC R210 Data recorder. Electrodes were placed in the standard positions for the Frank lead system. Lead X, Y, and Z were recorded simultaneously in analog form on magnetic tape. Analysis of vectorcardiograms was performed using this tape by off-line method as shown in Fig.1. The device used in this study was an analyzer of VAC-3 type (Fukuda Denshi Co.). This analyzer had a microcomputer Z ATA 80 A and its interval of sampling in A-C change was 1.25 msec.

Japanese Circulation Journal Vol. 48, December 1984
Fig. 3. Comparison of the magnitude of the maximum spatial QRS vector in males and females.

Fig. 4. Comparison of the azimuth and the elevation of the maximal spatial QRS vector according to age and sex.

Waves of P, QRS, and T in lead X, Y, Z were recognized manually from their shapes, onsets, and duration with the aid of vectorcardiogram VA 3G (Fukuda Denshi Co.). Calculation of the maximal spatial vector was based on Frank's formula. In this study, magnitude, angle (elevation, azimuth), and duration of maximal spatial QRS vector were collectively analyzed.

RESULTS

All values of magnitudes, angles, and durations of maximal spatial QRS vector are given in Table I.

1. Magnitude

Distribution of magnitudes is shown according to individualized age and sex in Fig. 2. Normal distribution patterns were seen in both sexes. Sex difference in magnitude for 15–16 year-olds was particularly evident. Fig. 3 shows distribution of means of magnitude according to age and sex. The means of both sexes ranged from 1.82 to 2.22 mV. With increasing age magnitudes in males became greater than those in females (9–10 and 12–13 years: \( p < 0.01 \), 15–16 years: \( p < 0.001 \)). While the means of magnitudes in males increased as they grew older, the values in females tended to decrease at age 12–13 years.
2. Angle (elevation and azimuth) (Fig. 4)

Means of elevation in both sexes ranged from 37.8° to 46.6°. In males, the elevation for those over 12 showed a downward movement as compared to that under 10 years. Also in females such a deflection was slightly observed. There was no significant difference of elevation in either sex. The means of azimuth were from -1.89 to +3.9. In both groups, azimuth tended to locate anteriorly with increasing age, with male predominancy.

3. Duration

The means of QRS durations in both sexes were from 0.075 to 0.091 sec. In males QRS duration became longer with increasing age (Fig. 5). On the other hand, its duration in females under 10 years was longer than that over 12 years. Significant sex difference in duration was seen at the age of 15–16 (p < 0.001).

DISCUSSION

Since there has been no pertinent data about the analysis of the pediatric spatial QRS vector in our country, emphasis will be placed mainly on a comparison between our data and those of Liebman and Kan.

The magnitudes of maximal spatial QRS vector were greater in males than in females at all ages. These findings were quite compatible with those reported by Liebman and Kan. However, interestingly, magnitude changes in longitudinal axis, i.e., aging process, were considerably different in the two studies. In our study the magnitudes in males tended to increase even at age 15–16. In contrast liebman and Kan demonstrated decreases in magnitudes above 11–15 years (2–5 years: 1.73 mV, 6–10: 1.82, 11–15: 1.83, 16–19: 1.67). Bearing in mind the Japanese adult data of Yamada who showed that the magnitudes decrease with increasing age over 20, it is very likely that the greatest magnitude in males is present between 16 and 20 years. This suggests that there is an age lag in magnitude lowering between Japanese and American adolescents, also such a delay was observed in females. The greatest magnitude in our study and their reports was seen at the age of 12–13, and 6–10, respectively. Roughly estimated in both sexes, the magnitudes in Japanese children appeared to decrease 5 years later compared to those in Americans. This shifting may be the result of differences in race, constitutional development, and so on.

The azimuth of the maximal spatial QRS vector was located more anteriorly in females than in males at all ages. This finding was similar to Liebman’s and Kan’s data. However, with increasing age its elevation in males showed a contrast: downward in our study and more horizontal in their analysis. In females such a discrepancy was not apparent. It was noteworthy that in both studies the elevations in both sexes became fairly close at about 10 years of age and afterwards they became higher in females than in males.

QRS duration became longer with increasing age in males and particularly at the age of 15–16, there was a significant difference in the sexes. These findings were fairly consistent with Liebman’s and Kan’s data.

Finally, although we could demonstrate not only the profiles of the maximal QRS vector in our population but also found similarities and differences between Japanese and American adolescents, further studies will be required to confirm our findings.

SUMMARY

Frank vectorcardiograms recorded from 835 healthy children at age 6–16 were pooled into magnetic tapes and they were analyzed by a computer. The magnitudes of the maximal spatial QRS vector were greater in males than in females at ages 9–10, 11–12, (p < 0.01) and 15–16 (p < 0.001). The elevation showed no significant difference in either sex. The azimuth tended to move more anteriorly in females than in males. The QRS duration in males became longer with increasing age, though in females it decreased at age 15–16 (p < 0.01).

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