PAEDIATRIC EPIDEMIOLOGY

Sudden Infant Death Syndrome and the time of death: factors associated with night-time and day-time deaths

PS Blair,1* M Ward Platt,2 IJ Smith3 and PJ Fleming1 and the CESDI SUDI Research Group

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Objective To investigate the diurnal occurrence of Sudden Infant Death Syndrome (SIDS) and interaction with established risk factors in the infant sleeping environment.

Methods A 3 year population-based case–control study, in five English Health Regions. Parentally defined day-time or night-time deaths of 325 SIDS infants and reference sleep of 1300 age-matched controls.

Results The majority of SIDS deaths (83%) occurred during night-time sleep, although this was often after midnight and at least four SIDS deaths occurred during every hour of the day. The length of time from last observed alive until the discovery of death ranged from <1 to 14 h but was not significantly different from the corresponding sleep period amongst the controls. Amongst the day-time deaths, 38% of the infants were observed alive 30 min prior to discovery and 9% within 10 min. The risk of placing infants asleep on their side was more marked for day-time deaths (interaction: \( P = 0.0001 \)) nearly half of whom were found prone, while the risk associated with paternal smoking [OR = 3.25 (95%CI: 1.88–5.62)] was more marked for night-time deaths (interaction: \( P = 0.02 \)). The adverse effect of unsupervised sleep recognized for night-time practice [OR = 5.38 (95%CI: 2.67–10.85)] was also significant for day-time sleep [OR = 10.57 (95%CI: 1.47–75.96)]. Significantly more \(( P = 0.002 \)) unobserved SIDS infants (24.8%) were found with bedclothes over the head compared with those SIDS infants where a parent was present in the room (11.3%).

Conclusions SIDS can happen at any time of the day and relatively quickly. Parents need to be made aware that placing infants supine and keeping them under supervision is equally important for day-time sleeps.

Keywords SIDS, time of death, interval until discovery, sleeping position, smoking, sleeping in a separate room, supervision

Sudden Infant Death Syndrome (SIDS) predominantly occurs during infant sleep periods and common infant care practices associated with this environment have been established as having an adverse or beneficial effect. However the infant sleeping environment and associated practices during the night are often different from those during the day, which may have implications both in terms of the specific advice we give to parents and the presumed mechanisms that lead to death. Few studies are sufficiently large to investigate these two different environments, and, consequently, the advice given to parents1,2 tends to be centred on the parental bedroom and night-time sleep.

Recent reports from New Zealand and the Nordic countries suggest that diurnal variations in major risk factors for SIDS may signify different causal mechanisms; prone sleep position was more strongly associated with SIDS occurring during day-light hours, while night-time deaths were more strongly associated with co-sleeping, maternal smoking, alcohol and...
drug consumption, infant illness, and the non-prone sleeping position.3–5

Characteristically SIDS deaths occur in unobserved infant sleep periods, even for day-time deaths. The exact time of death is unknown and an estimation cannot be determined at post-mortem. The typical picture has been described as an apparently well infant being put to bed in the evening and found dead the following morning, although there is some evidence that many of the deaths may occur in the latter part of the night sleep.6 Establishing the interval between last observation and discovery of the death, especially short intervals, is becoming increasingly important to validate potential mechanisms of causality and to understand the significance of why some risk factors are specifically associated with night-time or day-time deaths. Unusually long intervals may suggest poor parental practice although, to our knowledge, this has not been reported as a controlled observation.

The study of Sudden Unexpected Deaths in Infancy (part of the Confidential Enquiry into Stillbirths and Deaths in Infancy: CESDI SUDI study) was designed to elicit detailed information on the epidemiology and current risk factors associated with SIDS after the ‘Back to Sleep’ campaign in 1991 and subsequent fall in rates. This is a report of the temporal characteristics of the last sleep and risk factors associated with parentally defined day-time and night-time deaths of SIDS infants compared with the reference sleep of age-matched controls.

