THE ELECTROCARDIOGRAM OF NORMAL SCHOOL CHILDREN

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This investigation was undertaken to serve as a control to electrocardiographic observations on children of school age suffering from heart disease. We were particularly concerned to note the incidence of low voltage, bizarre and splintered Q.R.S. complexes, and of inversion of the T-waves.

In 1913 Hecht¹ studied the electrocardiogram of children and concluded that all the deflections were smaller in childhood, and the transmission time shorter, than in adult life. Krumbhaar and Jenks² in 1916 studied the changes occurring in the electro cardiogram in normal infants, but their investigations did not extend far into school years. Seham³ in 1921 studied the tracings of 101 children, aged from one hour to 13 years, these included 26 subjects aged 6 to 13 years. In 1928 Lincoln and Nicholson⁴ reported their findings in 222 normal children aged from 3 to 12 years in a very detailed paper.

Technique.—The method of investigation adopted in the present series of children was as follows. Children selected by the school doctor as having normal hearts were picked out for examination. These were examined clinically for any evidence of disease. All those showing any abnormal physical signs, abnormal blood-pressure readings, or giving a history of rheumatism or chorea were excluded from the series. One hundred children, fifty boys and fifty girls, were examined. These were cardiographed in the sitting position, with non-polarizable immersion electrodes, and the galvanometer standardized so that one millivolt gave a deflection of 10 mm.

Rate.—The average rate for the whole group was 92.6 beats per minute. For girls the average was 98.5 per minute, and for boys 86.8 beats per minute. Figure 1 shows the rate at different ages for the two sexes. There is a slight tendency for the rate to fall with increasing age, but this is not very marked. Girls have a slightly higher rate than boys. These figures are probably high on account of the nervous factor, through being examined with a strange apparatus. They are a little higher than Seham's. Lincoln and Nicholson found a more definite decrease in the rate with increase in age, and their girls up to the age of seven years had a higher rate than boys, but from that age to twelve the boys had the more rapid rate, and over twelve years of age the girls again showed the higher rate.

Rhythm.—Sinus arrhythmia, following Krumbhaar and Jenks' standard, was considered present when the difference in the longest and shortest pulse periods was 0.1 seconds or over. This occurred in 72 per cent. of the cases and,

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as shown in Table 1, was very largely a factor of the rate. There was no obvious agreement between age and the incidence of sinus arrhythmia. This agrees with Seham's results, but he found sinus arrhythmia in only 47 per cent. of his cases from six to thirteen years of age, and Lincoln and Nicholson in 62 per cent. As shown in Table 2 girls throughout show a lower incidence of arrhythmia, but this is probably to be explained by the higher average rate. In one case of a boy of thirteen years a single ventricular extrasystole was recorded. No other abnormalities in rhythm were detected.

P-wave.—No changes in the P-wave, either with sex or increasing age, were noticed. The P-wave was on the average largest in lead II, and smallest in lead III. The average heights of P_1 and P_2 (1.2 mm. and 1.5 mm. respectively) exactly corresponded with Seham's results, although slightly lower than those of Lincoln and Nicholson. The largest P_1 recorded was

FIG. 1.—Showing relationship between heart rate and age in the two sexes.

2.5 mm. and this was the only one over 2.0 mm. In one case P_1 was absent, or so small as to be unidentifiable. The largest P_2 was 5.0 mm., and there were eight curves showing a P_2 of greater deviation than 2.0 mm. In lead III the largest P-wave found was 2.5 mm. In this lead P was absent in 16 per cent. of the cases and inverted in 8 per cent.

P-R interval.—The average P-R interval showed no constant variation with age or sex, and the value varied in the three leads. The average in lead I was .142 seconds, in lead II .148 seconds, and in lead III .146 seconds. This is less than the average adult P-R interval, an observation which agrees with that of Seham and of Lincoln and Nicholson, although both these workers obtained rather lower figures still. The shortest P-R interval recorded was .12 seconds, which was found in several cases, and the longest .18 seconds, which was found in lead III in three cases.

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TABLE 1.

SHOWING THE INCIDENCE OF SINUS ARRHYTHMIA AT DIFFERENT HEART RATES.

Rate	No. of Cases	No. of with S.A.	Percentage with S.A.
60-70	4	4	100
70-80	7	7	100
80-90	28	24	85
90-100	30	23	76.6
100-110	19	11	57.8
110-120	6	3	50
120-130	4	0	0
130-140	1	0	0
140-150	1	0	0

TABLE 2.

