Seasonal variation of sudden infant death syndrome in Hawaii

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Objective: To test whether the sudden infant death syndrome (SIDS) rate displays the universal winter maximum and summer minimum in Hawaii where there is no appreciable seasonal variation of temperature.

Design: The null hypothesis is tested that there is no seasonal variation of necropsied SIDS in Hawaii. The numbers of live births and SIDS cases by month for the years 1979 to 2002 were collected and the monthly SIDS distribution is predicted based on the age at death distribution.

Setting: The state of Hawaii, located in the midst of the Pacific Ocean, has a semi-tropical climate with temperatures fluctuating diurnally as 25 ± 5°C throughout the year. Therefore homes are unheated and infants are not excessively swaddled. The Hawaii State Department of Health maintains vital statistics of all infant births and deaths.

Main results: The results reject the null hypothesis of no seasonal variation of SIDS (p = 0.026). An explanation for the seasonal effect of the winter maximum and summer minimum for Hawaiian SIDS is that it arises from the cycle of the school session and summer vacation periods that represent variable intensity of a possible viral infection vector. SIDS rates in both Hawaii and the United States increase with parity, also indicating a possible role of school age siblings as carriers.

Conclusions: The winter peak of the SIDS in Hawaii is support for the hypothesis that a low grade viral infection, insufficient by itself to be a visible cause of death at necropsy, may be implicated as contributing to SIDS in vulnerable infants.
that assuming all infants dying at age less than 1 month were occurring in the month after the month of birth, etc., provides a negligible change in the expected number of SIDS in any given month.15

Given the total of 384 necropsied SIDS and the 1979–2002 total of 444,699 live births, the procedure chosen to estimate the expected monthly number of cases from monthly birth totals if there is no seasonal variation is as follows: from table 1, there were 37,984 births in December, and from Table 2, showing the age distribution of SIDS, we expect that the fraction of children dying of SIDS in December who were born in December is 0.075. The contribution to the expected number of SIDS in December from children born in December is

\[ 2.46 = 384 \times \left( \frac{37,984}{444,699} \right) \times 0.075, \]

where:

- 384 = total numbers of SIDS in Hawaii during 1979–2002;
- 37,984/444,699 = probability that a SIDS infant was born in December;
- 0.075 = probability that an infant born in December who dies of SIDS died in December.

This computation is repeated for the November birth cohort of 36,848 infants using the 1–2 month fraction of 0.260 to estimate the number born in November and dying in December, as

\[ 8.28 = 384 \times \left( \frac{36,848}{444,699} \right) \times 0.260, \]

and likewise for the other 10 months.

For evaluation of the alternate hypothesis that SIDS is related to an infection vector that varies seasonally with the school year, the Hawaii State Department of Education provided the starting dates of the school years (range 1 to 5 September) and the last dates of school for each year (range 7–9 June), which makes the summer vacation period slightly different than the period from 1 June 31 August we defined as summer for our seasonal analysis. A small number of rural schools in Hawaii have recently shifted to a “multi-tract” system of school year round with shorter breaks in between rather than the traditional long summer break, but this effect is considered negligible for the analysis. By reference to the date of each SIDS we calculated the number of SIDS during the summer vacation and during the rest of the year when school was in session for comparison with the expectation for that period.

Statistical analyses of these data for seasonality were performed using the Yates’s \( \chi^2 \) test and the Edwards’ test for a sinusoidal cycle of independent events.17 The Edwards’ test is equivalent to placing a point for each calendar date of death about the rim of a circle corresponding to time intervals from 0 to 365.25 days. In the absence of any cyclic trend the centre of gravity of the data points will be at the centre of the circle, and will have a determinate sampling distribution. The distance from the centre has a test statistic equal to \( -2 \ln p \), which is a basis for rejecting a seasonal variation. The ray from the centre of the circle through the centroid of the data hits the rim at the point of peak incidence.

### RESULTS

In Hawaii the age distribution of SIDS and the ~50% male excess of SIDS are similar to those throughout the continental United States and rest of the world, with a maximum rate at a completed two months of life and a ~50% excess of male SIDS.13 Adding new data to the 95 male and 58 female SIDS reported from 1974 to 1982,13 there were 130 male and 106 female cases from 1983 to 1998,14 and 15 male and 9 female cases from 1999 to 2002 reported by Hawaii State Department of Health. This pronounced decrease in the SIDS rate is probably related to the adoption of the supine position for infant sleep after warning that prone sleep is the central contributory cause for SIDS.19 The totals of 240 male and 173 female SIDS, with a 6% male excess birth rate in Hawaii, represent a 31% male excess, which is not statistically different from an expected 50% male excess rate by a Yates’s \( \chi^2 \) test (\( p = 0.19 \)).2

The total numbers of live births and the observed and expected numbers of necropsy confirmed SIDS cases from 1979 to 2002 are shown in table 1 for each month of the year. There were 11 early June cases before the end of the school year and nine early September cases at the end of the summer vacation. This procedure of dividing the year into June through August. This procedure of dividing the year into summer (June–August) and non-summer (September–May) was originally suggested for testing for seasonality of hospital admissions for psychoses.20 Seventy five SIDS occurred during June to August with an expected 94.31, and 309 SIDS were observed September to May with an expected 289.69. A Yates’s \( \chi^2 \) test rejects the null hypothesis of no seasonal variation of SIDS (\( p = 0.026 \)). This result occurred during a period when the preferred sleep position had shifted from prone to supine, and while necropsy standards have become more rigorous. Despite such changes, the results confirm the earlier finding of a summer minimum for years 1974–1978 when prone sleep position was not contraindicated. There were then 11 summer and 55 non-summer
SIDS, which suggests the sleep position does not contribute to the seasonal variability in death rate. These results support the conclusions of others that the school session-school vacation cycle may be a contributing factor for the observed seasonality of SIDS.