Methodology

The methodology of the CESDI SUDI study has been described previously.7 Briefly, it was a large population-based case-control study conducted over a 3-year period from 1993 to 1996. The study aimed to include all SUDI cases aged 7–364 days from five former Health Regions in England (Northern, South-West, Trent, Wessex and Yorkshire), a total study population of 17.7 million. Parental data were collected on a standard questionnaire by research interviewers and from medical records. Bereaved families were visited within hours of the death for a narrative account and a second visit within 2 weeks to complete the questionnaire. Four age-matched control infants for each case were selected. The interviewer visited each control family within a week of the death to collect the same data as for the index case. A period of ‘day-time’ or ‘night-time’ sleep described as the ‘reference sleep’ was identified in the 24 h prior to the control interview corresponding to whether the death occurred during the day or night according to the index parents. Most of the control interviews were conducted on weekdays; thus, the control infants were matched for the month and time of day of the death occurred but not the day of the week.

Cause of death was established by a multi-disciplinary committee after a full paediatric autopsy to a standard protocol. All deaths were classified according to the Avon clinicopathological system.7,8 This approach has now been recommended nationally when a sudden unexpected death occurs.9

Variable definition

The time the death was discovered or control infant woke was taken as a precise point in time from the parent. The last observation was defined as the last time the parents heard or saw their baby alive before discovery of the death or the control infant woke. Position put down was the sleeping position the SIDS infant was put down for the final sleep before being discovered dead or the reference sleep of the control infant in the 24 h prior to interview. Infants described as ‘bed-sharing’ were those found after the last sleep co-sleeping with at least one parent (on a mattress, sofa, or chair). Infants described as sleeping in ‘another room’ were those infants sleeping outside the parental bedroom at night or unsupervised in a room during a daytime sleep. Infant health prior to the last sleep was determined using a modified form of the Cambridge ‘Baby Check’, a previously validated system10,11 used to quantify the degree of infant illness.

Statistical methodology

Data that were not normally distributed were described by using medians and inter-quartile ranges (iqr) and the Mann-Whitney test (two sided) was used to test differences between these distributions. Median point estimates of time were calculated assuming a 24 h distribution from 1 a.m. to 12 p.m. Odds ratios, 95% confidence intervals and P-values were calculated, taking into account matching, with conditional logistic regression by using the statistical package SAS. The factors adjusted for in the multivariate model were all significant in the univariate and multivariate analyses at the 5% level after stepwise logistic regression. The covariates included infant factors (age, birth centile, gender, and gestational age), family factors (young maternal age, unemployment, and family size), and previously identified risk factors that may interact with day and night sleep (sleeping position put down, parental proximity in terms of sharing the same room or the same sleep surface, parental smoking and taking of illegal drugs, recent maternal alcohol consumption, head covering, and recent infant illness).

Because of the time lag to arrange interviews the control infants were about 10 days older than the index infants. The variable for infant age was, therefore, included in all univariate and multivariate analyses. For the analysis of night-time and day-time sleeps the data are presented separately but the interaction was constructed by including the multiplicative term of two factors for the whole dataset. The sometimes large odds ratios given for the day-time deaths reflect the small numbers in the comparison groups and should be interpreted in the context of the large confidence intervals also provided.

Results

(i) Characteristics of infant sleep

We asked the parents whether their baby died during what they considered their night-time or day-time routine; 83% (270/325) responded that the death occurred during the night sleep and 17% (55/325) responded during the day. An attempt was made to match the control reference sleep to a similar day-time/night-time dichotomy and was to a large extent successful (93.0% successful matching). The proportion of controls with a day-time reference sleep was 16% (205/1300).

