

# 24-hour electrocardiographic study of heart rate and rhythm patterns in population of healthy children

D P SOUTHALL, F JOHNSTON, E A SHINEBOURNE, P G B JOHNSTON

*From the Department of Paediatrics, Cardiothoracic Institute, London*

**SUMMARY** Twenty-four hour electrocardiographic recordings were made on 104 randomly selected, healthy 7 to 11-year-old children. Ninety-two were technically adequate and suitable for analysis. The mean highest heart rate measured by direct electrocardiographic analysis over nine beats was  $164 \pm 17$ . The mean lowest heart rates were  $49 \pm 6$  over three beats', and  $56 \pm 6$  over nine beats' duration. The maximum duration of heart rates  $< 55$ /minute was 40 minutes. At their lowest heart rates 41 children (45 per cent) had junctional escape rhythms, the maximum duration of which was 25 minutes. Nine children showed PR intervals  $\geq 0.20$  s and included three with Mobitz type I second degree atrioventricular block. Nineteen (21%) had isolated supraventricular or ventricular premature beats ( $< 1$ /hour). Sixty subjects (65%) had sinus pauses that could not be distinguished on the surface electrocardiogram from those previously described as sinuatrial exit block or sinus arrest. The maximum duration of sinus pause measured over 24 hours on each child was  $1.36 \pm 0.23$  seconds.

Thus apparently healthy children show variations in heart rate and rhythm over 24 hours hitherto considered to be abnormal.

Several recent reports have ascribed a number of fits, faints, and attacks of dizziness in childhood to abnormalities of sinus node function,<sup>1-4</sup> a diagnosis often made from the interpretation of patterns on the surface electrocardiogram alone.<sup>5</sup> The supposition, however, that these patterns were abnormal has been made in the absence of adequate long-term electrocardiographic data on the incidence of such patterns in healthy symptom-free children without heart disease. This study of 24-hour recordings of the electrocardiogram in a randomly selected population of apparently healthy school children provides normal data with which suspected abnormal electrocardiographic patterns can be compared.

## Patients and methods

One hundred and four apparently healthy school children between the ages of 7 and 11 years (mean 9.4 years) were randomly selected for 24-hour electrocardiographic recordings from the register of a primary school in Dorchester. The school served both an urban and a rural community and contained children of all social classes.

Twelve recordings were rejected because of poor

quality. Five had undetected intermittent lead fractures, two had electrode displacement, in four a fault in the cassette resulted in jamming of the tape, and in one oxide coating of the recording head prevented signal reception. Forty-nine recordings of good quality came from boys and 43 from girls. Eleven of the girls, but none of the boys, were pubertal.

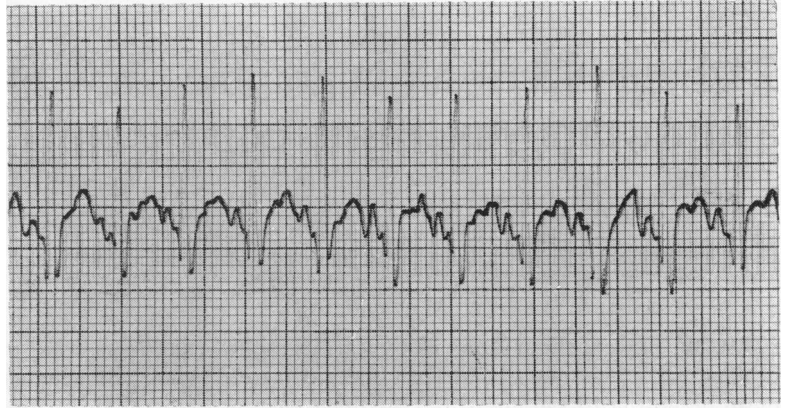
A questionnaire was sent to the parents requesting historical information of previous fits, faints, or "funny turns" or of other serious illness, and was completed in all cases. A full clinical examination was also performed. Standard electrocardiographic recordings were not made.

Each child was fitted at school with a 24-hour electrocardiographic\* recorder and this remained in place until the following day. Normal activities were encouraged throughout the recording. An attempt was made to document diaries of activity during the recordings but notes kept by the children were often inaccurate and these were therefore abandoned.

Recordings were analysed directly using a system that automatically detected heart rate or rhythm patterns outside preset standards. On detection of such an abnormality the preceding 30 seconds and subsequent 10 seconds of the electrocardiogram

\*Oxford Medical Systems.

Fig. 1 Twenty-four-hour electrocardiographic recording (including a timed reference signal for accurate analysis of heart rates) showing a sinus tachycardia of 180/minute in a healthy 9-year-old boy on exercise.



were displayed. The recording and analysis system incorporated a synclock mechanism which, by providing and processing a reference time signal, ensured that possible variations in tape speed did not produce artefacts of rhythm or rate.

The highest and lowest heart rates occurring in each child over a 24-hour period were measured from the electrocardiographic print-out after direct analysis of the whole of the recording from 3, 5, and 9 beats or 2, 4, and 8 RR intervals, respectively (Fig. 1).

A search over three randomly selected hours of daytime (10.00 to 18.00 hours) and night-time (00.00 to 06.00 hours) recordings in 26 subjects with bradycardia below 55/min was made for the frequency of episodes of bradycardia at each of three levels: <55/minute, <50/minute, and <45/minute (as measured over nine or more beats). The maximum duration of bradycardia <55/minute was also measured in these 26 subjects. The presence of junctional escape rhythm, when present over three or more beats, was also noted (Fig. 2), and the frequency and maximum duration of this rhythm over the 24 hours of recording were measured in 24 children with episodes of junctional rhythm.