The Edwards' test for an annual cycle with a single peak and a single trough as fit by a cosine wave was also used. Following the procedure, using the exact numbers of days in each month (31 January, 28.25 February, ...) the test statistic of 11.06 was found, which is equal to $2 \log p$, where $p = 0.004$. Thus the null hypothesis is rejected and the data are consistent with a seasonality of SIDS. The peak incidence was found at 31 days, corresponding to 31 January at 11:59 p.m.

In a related manner, we let an average year consist of 365.25 days so that an annual cycle can be modelled by equation 1.

\[
pS(t) = A + B[1 + \cos(2\pi(t - \phi)/365.25)],
\]

where $pS(t) = $ rate of SIDS at time $t$: 0$<t<365.25$, $A$ = a constant rate of SIDS from non-seasonal causes, $B$ = the average of the variable rate of SIDS from seasonal causes, $\phi$ = the time of maximum SIDS in the annual cycle, and $pS(t)\, dt = $ probability of a SIDS occurring between time $t$ and time $t+dt$.

Integrating equation 1, as $pS(t)\, dt$ we can obtain an expression for the monthly expectations accounting for variable numbers of days in the monthly data, as equation 2.

\[
S(T2) - S(T1) = (A + B)(T2 - T1) + \frac{[B \cdot 365.25/2\pi] \cdot [\sin(2\pi(T2 - \phi)]}{365.25} - \frac{[\sin(2\pi(T1 - \phi)]}{365.25}
\]

where $T1$ is the start of a month (for example, $T1 = 0$ at 12 01 am on 1 January), $T2$ is the end of that month (for example, $T2 = 31$ at 11 59 pm on 31 Januar.

### Table 2 Age distributions of SIDS during summer vacation and school year in Hawaii, 1979–2002

<table>
<thead>
<tr>
<th>Monthly age interval of the death by SIDS</th>
<th>Numbers of SIDS cases</th>
<th>Fractions of SIDS by monthly age at death (number/total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Summer school vacation</td>
<td>Non-summer school year</td>
</tr>
<tr>
<td>0–1 (0 to 30 days)</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>1–2</td>
<td>15</td>
<td>86</td>
</tr>
<tr>
<td>2–3</td>
<td>15</td>
<td>69</td>
</tr>
<tr>
<td>3–4</td>
<td>12</td>
<td>55</td>
</tr>
<tr>
<td>4–5</td>
<td>5</td>
<td>37</td>
</tr>
<tr>
<td>5–6</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>6–7</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>7–8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>8–9</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>9–10</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>10–11</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11–12</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>12–13</td>
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<td>0</td>
</tr>
<tr>
<td>13–14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14–15</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>73</td>
<td>315</td>
</tr>
</tbody>
</table>

*Including four non-necropsied SIDS cases.*

### Figure 1 Seasonal distributions of SIDS and household URI in Hawaii, 1974–1982, showing winter maximums and summer minimums.
S(T2) - S(T1) = the expected numbers of SIDS in the month. An optimisation program was run to minimise the sum of the squared differences between the predicted numbers of monthly SIDS and the observed numbers shown in table 1. The two parameters of the model were found to be A = 296/384 and \( \phi = 30 \) (30 January at 11:59 pm), and B is determined by continuity as \( 1 - A = 88/384 \). Equation 2 predicts 39.74 SIDS for January compared with the observed value of 41, and the procedure is followed for the other 11 months. A Yates’s \( \chi^2 \) statistic of the 12 predicted and observed monthly values was 8.02 with 9 df, for \( p = 0.523 \), so the cosine function of equation 1 is not rejected by this method as a reasonable description of the Hawaiian monthly SIDS data.

**DISCUSSION**

According to Samuels, "Viral respiratory infections are the most likely trigger for sudden infant death syndrome (SIDS)." These viruses follow the seasonal pattern of SIDS with winter maximums and summer minimums. Figure 1 shows this seasonal pattern for household upper respiratory infections (URI) in Hawaii, 1974–1982, which follows the pattern for respiratory syncytial virus in the US in the period 2000–2003. The cosine function of equation 1 can be interpreted as 296 of the SIDS were not associated with a paradoxical overheating during the colder months of the year (winter) and with a higher frequency of respiratory infections (not sufficient to be diagnosed as the cause of death at necropsy) may be a contributory factor in the terminal process that leads to the seasonality of the SIDS.

A myriad of other risk factors have been associated with SIDS, such as neurological prematurity, parental tobacco smoking, and a prone sleep position. Because these risk factors are all non-seasonal and gender independent they also cannot be the cause of either the seasonal relation or the 50% male excess. This suggests that a low grade respiratory infection (not sufficient to be diagnosed as the cause of death at necropsy) may be a contributory factor in the terminal process that leads to the seasonality of the SIDS.

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**Policy implications**

Hawaiian parents need to be educated to put their infants to sleep in the supine position, to recognise the symptoms of low grade respiratory infection in infancy, and not to over clothe their infants at night during cool evenings that seem cold in comparison with the normally semi-tropical weather.
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Conflicts of interest: none declared.

REFERENCES

27. East PL. Kiernan EA. Risks among youths who have multiple sisters who were adolescent parents. Fam Plann Perspect 2001;33:75-80.