Relations between the development of patterns of sleeping heart rate and body temperature in infants

S A Petersen, C Pratt, M P Wailoo

Abstract
Overnight patterns of rectal temperature and heart rate were recorded from 119 normal infants at weekly intervals from 7 to about 16 weeks of age. All data were collected in the infants’ own homes. As previously reported, different infants developed an adult-like night time rectal temperature pattern abruptly at different ages. When heart rate data were collated by age, there was an apparently gradual fall in sleeping heart rate from 7 to about 14 weeks of age. This was, however, an artefact of data collation. Individual infants showed abrupt falls in heart rate at the time that the adult-like body temperature pattern appeared, but this occurred at different ages in different babies, so when data were collated cross sectionally, an apparently gradual fall resulted. The relation between the developmental changes in sleeping heart rate and rectal temperature was different in boys and girls, with girls showing a more abrupt and greater change in heart rate at the time of development of the adult-like body temperature pattern. Infants whose parents smoked had significantly lower heart rates once the adult-like body temperature pattern had appeared. (Arch Dis Child Fetal Neonatal Ed 2001;85:F133–F136)

Keywords: heart rate; sleeping; body temperature

There are pronounced changes in patterns of sleeping body temperature over the first months of life. We have shown1 2 that babies develop an adult-like night time body temperature pattern (body temperature falling to about 36.2°C) over the course of a few days at some- where between 2 and 5 months of age. The age of onset of this adult-like pattern is very variable, ranging in normal infants from 7 to about 16 weeks. It occurs even later in some groups, particularly infants with low Apgar scores at birth.3 The abruptness of the change is only shown by detailed longitudinal studies of individual infants. If cross sectional data are collated by age, sleeping body temperature appears to fall gradually with age, as an increasing fraction of the babies sampled acquire the adult-like pattern.

Previous studies of heart rate patterns in infants that have passed the newborn stage4 5 appear to show a similar progressive fall in sleeping heart rate with age. This gradual decline may also be an artefact of the cross sectional analysis of the data. In this paper therefore we describe detailed longitudinal measurements of sleeping body temperature and heart rate of infants, in order to establish how the two are related. We report that heart rate changes in a similarly abrupt way to body temperature and at the same time, but in a different way, in the two sexes. Furthermore sleeping heart rate in infants is affected by home circumstances, such as parental smoking.

Methods
A total of 119 babies were studied over three years during 1990–1993. Subjects were recruited soon after birth from babies born in the Leicestershire maternity hospitals. A trained health visitor approached parents, and explained the purpose of the study to them. Over this and a range of other studies, about 40% of parents approached agreed to the monitoring of their infants. There were no significant differences in demographic variables between those families who agreed and those who did not. Parents gave informed consent to the monitoring of their infants at home one night a week from 6 to at least 16 weeks of age. Ethical permission was obtained for the studies.

Full perinatal data were collected on each infant. A trained health visitor undertook each of the home monitorings. The infant was visited at home late afternoon or early evening. It was weighed naked, and a soft probe inserted 5 cm from the anal margin to monitor rectal temperature by a Grant Squirrel Data logger set to sample once a minute throughout the night. We have used rectal probes to monitor the development of body temperature patterns in over 500 babies over a period of 14 years with no adverse effects. Parents very rarely raise any objections. A second probe connected to the same logger monitored room temperature. Each infant was also connected to a Nellcor NL200 pulse oximeter through a toe probe. Electrocardiograph electrodes were attached, so that the oximeter output would reliably indicate heart rate. Heart rate was monitored from bedtime until the first morning feed. Monitoring continued during night time feeds or changes, and parents were instructed on the refitting of the oximeter probe. Each night parents were given a diary to record, prospectively, all events affecting the baby, such as feeds, nappy changes, periods of disturbance, etc. A second portion of the diary allowed the recording of the baby’s condition over the days preceding recording, so that periods of illness.
night. This pattern did not change from week to week after the adult-like pattern appeared, and there was a highly significant change with age (t = 7.96; 118 df; p < 0.001) between that week and the previous week. Thereafter there were no significant differences from week to week before this week 0, but a highly significant difference (Student’s t test, t = 6.01; 118 df; p < 0.001) between that week and the previous week. Thereafter there were no significant differences from week to week. It was always possible to identify the week in which the adult-like body temperature pattern first appeared.

RESULTS

SUBJECTS
Just over half (63; 53%) of the 119 subjects were boys. Mean (SD) birth weight was 3276 (545) g, mean (SD) gestation was 39.1 (2.17) weeks, and mean (SD) maternal age was 26.4 (4.88) years. Some 71 (60%) of the babies were bottle fed at 6 weeks. The social class distribution reflected that of the Leicestershire population with 20 (17%) in social classes I and II and 44 (35%) in social classes IV and V.

A total of 640 successful overnight recordings of heart rate were analysed, which averages 5.4 per infant. Six or more successful consecutive weekly recordings were made in 49 (41%) infants around the age at which an adult-like body temperature pattern appeared.