In each child the 24-hour electrocardiogram was examined for the following PP interval patterns.

(1) A gradual increase and decrease in PP intervals, (usually termed sinus arrhythmia).<sup>6</sup>

(2) A sudden increase in PP or PQ interval exceeding the previous PP interval by more than 110 per cent (a pattern usually described as resulting from sinus arrest (Fig. 3)).

(3) A sudden increase in PP interval exceeding the immediately preceding PP interval by between 90 and 110 per cent; an electrocardiographic pattern that has previously been described as probably resulting from sinus arrest. Classical Mobitz type II second degree sinoatrial block<sup>7-9</sup> (Fig. 4) would also result in such a pause but the sinus interval subsequent to the pause should be equal in length to the pre-pause interval. This latter situation, however, may be modified by autonomic tone and it is possible that this sudden doubling of PP interval may be described as second degree sinoatrial block rather than sinus arrest.

(4) A progressive decrease in PP interval ending with a sinus pause exceeding the previous PP interval by between 50 and 90 per cent (the pattern described as representing probable Wenckebach second degree SA block).<sup>7-9</sup> This pattern was only counted when the calculations of PP increments and the graphical differentiation from sinus arrhythmia could be made<sup>10</sup> (Fig. 5). Fig. 6 on subject A shows a PP interval pattern previously labelled by other authors<sup>7-9</sup> sinus arrhythmia and Fig. 7 on a different

Fig. 2 Twenty-four-hour recording showing an episode of junctional rhythm at a rate of 37/minute (as measured over three beats' duration).

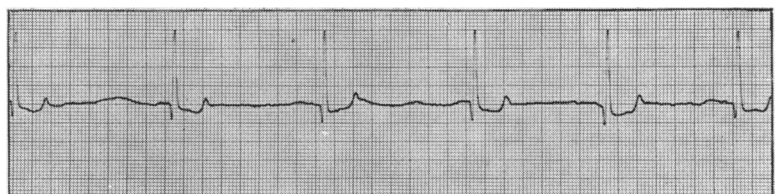




Fig. 3 Twenty-four-hour electrocardiographic recording showing a sudden prolongation of PP interval (1120 ms) exceeding the previous PP interval (480 ms) by more than 110 per cent. This pattern cannot be distinguished from those previously described as probably representing sinus arrest. Temporary complete sinoatrial exit block with high atrial escape (P wave indistinguishable from sinus) or with a variation in timing of sinus impulse generation caused by autonomic tone could also be described as a possible cause of this sinus pause.

subject, "B", shows a PP interval pattern previously called by other authors<sup>10</sup> Wenckebach second degree sinoatrial block.

The frequency of patterns (2), (3), and (4) in the total population of children is shown in Table 4. The number of episodes of patterns (2), (3), and (4) in a subgroup of 30 children with these patterns was also measured (Table 2).

The maximum sinus pause (the longest PP or PQ interval) was measured from the 24-hour electrocardiogram of each child.

Finally, all recordings were analysed for the presence of premature beats (number per hour) by a direct count from six randomly selected hours of recording.

## Results

In all cases a full clinical examination failed to detect evidence of structural congenital heart disease or of any other serious illness. No child studied felt dizzy or fainted during the course of the 24-hour recording.

Ten of these randomly selected, healthy children have a history of previous fainting episodes but none of the children had regular faints. There was

no difference in heart rate values or rhythm pattern findings between this group of children and those who had not fainted (Table 5).

Mean values for the highest and lowest heart rates over 24 hours in each subject are shown in



Fig. 4 Twenty-four-hour electrocardiographic recordings from two subjects showing sinus pauses with a sudden prolongation of PP interval exceeding the previous PP interval by between 90 and 110 per cent. This sudden doubling of PP interval on the surface electrocardiogram has been previously described as resulting from sinus arrest. Classical Mobitz type II second degree sinoatrial exit block could also result in such a pause but the sinus interval subsequent to the pause should be equal in length to the pre-pause interval. This latter situation, however, may be modified by autonomic tone and it is possible that this sudden doubling of PP interval may result from second degree sinoatrial block rather than sinus arrest.

Table 1 Heart rate from 24-hour electrocardiogram in 92 children

	Highest rate		Lowest rate	
	Measured over 9 beats or 8 RR intervals	Measured over 3 beats or 2 RR intervals	Measured over 5 beats or 4 RR intervals	Measured over 9 beats or 8 RR intervals
Mean $\pm$ SD	164 $\pm$ 17	49 $\pm$ 6	52 $\pm$ 6	56 $\pm$ 6
Maximum	195	64	68	69
Minimum	130	37	38	42