Figure 1 shows the distribution of the times at which the SIDS deaths were discovered or the control infants awoke. The
matching produced distributions that were similar in shape although fewer control infants woke during the evening period and more tended to wake in the morning at an earlier time than when the deaths were discovered. The median time SIDS deaths were discovered [8.30 a.m. (iqr: 7.00–11.10 a.m.)] was 90 min later (P < 0.0001) than the median time control infants woke [7.00 a.m. (iqr: 5.45–8.30 a.m.)]. This difference was slightly more marked during weekends and amongst the more deprived families (social classes IV, V, and the unemployed) but was still significantly different (P < 0.0001) during weekdays and amongst the less deprived families. SIDS infants found in the co-sleeping environment tended to be discovered earlier [median = 7.30 a.m. (iqr: 5.50–8.50 a.m.)] than solitary sleeping SIDS infants [median 9.00 a.m. (iqr: 7.25–12.45 a.m.)] but this was still significantly later (P = 0.002) than when the corresponding co-sleeping controls awoke from reference sleep [median = 6.30 a.m. (iqr: 4.40–8.00 a.m.)]. Half of the SIDS infants (51%) were discovered during the morning hours (5.30 a.m. to 9.30 a.m.) although at least four SIDS deaths occurred during every hour of the 24 h day.

The median age of those SIDS deaths occurring during the night sleep [84 days (iqr: 53–141 days)] was over a month less (P = 0.001) than those SIDS deaths occurring during a day-time sleep [120 days (iqr: 85–184 days)]. Notably the median age of the co-sleeping SIDS infants [59 days (iqr: 33–100 days)], a practice which predominantly occurs during the night, was much less than those SIDS infants who slept alone [112 days (iqr: 69–141 days)]. Restricting the age comparison of day-time and night-time deaths to the solitary sleeping SIDS infants yielded no significant difference (P = 0.10).

The length of time from last seen or heard alive until discovery of the night-time death ranged from less than an hour to 14 h (Figure 2). The median interval for the SIDS infants was 4 h 45 min (iqr: 2h 30 min—7 h 15 min), slightly less than the corresponding interval for the controls, 5 h 5 min (iqr: 3–8 h), and not quite significant (P = 0.054). Of the 270 parentally defined night-time deaths, 29.1% were last observed alive between 6 p.m. and prior to midnight, 46.1% between midnight and prior to 4 a.m., and 24.8% from 4 a.m. onwards. A fifth of the SIDS infants (20.1%) were observed alive within 2 h before discovery of the night-time death, 11.4% within an hour, and 6.8% within 30 min. At last observation 78.7% of the night-time SIDS infants were described by the parents as apparently healthy.

Figure 3 shows this time interval was much shorter for day-time sleeps, for both SIDS infants and controls. The median time from when the SIDS infants were last seen or heard alive until they were discovered dead after a day-time sleep was 1 h 15 min (iqr: 28 min–1 h 35 min), slightly longer than the time until the controls awoke, 50 min (iqr: 30 min–1 h 30 min), but again not significantly different (P = 0.22).

For day-time sleeps, 37% (69/186) of control infants and 38% of the SIDS infants (20/53) had been checked within 30 min of waking or being found dead. For 9% (5/53) of SIDS infants, and 11% (21/186) of controls this interval was 10 min or less. At last observation 78.2% of the day-time SIDS infants were described by the parents as apparently healthy.

**Interaction with day-time or night-time sleep**

Table 1 lists risk factors investigated for an interaction with day-time or night-time sleep.

The interaction between the position in which the infant was placed for sleep and whether this was a day-time or night-time sleep was significant (P = 0.0003), although this was largely due to infants being placed on their side (interaction: P = 0.0001) rather than prone (P = 0.40). The risk of placing infants on their side was not significant at night when controlled for other covariates in the multivariate model (P = 0.11) but was significant during the day (P = 0.003). Of those SIDS infants put down on their side to sleep at night 30% were found prone compared with 45% during the day, although this did not reach significance (P = 0.19). Most of the control infants (97%) put down on their side were usually put down in that position; however, the corresponding proportion was 86% for night-time deaths and 75% for day-time deaths.