SHOWING AGE AND SEX INCIDENCE OF SINUS ARRHYTHMIA.

Age : years	No. of boys	No. showing S.A.	% showing S.A.	No. of girls	No. showing S.A.	% showing S.A.	Total	Total showing S.A.	% showing S.A.
5	2	2	100	3	3	100	5	5	100
6	3	2	66.6	3	2	66.6	6	4	66.6
7	1	1	100	3	1	33.3	4	2	50
8	3	2	66.6	4	1	25	7	3	42.8
10	30	24	80	20	14	70	50	38	76
11	4	4	100	5	1	20	9	5	55.5
12	1	1	100	6	4	66.6	7	5	71.4
13	6	6	100	6	4	66.6	12	10	83.3
All ages	50	42	84	50	30	60	100	72	72

Q.R.S. complex.—The only change noted with increasing age in the Q.R.S. complex was that at the age of five and six years there was a well marked Q_3 . This did not occur at any of the later ages, and would appear to represent the last remnants of the right ventricular preponderance of infancy. No marked difference in amplitude in the two sexes, such as was recorded by Lincoln and Nicholson was observed. Composite tracings for each sex, and the total at each age are shown in Figure 2 (A—I), and these show no significant variation apart from the change in Q_3 already noted. The tracings confirm the observations of Lincoln and Nicholson, and of Seham, that the Q.R.S. was of low voltage (i.e., the sum of the deflections was less than 6 mm.) in lead III in all cases at seven years. In lead III the Q.R.S. complex showed notching, marked slurring or vibratory curves in 21 per cent. of the cases. In 16 per cent. this was associated with an inversion of the T-wave, which in two cases was also accompanied by an inversion of the P-wave. The largest Q-wave recorded was in lead III with a value of 5 mm. Q was frequently absent in any of the leads. The largest R occurred in lead II and measured 22 mm. The largest S was in a case showing marked left ventricular preponderance where its value in lead II was 12 mm.

S-T interval.—Lincoln and Nicholson found a very short or absent iso-electric period between the S and T deflections, the T-wave often sloping directly off from the R-or S-wave. This investigation does not support their findings as most of the curves show quite a definite iso-electric period. The average duration of the S-T interval (from the peak of the S-wave to the end of the T-wave) was, for lead I .262 seconds, for lead II .261 seconds, and for lead III .256 seconds. The longest S-T interval recorded was .32 seconds in all leads for a boy of thirteen, and the shortest .21 seconds in a girl of six. The S-T interval tended to be rather shorter in girls than in boys, which agrees with sex difference noted by Bazett⁵.

T-wave.—The T-wave did not vary constantly with age or sex to any appreciable extent. In leads I and II this wave was always directed upwards. In lead III the average of the whole group gave a value of—3 mm. for T, which was inverted in this lead in 54 per cent. of the cases and absent in 8 per cent. Seham found T_3 inverted in 15 per cent. of his cases, and Lincoln and Nicholson in 35.5 per cent. of theirs. This inversion of T_3 was associated with slurring or splintering of Q.R.S. in 16 of these tracings, and in addition the P-wave was inverted in 2 of them. This relationship is more clearly shown by the fact that of the tracings showing splintering or slurring of Q.R.S. in lead III, 14 (66.6 per cent.) showed an inverted T-wave. This corresponds to the association between these phenomena in adults pointed out by Pardee⁶.

Electrical axis.—The direction of the electrical axis of the heart was calculated by the graphic method described by Carter, Richter and Greene⁷, who found the axis of the normal heart to lie between 40° and 90° . The average value of the angle of the axis in this series was 56.6° , and 78 per cent. of the cases fell between 40° and 90° . There was no relationship between age or sex and the electrical axis,

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FIG. 2. Composite electrocardiograms for each sex, and the whole at the different ages.

Conclusions.

1. The incidence of sinus arrhythmia varies inversely with the rate of the heart. Other types of arrhythmia are rare in childhood.
2. The P-R interval tends to be shorter in children than in adults.
3. The Q.R.S. complex may be notched or splintered in lead III with no clinical significance.
4. This is frequently associated with inversion of T in lead III which occurs with such great frequency (54 per cent.) as to be almost the normal finding.
5. Splintering of Q.R.S. and inversion of the T-wave does not occur normally in children except in lead III.
6. There is no significant age change or sex difference in the electrocardiogram of children between the ages of five and fourteen years.

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