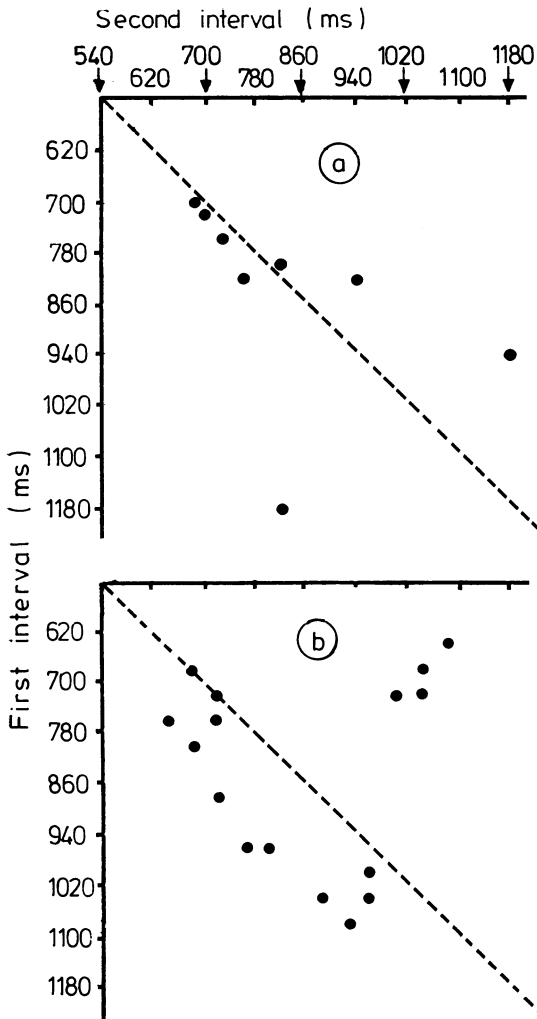


Fig. 5 Two graphs showing a plot of PP intervals on the Y axis against succeeding PP intervals on the X axis. The line at 45° shows the position of PP intervals of equal duration. Graph (a) from subject A shows the pattern previously called sinus arrhythmia. Graph (b) from subject B shows the pattern previously labelled sinatrial Wenckebach block.

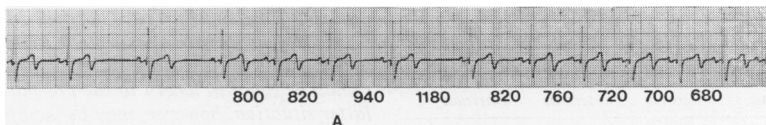


Fig. 6 Twenty-four-hour electrocardiographic recording on subject A showing a phasic variation in heart rate previously termed sinus arrhythmia.

Table 1. Lowest and highest heart rate histograms did not significantly differ from those of a normal distribution (proven by the Kolmogorov-Smirnov test<sup>11</sup>). All children showed at times a phasic variation in rate, normally termed sinus arrhythmia.<sup>6</sup> Abrupt changes in heart rate were also a frequent finding (Fig. 8).

Table 2 shows the following.

- (1) The number of episodes (over 24 hours) of junctional rhythm, in a subgroup of 24 subjects.
- (2) The number of episodes (over 24 hours) of the different PP interval patterns, in a subgroup of 30 subjects.
- (3) The number of episodes (over 3 hours of daytime and night-time recordings) of heart rates below 55/min, below 50/min, and below 45/min, in a subgroup of 26 subjects.

The mean longest sinus pause occurring over 24 hours for each child was  $1.36 \pm 0.23$  s. The overall longest pause seen in this population was 1.88 s.

The maximum duration of junctional rhythm and episodes of bradycardia below 55/min over 24 hours in the subgroups of 24 and 26 subjects respectively are shown in Table 3.

The frequencies of junctional escape rhythm, PP interval pattern variations, premature beats, and atrioventricular block in the total population of children are shown in Table 4.

Nine children showed *intermittent* PR prolongation  $\geq 0.20$  s including three with Mobitz type 1 second degree atrioventricular block (Table 6) (Fig. 9 and 10).

Isolated supraventricular premature beats were seen in 19 children (21%), but none had more than one an hour. One additional child had isolated ventricular premature beats (again less than one an hour).

### Discussion

Analysis of tape recordings of the electrocardiogram has proved a valuable technique for the investigation of heart rate and rhythm over long periods of time. Care must be taken, however, in comparing data over 24 hours with data from relatively brief standard electrocardiograms. Thus a range of heart

**Table 2** Number of episodes of junctional rhythm, PP interval patterns, and episodes of bradycardia in subgroups with these findings on 24-hour electrocardiogram

No of episodes	Junctional rhythm	Sinus pauses			Rates below 55/min		Rates below 50/min		Rates below 45/min	
		A*	B*	C*	Day	Night	Day	Night	Day	Night
1-5	4	1	3	7	2	8	1	11		3
6-10	5	4	6		1	5		2		1
11-15	1	3	7			2		2		
16-20		1	1			3		1		1
21-25		3	1			3				
26-30		2	1			2				
31-35		4	1			1				
36-40	1	2				1				
41-45										
46-50		1	1							
>50	13*	3	1	1		1		1		
Total no. subjects studied	24	30			26					

\*Present at all rates below 60/minute.

A\*, PP or PQ exceeding previous PP by 50 to 90 per cent with incrementally decreasing PP before pause.

B\*, PP or PQ exceeding previous PP by 90 to 110 per cent.

C\*, PP or PQ exceeding previous PP by > 110 per cent.

rate from 37 a minute to 195 a minute was found over 24 hours in this population of healthy children. Previous studies of heart rate variation in children at this age using standard electrocardiograms have shown, not surprisingly, a much narrower range (55 to 115 for 8 to 12-year-old children).<sup>12</sup> Abrupt changes in heart rate were also a frequent finding over 24 hours and may represent the effects of variations in autonomic tone. Alternatively, sinus tachycardia of sudden onset may result from so-called sinus node re-entry.<sup>13 14</sup> Long-term electrocardiographic recordings, though recommended,<sup>4</sup> have not previously been performed on healthy children. It is interesting to recall, however, that Holter monitoring of 50 healthy medical students aged 23 to 27 years showed a similar, and unexpected, variation in heart rate and rhythm.<sup>15</sup>