BODY TEMPERATURE
The cohort of infants taking part in this study developed night time body temperature patterns as we have described previously. For the early weeks of monitoring, body temperature fell to approximately 36.8°C with sleep at night. This pattern did not change from week to week for a variable number of weeks until, suddenly, between one week and the next the pattern changed. Body temperature fell to approximately 36.3°C. Once established, this pattern was maintained, essentially unchanged, from week to week unless the baby became ill or was immunised. Figure 1 illustrates this process. Data from all the infants have been normalised to the first week in which the minimum night time sleeping body temperature fell below 36.5°C which is week 0. This occurred at ages ranging from 7 to 17 weeks in different babies. There were no significant differences from week to week before this week 0, but a highly significant difference (Student’s t test, t = 7.96; 118 df; p < 0.001) between that week and the previous week. Thereafter there were no significant differences from week to week. It was always possible to identify the week in which the adult-like body temperature pattern first appeared.

CHANGES IN PATTERN OF HEART RATE WITH AGE
Figure 2 shows a cross sectional analysis of the heart rate data by age. Both the mean heart rate over the night (from bedtime until eight hours later) and the minimum sleeping heart rate apparently fell steadily until about 14 weeks of age, and remained stable from week to week thereafter. There was a highly significant change with age (t = 6.01; 118 df; p < 0.001 comparing 8 weeks with 14 weeks). This gradual change was, however, an artefact of data collation. Figure 3 shows individual patterns of minimum sleeping heart rate with age, plotted alongside changes in the minimum sleeping body temperature. In these cases, both girls (see below) there was a sudden change in heart rate of between 5 and 8 beats/min at the time that the minimum body temperature suddenly fell. The age of this transition correlated closely with the age at which the adult-like body temperature pattern appeared, and therefore varied from 7 to 17 weeks.

Figure 4 shows heart rate data normalised in the same way as the temperature data from the same infants in fig 1. In the population as a whole, the sleeping heart rate fell significantly
SEX DIFFERENCES IN THE RELATION BETWEEN HEART RATE AND BODY TEMPERATURE PATTERNS

The apparent two stage change in heart rate pattern around the time of onset of the temperature rhythm can be explained if data are collated separately for the two sexes. Figure 5 shows the minimum sleeping heart rate (between two and five hours after bedtime) in the weeks before and after the adult-like temperature pattern appeared, separately for boys and girls. In boys, the heart rate fell between two and one week before the adult-like temperature pattern developed but then did not change significantly from week to week. In girls, heart rate did not fall until the adult-like temperature pattern appeared, then reached a significantly lower value than the boys. Before the adult-like temperature pattern, boys had a higher heart rate than girls, although the difference barely reached statistical significance. One week after the adult-like pattern had appeared, however, girls had a significantly lower heart rate than boys.

HEART RATE AND PARENTAL SMOKING

At each visit, parents were asked whether they smoked. Data were then collated separately for babies for whom one or more parents smoked and those for whom neither parent smoked. The analyses were also performed separately for infants before and after the adult-like body temperature pattern appeared. Before the adult-like pattern appeared, there was no significant effect of parental smoking on the night time heart rate pattern of infants, but
once the adult-like pattern had appeared the
infants of smoking parents reached signifi-
cantly lower heart rates (fig 6) ($t = 5.76; 117$ df; $p < 0.01$).

**Discussion**

We have shown that a detailed longitudinal
study of individual infants is essential if the
precise nature of developmental changes in
sleeping heart rate pattern is to be shown.
Although a cross sectional analysis such as that
in previous studies indicates, as previously
reported, an apparently gradual fall in sleeping
heart rate from 6 to about 14 weeks of age, this
is an artefact of averaging together individual
developmental patterns which consist of a sud-
den change from one heart rate pattern to
another at different ages in different babies.
This sudden transition is associated with a
similarly abrupt transition between two differ-
ent patterns of sleeping body temperature.

The age of transition varies from infant to
infant. It may be as young as 7 weeks or as old
as 17 weeks in this cohort of infants. This
means that some babies may maintain a
relatively high heart rate (around 130 beats/
min) for up to twice as long as others. The
consequences of this are not obvious, but in
other studies we have shown that babies with
later development of an adult-like body tem-
perature pattern share some characteristics
with infants at increased risk of sudden death
in infancy.23

The relation between developmental
changes in heart rate and temperature is differ-
ent in boys and girls. The heart rate of boys falls
before an adult-like body temperature devel-
ops, and to a lesser extent than that of girls,
who show an abrupt, relatively large fall
(around 10 beats/min) when they develop an
adult-like body temperature pattern. We can, at
present, offer no explanation for these differ-
ences, except that boys do tend to develop
adult-like temperature patterns about one
week later than girls, which means that, on
average, but not of course individually, boys
and girls achieve the more mature heart rate
pattern at the same age. Boys tend to gain
weight faster, which may be a reason why their
metabolic rate and perhaps therefore their
heart rate cannot fall as much as girls.

The effect of parental smoking on sleeping
heart rate was both unexpected and inexplica-
ble. Why heart rate should be lower in passive
smoking infants we cannot say. Perhaps the
function of the autonomic nervous system in
these infants is altered by nicotine.

Surprisingly, we found no evidence for a dif-
ference in heart rate between bottle fed and
breast fed babies at any stage of development.
Had there been such a difference, it might have
offered some explanation for the sex differ-
ences (boys being more likely to be breast fed
than girls) and the apparent effects of smoking
(parental smoking is well correlated with bottle
feeding).

We have, however, shown substantial indi-
vidual differences in the development of
patterns of sleeping heart rate that warrant fur-
ther investigation.

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