Co-sleeping was a significant risk for both night-time and day-time sleep as was infants sleeping in a different room from their parents. This latter practice, which occurs in a quarter of the control population at night-time, is the most common

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**Figure 1** The time the SIDS death was discovered or controls awoke (to the nearest hour)

**Figure 2**

**Figure 3**
practice during the day, 64% of the day-time control reference sleeps and 75% of the day-time deaths occurring in an unsupervised room. Notably 31.0% of SIDS infants sleeping separately from the parental bedroom were found with bedclothes over their head compared with 14.8% by the parental bed and 7.5% who slept in the parental bed. Similarly 13.2% of SIDS infants found after an unsupervised day-time sleep were found with head covering compared with none of the supervised SIDS infants. Overall 24.8% (27/109) of unsupervised SIDS infants were found with head covering compared with 11.3% (22/194) where the parent was present ($P < 0.002$).

The prevalence of maternal smoking during pregnancy was higher amongst mothers of infants who died during the night although there was no significant interaction. There was, however, a significant interaction with habitual paternal smoking, which carried a significant risk for night-time deaths ($P < 0.0001$) but not for those deaths that occurred during the day ($P = 0.89$).

There was no significant multivariate interaction with other risk factors in the sleeping environment such as maternal alcohol consumption ($P = 0.63$), parental use of illegal drugs ($P = 0.78$), recent infant illness ($P = 0.63$), or head covered by bedding ($P = 0.77$).

**Discussion**

Although SIDS victims are often discovered after a night-time sleep the death can occur during any hour of the day and relatively quickly. Three-quarters of the infants who died during what the parents described as a night-time sleep were still observed alive after midnight, a fifth were still alive within 2 h of the final event. Of those who died during the day over a third were observed alive 30 min prior to death, 9% within 10 min. The fact that most SIDS parents described their infants as seeming to be well for this last observation suggests at least for some of these deaths that the onset of the final event was undetectable or very quick. For some deaths the time between when the SIDS infant was last observed alive and found dead seemed very long but was actually no different from when some of the control infants were last observed and found after the reference sleep suggesting little evidence of poor parental practice.

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**Figure 2** Length of time until SIDS discovered or controls awoke (Night) (Nearest hour from time last seen/heard until discovered)

**Figure 3** Length of time until SIDS discovered or controls awoke (Day) (Nearest hour from time last seen/heard until discovered)
Many of the risk factors associated with SIDS were significant for both night-time and day-time deaths, but there were some important differences. We confirm the significant interaction between infant sleeping position and day-time deaths but unlike the New Zealand and Nordic studies the marked increase in the significance was for infants being put down on their side rather than prone. The prevalence of being positioned prone was more marked for day-time sleep but the interaction was not significant and was not explained by the difference in the definition of what constitutes a ‘day-time’ or ‘night-time’ sleep between the studies, as it persisted when we re-analysed our data using the New Zealand\(^3,4\) and Nordic definitions.\(^5\) The proportion of infants put down prone were much higher in these previous studies, which may suggest that our findings are more synonymous with infant care practices after the ‘Back to Sleep’ campaign. Although the prone position is now used infrequently\(^12,13\) the side positioning is still commonly used,\(^14\) especially amongst pre-term infants after hospital discharge\(^15\) and amongst bed-sharing infants.\(^16\) Placing infants on their side to sleep was the most common practice amongst SIDS infants who died during the day in our study, almost half of them were found prone and a quarter were not usually placed in this position. The key message from all of these studies is to place the infant supine for day-time as well as night-time sleeps.