Irregularities of sinus rhythm have been described either as sinus arrhythmia<sup>6 16</sup> (a "normal" finding said to be sometimes related to respiration) or as a manifestation of abnormal sinus node function. An accurate diagnosis of sinoatrial exit block or sinus arrest can, however, only be made by recording potentials directly from the sinus node. Though it has been stated<sup>7-9</sup> that measurement of intervals between atrial potentials, on the surface electrocardiogram, may be used to diagnose exit block such measurements may be complicated by other factors. Thus, in electrocardiographic patterns described as sinoatrial block exact whole multiples of PP intervals may be disturbed by autonomic effects or by escape pacemakers whose inherent rates are only slightly slower than that of the sinus pacemaker. Thus, we have not attempted to define electrocardiographic patterns of exit block or sinus

arrest but instead have measured PP or PQ intervals and categorised pauses arithmetically into groups. On the basis of this categorisation, and considering the effects of autonomic tone and escape pacemaker activity, we contended that it is impossible to differentiate on the surface electrocardiogram the pauses we have described from those previously described as sinoatrial exit block or sinus arrest. Whether the primary mechanism of the pauses is sinus arrest, sinoatrial exit block, or the effects of autonomic tone remains uncertain but the high frequency of these pauses in healthy children suggests that the underlying mechanism is not of clinical importance.

Prolonged sinus pauses said to result from sinus

**Table 3** Maximum duration of junctional escape rhythm and episodes of bradycardia < 55/minute in subgroups with these findings on 24-hour electrocardiogram

Maximum duration of episode	Junctional rhythm	Heart rates less than 55/minute
1 to 10 seconds	12	
11 to 20 seconds		13
21 to 30 seconds	4	4
31 to 40 seconds	1	
41 to 50 seconds		1
51 to 60 seconds	2	
1 to 2 minutes		6
3 to 5 minutes	1	1
6 to 10 minutes	1	
10 to 20 minutes	2	
20 to 30 minutes	1*	1**
Total no. subjects studied	24	26

\*25 minutes.

\*\*40 minutes.

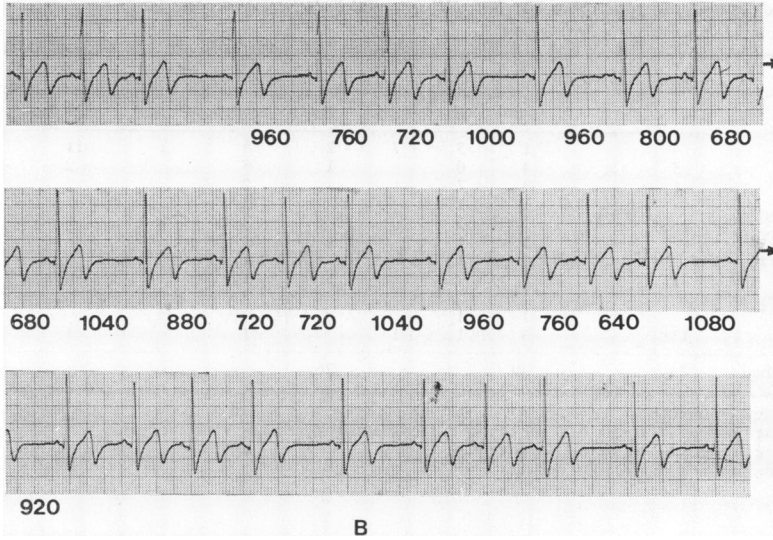


Fig. 7 Twenty-four-hour electrocardiographic recording on subject B showing episodes of progressive reduction in PP interval followed by pauses exceeding the immediately preceding PP interval by between 50 and 90 per cent. The calculations of PP interval increment, according to Schamroth and Dove,<sup>10</sup> describe a pattern that has been called Wenckebach sinuatrial exit block rather than sinus arrhythmia.

arrest or complete sinuatrial exit block have been reported.<sup>17</sup> In this study of healthy children the mean longest pauses seen were  $1.36 \pm 0.23$ . Perhaps pauses in excess of  $1.82$  s (two standard deviations above the mean longest pauses) should be regarded as evidence for abnormal sinus node and escape pacemaker function at this age.

Sinus arrhythmia has been renamed irregular sinus rhythm by the World Health Authority Working Party on terms relating to cardiac rhythm.<sup>18</sup> Perhaps short sinus pauses, previously labelled sinus arrest or Mobitz type I and II sinuatrial block, may also be more appropriately included in this latter definition.

Junctional rhythm may occur for two reasons. Firstly, the inherent pacemaker rate of the sinus

node may fall below that of the atrioventricular node, the latter then initiating further impulse formation. This junctional escape rhythm may result from normal sinus bradycardia or because of abnormal sinus node function.<sup>19</sup> Secondly, the inherent pacemaker rate of the atrioventricular node may be accelerated.<sup>20</sup> Junctional rhythm was seen frequently in this population of normal children and we suspect that these episodes were related to a small difference in intrinsic pacemaker rate between the sinuatrial and atrioventricular node. The 95th centile for maximum duration of junctional rhythm seen in this population was 20 minutes. More prolonged episodes (of junctional rhythm) may indicate either abnormal sinus node function or the presence of an accelerated junctional focus.

Table 4 Rhythm patterns on 24-hour electrocardiogram recordings

	Rhythm at lowest rate		Sinus pauses† Total no. subjects = 60			Premature beats		1st degree AV block (PR ≥ 0.20s)	2nd degree AV block
	Junctional	Sinus	A*	B*	C*	0	< 1/h		
No. of subjects (total n = 92)	41	51	43	34	8	73	19	9	3

A\*, PP or PQ exceeding previous PP by 50 to 90 per cent with incrementally decreasing PP before pause.

B\*, PP or PQ exceeding previous PP by 90 to 110 per cent.

C\*, PP or PQ exceeding previous PP by > 110 per cent.

†Some subjects had more than one type of sinus pause.

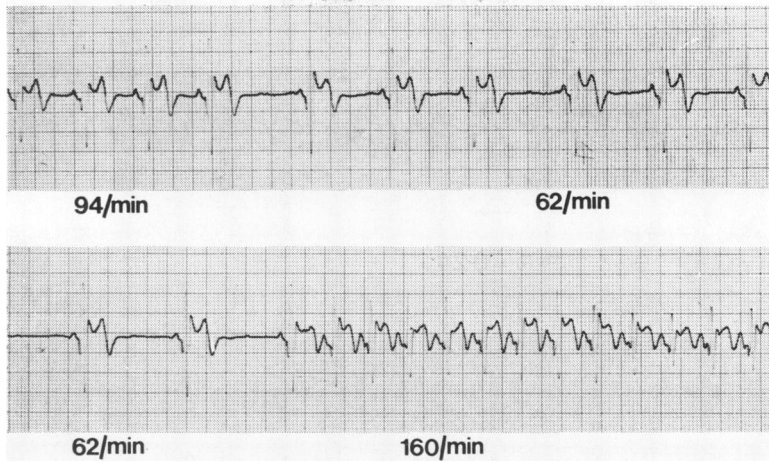


Fig. 8 Twenty-four-hour electrocardiographic recording showing abrupt changes in heart rate. After sinus rhythm of 94 a minute there is an irregular slowing of heart rate to 62 a minute. The first two beats in the second panel have an abnormal P wave and shortened PR interval preceding the QRS complex; they may represent junctional escape beats. The subsequent tachycardia of 160 a minute is presumably sinus in origin. It is possible that a re-entry mechanism may be responsible for this sinus tachycardia but only electrophysiological studies would be able to show this mechanism.

Junctional escape rhythms and sinus pauses, previously described as probable sinuatrial exit block or sinus arrest, were therefore found in a high proportion of this large, randomly selected, apparently healthy, population of children. A knowledge of these normal findings must be taken into consideration when surface electrocardiographic recordings are used to diagnose sinus node dysfunction at this age. Sinus pauses said to be abnormal and to represent sinus arrest or sinuatrial

exit block, episodes of bradycardia below 50 a minute, and junctional escape rhythms in children with syncope or episodes of dizziness have led others to a diagnosis of causative abnormal sinus node function.<sup>1 2 4</sup> Many patients with sinus node dysfunction have tachyarrhythmias in addition to abnormal episodes of bradycardia (“the sick sinus or tachycardia-bradycardia syndrome”).<sup>21 22</sup> The degree and nature of both tachycardia (where P wave discrimination is often difficult) and brady-

Table 5 Heart rhythm and rate variations in children with history of fainting

Case no.	Age	Sex	Lowest rate over 24 hours (over 9 beats)	Premature beats	Sinus pauses A* B* C*	Junctional rhythm	Longest sinus pause (s)	AV block	No. of faints	
1	9	M	51	0	+ + +	+	1.40	—	1	
2	9	F	50	0	+ + —	+	1.44	—	1	
3	9	M	62	0	+ — —	—	1.20	—	2	
4	8	M	50	0	+ + —	+	1.70	—	4	
5	11	M	52	0	+ — —	+	1.52	—	1	
6	11	F	63	0	— — —	—	1.28	—	1	
7	11	M	56	+	— — —	—	1.72	—	1	
8	11	M	56	+	— — —	—	1.50	—	1	
9	11	M	47	0	— — —	+	1.64	PR 0.28	1	
10	9	F	55	+	+ + —	+	1.32	PR 0.24 Mobitz I	3	
Significance tests against 82 children who have not fainted			Mann Whitney U test = 343 NS	$\chi^2$ 5.36 NS	$\chi^2$ 0.014 NS	$\chi^2$ 0.018 NS	$\chi^2$ 0.193 NS	$\chi^2$ 0.494 NS	Mann Whitney U test 275 NS	$\chi^2$ 0.346 NS

A\*, PP or PQ exceeding previous PP by 50 to 90 per cent with incrementally decreasing PP before pause.  
 B\*, PP or PQ exceeding previous PP by 90 to 110 per cent.  
 C\*, PP or PQ exceeding previous PP by > 110 per cent.