### Table 1 Interaction of risk factors with day-time and night-time sleep

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Night-time</th>
<th>Day-time</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SIDS Controls</td>
<td>OR (95% CI)</td>
<td>P-value</td>
</tr>
<tr>
<td>Position put down</td>
<td>120 45.6 732 67.0</td>
<td>1.00 (Ref)</td>
<td>3.005</td>
</tr>
<tr>
<td>Back</td>
<td>105 39.9 326 29.9</td>
<td>1.54 (0.91–2.59)</td>
<td>0.11</td>
</tr>
<tr>
<td>Side</td>
<td>38 14.4 34 3.1</td>
<td>6.20 (2.21–17.40)</td>
<td>0.0005</td>
</tr>
<tr>
<td>Front</td>
<td>97x232</td>
<td>1.00 (Ref)</td>
<td>3.005</td>
</tr>
<tr>
<td>Parental proximity</td>
<td>103 38.1 622 56.8</td>
<td>1.00 (Ref)</td>
<td>3.005</td>
</tr>
<tr>
<td>Same room</td>
<td>94 34.8 183 16.7</td>
<td>7.02 (3.54–13.91)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Same bed(^b)</td>
<td>73 27.0 290 26.5</td>
<td>5.38 (2.67–10.85)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Different room</td>
<td>94 34.8 183 16.7</td>
<td>7.02 (3.54–13.91)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Maternal smoking(^c)</td>
<td>83 31.1 801 73.2</td>
<td>1.00 (Ref)</td>
<td>3.005</td>
</tr>
<tr>
<td>No</td>
<td>184 68.9 293 26.8</td>
<td>2.66 (1.56–4.53)</td>
<td>0.003</td>
</tr>
<tr>
<td>Yes</td>
<td>88 33.0 694 63.4</td>
<td>1.00 (Ref)</td>
<td>3.005</td>
</tr>
<tr>
<td>Paternal smoking(^d)</td>
<td>226 87.3 1058 96.7</td>
<td>1.00 (Ref)</td>
<td>3.005</td>
</tr>
<tr>
<td>No</td>
<td>179 67.0 400 36.6</td>
<td>3.25 (1.88–5.62)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Yes</td>
<td>35 12.7 36 3.3</td>
<td>7.60 (2.54–22.71)</td>
<td>0.003</td>
</tr>
<tr>
<td>Maternal alcohol(^e)</td>
<td>217 83.5 1039 95.1</td>
<td>1.00 (Ref)</td>
<td>3.005</td>
</tr>
<tr>
<td>No</td>
<td>43 16.5 54 4.9</td>
<td>1.95 (0.82–4.61)</td>
<td>0.13</td>
</tr>
<tr>
<td>Yes</td>
<td>252 88.2 1050 96.3</td>
<td>1.00 (Ref)</td>
<td>3.005</td>
</tr>
<tr>
<td>Infant illness(^g)</td>
<td>31 11.8 40 3.7</td>
<td>2.85 (1.03–7.89)</td>
<td>0.04</td>
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<tr>
<td>No</td>
<td>209 82.6 1050 96.7</td>
<td>1.00 (Ref)</td>
<td>3.005</td>
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<tr>
<td>Yes</td>
<td>44 17.4 36 3.3</td>
<td>17.43 (6.19–49.14)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

\(a\) Controlling for (i) infant factors: age, birth centile, gender, gestational age, (ii) family factors: young maternal age, unemployment, family size, and (iii) the above risk factors.

\(b\) Includes co-sleeping in the parental bed, on a sofa, or on a chair.

\(c\) Maternal smoking during pregnancy.

\(d\) Mothers without partners were assumed to be mothers with non-smoking partners.

\(e\) Mothers who consumed more than 2 units of alcohol (equivalent to 1 pint of beer or 2 small glasses of wine) in the 24 h prior to the death or end of control reference sleep.

\(f\) Parental use of illegal drugs (mainly cannabis) after the birth of the infant.

\(g\) Based on Cambridge Baby Check score of 13 or more (infant ill and requires a doctor).