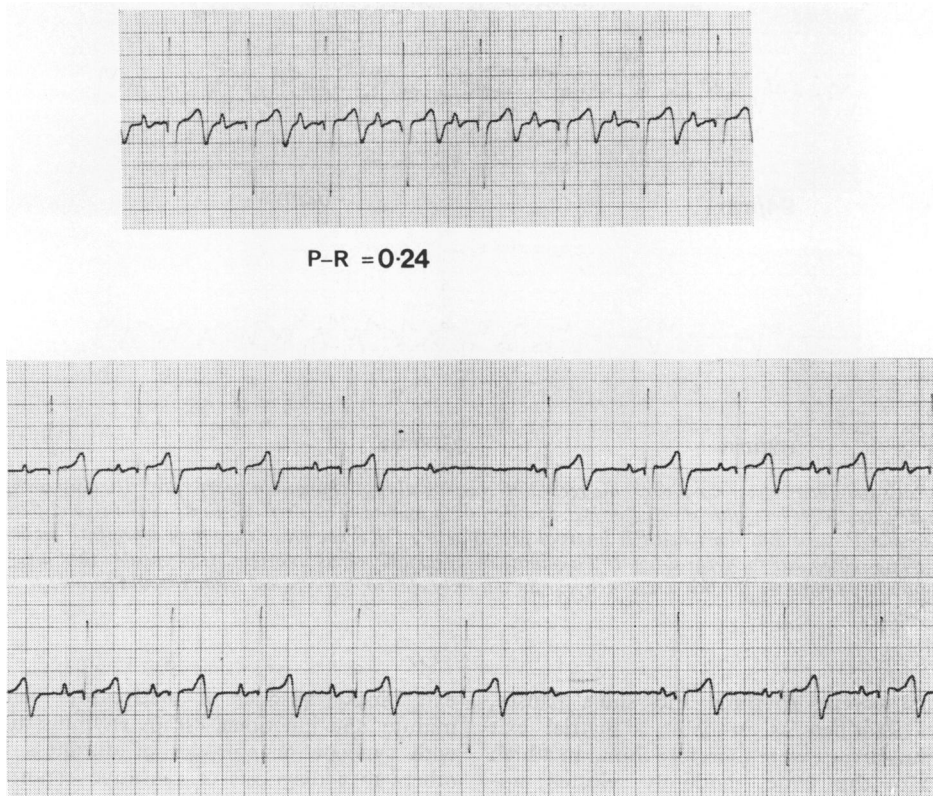


Fig. 9 Twenty-four-hour electrocardiographic recording from a healthy 9-year-old girl. The top panel shows an episode of sinus rhythm with a PR interval of 0.24 s. The lower two panels show Mobitz type I (Wenckebach) atrioventricular block.

cardia regarded as abnormal must also take a knowledge of normal heart rate values into consideration. Reports<sup>23-27</sup> on the results of surgery for congenital heart disease have also in some cases, in our opinion, wrongly assigned these normal rate and rhythm patterns, when seen postoperatively, to sinus node injury. We contend that these patterns are normal findings and equally may have been present preoperatively.<sup>28</sup>

Intermittent prolongation of the PR interval  $\geq 0.20$  s<sup>12</sup> representing first degree atrioventricular block was found in nine subjects studied and included three children with Mobitz type I second degree atrioventricular block. Mobitz type I atrioventricular block has previously been described on standard electrocardiograms in apparently healthy young athletes<sup>29-30</sup> and in older men undergoing strenuous exercise.<sup>31-32</sup> In two large standard electrocardiographic studies on asymptomatic adults it was found in three of 67 375<sup>33</sup> and in two of 19 000,<sup>34</sup> respectively. The latter study showed

atrioventricular block in the supine position which was abolished by standing up. His bundle and autonomic function tests were performed in two male adolescents being routinely examined.<sup>29</sup> Electrophysiological studies showed an area of block proximal to the His bundle, and exercise and atropine both abolished this conduction pattern. Intracardiac electrophysiological and autonomic function tests would have been of interest in our three subjects with Mobitz type I atrioventricular block since a recent report by Young *et al.*<sup>35</sup> has shown that seven of 16 children with this subsequently developed complete atrioventricular block and two needed pacemaker treatment for syncope. One of the three children with second degree atrioventricular block in our study had suffered from four previous fainting episodes but none had occurred for three years. There was also a strong history of fainting in her family. Finally, some of the reported studies on atrioventricular block patterns in healthy subjects without structural heart disease have suggested that



the atrioventricular block is autonomic in origin and does not represent a primary atrioventricular nodal conduction abnormality.<sup>29,30</sup> A study by Gambetta *et al.*<sup>36</sup> convincingly showed that second degree atrioventricular block in two healthy adolescents was the result of a differential effect of vagal tone on the sinus and atrioventricular nodes.

Isolated premature beats were seen in 21 per cent of children but none had more than one per hour. It is interesting to compare this finding with a 24-hour electrocardiographic study of a population of 134 healthy neonates with normal standard electrocardiograms where 19 had premature beats but six had more than one an hour.<sup>37</sup> In addition, 14 of 2030 neonates on a standard electrocardiogram alone have been shown to have multiple premature beats. Eleven had ventricular, 14 supra-ventricular, and one had both.<sup>38</sup>

In considering patterns of rhythm on surface electrocardiography that should be regarded as normal findings, it may be important to differentiate between the standard and the 24-hour electrocardiogram. For example, at this age a constant heart rate of 40 a minute on a standard electrocardiogram is probably abnormal because it implies that it is

Table 6 Details on subjects with first or second degree atrioventricular block on 24-hour electrocardiographic recordings

Case no.	First degree AV block	Second degree AV block
	PR interval(s)	Number of episodes
1	0.24	53**
2	0.24	5*
3	0.24	9
4	0.20	
5	0.24	
6	0.24	
7	0.24	
8	0.20	
9	0.28	

\*\*49 occurred during the day.

\*History of three faints.

present for a large part of the time, whereas a sthor episode of bradycardia down to 40 a minute on a 24-hour recording is probably normal. The assessment of the frequency and duration of rate or rhythm changes is therefore as relevant as their occurrence. It is, however, possible, by chance alone, that any arrhythmia detected by long-term electrocardiographic recording may appear on a standard electrocardiogram. Thus, arrhythmias which are



Fig. 10 Twenty-four-hour electrocardiographic recording from a healthy 9-year-old girl. The top panel at 1435 hours shows a sinus tachycardia of 130/minute with a normal PR interval. At other times during the recording the PR interval was 0.24 s. At 2133 hours and 2051 hours there are episodes of Mobitz type I (Wenckebach) atrioventricular block.

normal on a 24-hour electrocardiogram could in theory also be normal on a standard electrocardiogram. The findings of this study also suggests, therefore, that the range of normal for standard electrocardiograms in children requires reappraisal.

From the data in this paper we consider that the following heart rate and rhythm patterns occur so frequently in normal, healthy children that, though long-term studies of their natural history have not been performed, they are probably *not* harmful.

- (1) Short episodes of bradycardia down to 37 a minute and of tachycardia up to 195 a minute (within two standard deviations of the mean in this normal distribution of lowest and highest heart rates).
- (2) Junctional escape rhythms of up to 20 minutes' duration (95th centile for maximum duration in 24 subjects, Table 3).
- (3) Sinus pauses containing PP interval patterns previously described by other authors as evidence of abnormal sinus node function.<sup>7-10</sup> The maximum sinus pause should not exceed 1.82 seconds (two standard deviations above the mean longest sinus pause).
- (4) Isolated superaventricular premature beats (no more than one an hour).

We remain hesitant in describing intermittent first or second degree atrioventricular block as a normal, and therefore by inference a harmless rhythm pattern. There is a significant incidence of sudden unexpected death in adolescents, particularly those undergoing competitive sport,<sup>39</sup> and it is possible that children with an inbuilt tendency to atrioventricular block are more at risk. Prospective long-term studies are required to answer this important question.

Ten per cent of children in this study had a history of fainting but their incidence of rhythm or rate patterns was not significantly different from those children who did not faint. Though cardiac arrhythmias may cause a fall or cessation of cardiac output sufficient to produce cerebral hypoperfusion and hence syncope, autonomic changes may also produce similar disturbances of cardiac conduction together with direct effects on venous or arterial tone. Moreover, isolated sinus node failure should not result in asystole unless there is also a failure of the atrioventricular nodal or ventricular escape mechanism. How then should children who present with fits, faints, or dizziness be investigated? Causes outside the cardiovascular system, such as epilepsy, should first be excluded. Standard and 24-hour electrocardiograms should be performed and examined for features outside the normal range. Carotid sinus massage or autonomic function tests may help to establish a cardiovascular cause but

do not differentiate between vagal hypersensitivity and a primary abnormality of cardiac rhythm.<sup>40</sup> Intracardiac electrophysiological studies may also be valuable in selected cases with abnormalities on the standard or 24-hour electrocardiogram. Abnormalities of sinus node function, however, may not be elicited by this technique.<sup>41</sup> Ambulatory electrocardiographic monitoring is a simple and safe technique which may provide valuable information in children suffering from attacks of dizziness or syncope. Interpretation of recordings in symptomatic children, however, requires knowledge of the range of heart rate and rhythm variations in normal children.

In conclusion, this study has shown that electrocardiographic patterns previously reported to indicate abnormality of sinus node function occur frequently in the healthy child. Similarly, the range of heart rates is wider than previously reported at this age. It is essential that findings in normal, healthy children are taken into consideration when interpreting heart rate and rhythm patterns in clinical situations.

Dr Southall is a Senior Research Fellow with the British Heart Foundation. This project was funded by the Foundation for the Study of Infant Deaths and the 24 hour electrocardiograph analyser was provided by the British Heart Foundation. We would like to acknowledge the help of Mr D Hall, Headmaster of St Osmund's School, Dorchester, and Dr K Adams and Mr F House of the Community Medical Department, West Dorset Health Care District.

## References

- 1 Radford DJ, Izukawa T. Sick sinus syndrome. Symptomatic cases in children. *Arch Dis Child* 1975; **50**: 879-85.
- 2 Scott O, Macartney FJ, Deverall PB. Sick sinus syndrome in children. *Arch Dis Child* 1976; **51**: 100-5.
- 3 Young D, Eisenberg RE. Symptomatic sinus arrest in a young girl. *Arch Dis Child* 1977; **52**: 331-4.
- 4 Yabek SM, Jarmakani JM. Sinus node dysfunction in children, adolescents and young adults. *Pediatrics* 1978; **61**: 593-8.
- 5 Yabek SM, Swensson RE, Jarmakani JM. Electrocardiographic recognition of sinus node dysfunction in children and young adults. *Circulation* 1977; **56**: 235-9.
- 6 Urbach JR, Pluvichit B, Zweizig H, *et al.* Instantaneous heart rate patterns in newborn infants. *Am J Obstet Gynecol* 1965; **93**: 965-74.
- 7 Myerburg RJ. Electrocardiographic diagnosis of sinus node rhythm variations and SA block. In: Schlant RE, Willis-Hurst J, eds. *Advances in*