\(h\) Infant found with head covered by bedding.
Co-sleeping, recent maternal alcohol consumption, and parental use of illegal drugs were more marked during night-time deaths, but, unlike the New Zealand study, we did not find any significant interaction. Co-sleeping infants tended to be discovered dead earlier than solitary sleeping SIDS infants, although the bed-sharing control infants also woke from the reference sleep significantly earlier than the control infants who slept elsewhere. The finding that SIDS infants found after a night sleep were significantly younger than those found in the day appears to be a feature of co-sleeping rather than night-time sleep.22

Previous findings of a lower SIDS risk if infants share the same room but not the same bed as the parents19,20 has led to current advice that parents should put the infant cot by the parental bed for at least the first 6 months.1,2 This analysis suggests that the risk associated with the absence of parental supervision is also significant for day-time sleeps, a setting in which it was far more common for infants to sleep alone in a room and challenges the assumption of protection being limited to where infants sleep at night. In particular we found that unsupervised SIDS infants were more likely to be found with bedclothes covering their head. Parental presence during infant sleep does not guarantee the infant is being constantly observed, indeed this is not usually the case and SIDS can also occur under closely monitored conditions.21 However, having the sleeping infant nearby during the day may alert parents to circumstances such as infants rolling from the side to the prone position or bedclothes covering the infant head or face. In conjunction with this parents also need to be made aware of the risks associated with inappropriate sleeping environments for young infants during day-time naps such as car seats.22

The prevalence of maternal smoking during pregnancy was marked amongst the day-time deaths.17,18 maternal smoking was only significant for night-time deaths and placing infants on their side to sleep was more significant for infants who died at night. These findings are in the same direction as the New Zealand and Nordic studies and potentially support previous indications of a strong link between prenatal and post-natal infant exposure to tobacco smoke and co-sleeping.17,18,23,24

The significant interactions found in other studies between infant illness, sweating, and colds with night-time sleep was not confirmed in this study neither was an interaction found with head covering and period of sleep.

The SIDS deaths were discovered on average 90 min later than when the control infants woke. This does not appear to be explained by socioeconomic status nor any differences in practice between weekdays or weekends. Recall bias is unlikely as most of the SIDS mothers were interviewed within hours of the death. This difference between discovery and waking could be related to patterns of parental sleep, as we have previously reported that SIDS parents in general went to bed later than the controls.7 Although this finding could be an artefact of comparing sleeping infants to dead ones, a unique study of sleep recordings obtained from infants who subsequently died of SIDS showed decreased waking time during the early morning.25 Another study comparing SIDS deaths with near-miss SIDS found that the latter were discovered and rescued earlier than those infants who died, suggesting that the lack of observation could be a key factor in these deaths.26

We conclude that although SIDS commonly occurs unobserved during night-time sleep, the onset of the final event can occur relatively quickly and at any time of the day. There are important differences between sleeping during night and day that may reflect a different diurnal pathogenesis for sudden infant deaths. Current advice on reducing risk should emphasize that placing infants supine for sleep, and keeping them under supervision, is important both by night and day.

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**KEY MESSAGES**

- SIDS is predominantly an unobserved event that occurs during night-time and day-time infant sleep.
- The length of time from last parental observation of a seemingly well infant until the discovery of death was sometimes quite short suggesting that the onset of the final event for some deaths was undetectable or very quick.
- The possible protective effect of having an adult in the same room as the sleeping infant during the night is equally applicable for day-time deaths and may reduce the risk of young infants rolling prone or bedclothes covering the infant head.
- Most risk factors associated with SIDS were significant for both night-time and day-time deaths although paternal smoking was only significant for night-time deaths and placing infants on their side to sleep was more marked amongst the day-time deaths.
References


9 The Kennedy Report. Sudden death in infancy. The report of a working group convened by the Royal College of Paediatrics & Child Health. Copies can be obtained from the college websites. Available at: http://www.rcpch.ac.uk