- electrocardiography. New York: Grune and Stratton, 1972: 73-80.
- 8 Stock JPP, Williams DO. *Diagnosis and treatment of cardiac arrhythmias*. 3rd ed. London: Butterworth, 1974: 224-65.
  - 9 Schamroth L. *The disorders of cardiac rhythm*. Oxford and Edinburgh: Blackwell Scientific Publications, 1971: 193-6.
  - 10 Schamroth L, Dove E. The Wenckebach phenomenon in sino-atrial block. *Br Heart J* 1966; **28**: 350-8.
  - 11 Siegel S. *Non parametric statistics for the behavioral sciences*. New York: McGraw Hill, 1956: 36-40.
  - 12 Liebman J. Electrocardiography. In: Moss AJ, Adams FH, eds. *Heart disease in infants, children and adolescents*. Baltimore: Williams & Wilkins, 1968: 183-231.
  - 13 Goldreyer BN, Damato AN. Sinoatrial-node entrance block. *Circulation* 1971; **44**: 789-802.
  - 14 Wu D, Amat-y-Leon F, Denes P, Dhingra RC, Pietras RJ, Rosen KM. Demonstration of sustained sinus and atrial re-entry as a mechanism of paroxysmal supraventricular tachycardia. *Circulation* 1975; **51**: 234-43.
  - 15 Brodsky M, Wu D, Denes P, Kanakis C, Rosen KM. Arrhythmias documented by 24-hour continuous electrocardiographic monitoring in 50 male medical students without apparent heart disease. *Am J Cardiol* 1977; **39**: 390-5.
  - 16 Varghese PJ. Sinus node disorders. In: Roberts NK, Gelband H, eds. *Cardiac arrhythmias in the neonate, infant and child*. New York: Appleton-Century-Crofts, 1977: 159-71.
  - 17 Onat A, Domaniç N, Onat T. Sick sinus syndrome in an infant: severe disturbance of impulse formation and conduction involving the S-A node and the A-V junctional tissue. *Eur J Cardiol* 1974; **2**: 79-83.
  - 18 WHO/ISC Task Force. Definition of terms related to cardiac rhythm. *Am Heart J* 1978; **95**: 796-806.
  - 19 Stock JPP. *Diagnosis and treatment of cardiac arrhythmias*. London: Butterworth, 1969: 35-43.
  - 20 Stock JPP. *Diagnosis and treatment of cardiac arrhythmias*. London: Butterworth, 1969: 93-106.
  - 21 Ferrer MI. The sick sinus syndrome. *Circulation* 1973; **47**: 635-41.
  - 22 Kaplan BM, Langendorf R, Lev M, Pick A. Tachycardia-bradycardia syndrome (so-called "sick sinus syndrome"). Pathology, mechanisms and treatment. *Am J Cardiol* 1973; **31**: 497-508.
  - 23 Nugent EW, Varghese PJ, Pironi DR, Rowe RD. "Sluggish" sinus node syndrome as a part of congenital heart disease (abstract). *Am J Cardiol* 1974; **33**: 160.
  - 24 Greenwood RD, Rosenthal A, Sloss LJ, LaCorte M, Nadas AS. Sick sinus syndrome after surgery for congenital heart disease. *Circulation* 1975; **52**: 208-13.
  - 25 El Said G, Rosenberg HS, Mullins CE, Hallman GL, Cooley DA, McNamara DG. Dysrhythmias after Mustard's operation for transposition of the great arteries. *Am J Cardiol* 1972; **30**: 526-32.
  - 26 El-Said GM, Gillette PC, Cooley DA, Mullins CE, McNamara DG. Protection of the sinus node in Mustard's operation. *Circulation* 1976; **53**: 788-91.
  - 27 Saalouke MG, Rios J, Perry LW, Shapiro SR, Scott LP. Electrophysiologic studies after Mustard's operation for d-transposition of the great vessels. *Am J Cardiol* 1978; **41**: 1104-9.
  - 28 Southall DP, Keeton BR, Leanlage R, et al. Cardiac rhythm and conduction before and after Mustard's operation for complete transposition of the great arteries. *Br Heart J* 1980; **43**: 21-30.
  - 29 Lightfoot PR, Sasse L, Mandel WJ, Hayakawa H. His bundle electrograms in healthy adolescents with persistent second degree A-V block. *Chest* 1973; **63**: 358-62.
  - 30 Meytes I, Kaplinsky E, Yahini JH, Hanne-Paparo N, Neufeld HN. Wenckebach A-V block: a frequent feature following heavy physical training. *Am Heart J* 1975; **90**: 426-30.
  - 31 Cullen KJ, Collin R. Daily running causing Wenckebach heart-block. *Lancet* 1964; **ii**: 729-30.
  - 32 Grimby G, Saltin B. Daily running causing Wenckebach heart block (letter). *Lancet* 1964; **ii**: 962-3.
  - 33 Johnson RL, Averill KH, Lamb LE. Electrocardiographic findings in 67,375 asymptomatic subjects. VII Atrioventricular block. *Am J Cardiol* 1960; **6**: 153-77.
  - 34 Manning GW, Sears GA. Postural heart block. *Am J Cardiol* 1962; **9**: 558-63.
  - 35 Young D, Eisenberg R, Fish B, Fisher JD. Wenckebach atrioventricular block (Mobitz Type 1) in children and adolescents. *Am J Cardiol* 1977; **40**: 393-9.
  - 36 Gambetta M, Denes P, Childers RW. Vagally induced second degree A-V block, Mobitz Type 1, and the hyporeactive SA node. *Chest* 1972; **62**: 152-5.
  - 37 Southall DP, Richards JM, Mitchell P, Brown DJ, Johnston PGB, Shinebourne EA. Study of cardiac rhythm in healthy newborn infants. *Br Heart J* 1980; **43**: 14-20.
  - 38 Southall DP, Orrell MJ, Talbot JF, et al. Study of cardiac arrhythmias and other forms of conduction abnormality in newborn infants. *Br Med J* 1977; **ii**: 597-9.
  - 39 Roland JMA, Varghese PJ, Shematek J, Pironi D. Sinus node dysfunction in young athletes: a possible cause of sudden death. *Circulation* 1975; **51**, suppl: 233.
  - 40 Thormann J, Schwartz F, Ensslen R, Sesto M. Vagal tone, significance of electrophysiologic findings and clinical course in symptomatic sinus node dysfunction. *Am Heart J* 1978; **95**: 725-31.
  - 41 Yabek SM, Jarmakani JM, Roberts NK. Sinus node function in children. Factors influencing its evaluation. *Circulation* 1976; **53**: 28-33.

Requests for reprints to Dr D P Southall, Department of Paediatrics, Cardiothoracic Institute, Fulham Road, London SW3 6HP.