Weather and the risk of sudden infant death syndrome: the effect of wind

P M Macey, P J Schluter, R P K Ford

Abstract

Study objective—To examine and identify relations between sudden infant death syndrome (SIDS) and wind, particularly the föhn wind, in Christchurch, New Zealand.

Design—A retrospective epidemiological study combining details of regional hourly meteorological variables and reported SIDS cases.


Participants—All 646 infants reported as dying from SIDS within the greater Christchurch region.

Main results—Analysis of 1968–1989 data revealed nine wind variables significantly related to SIDS. When compared with corresponding variables calculated over the 1990–1997 period, only the northerly wind on the day of death and the southerly wind three days before a SIDS death had estimated associations with similar effect size and sign. However, both these variables had confidence intervals that included unity.

Conclusions—No evidence was found to suspect that föhn winds influenced SIDS occurrence. The relations identified between SIDS incidence and wind, after controlling for the effects of temperature and trend, were tenuous and relatively small. More data are necessary to substantiate whether northerly winds on the day of death or southerly winds occurring three days before a death are truly associated with SIDS. It seems that wind has little, if any effect on SIDS incidence in Christchurch.

Historically, one of the more important climatic factors associated with ill health, other than temperature, has been that of wind, particularly hot, dry and turbulent wind.1–12 Internationally, this type of wind has many nomenclatures, including: the föhn (or foehn) wind in Switzerland and Germany; the Santa Ana or witches wind in the USA;13 the Sirocco in south eastern Europe;14 the Chinook in Canada; the Zonda in the Andes; and, the Sharav in Israel.14 Föhn winds have been associated with increased irritability, headaches and heart problems.10 15 16 In Bermuda, such winds have also been related to worsening asthma.17 However, not all studies have demonstrated deleterious associations between wind and health.13–20

Few studies have specifically related meteorological patterns, other than temperature, to SIDS. Among those that have, one identified an association between visibility and SIDS, but found no statistical evidence for associations between wind speed, precipitation, cloud, or pollution levels.21 Another study noted that SIDS incidence increased on drier and windier days, but this finding was not explicitly related to föhn wind occurrence.22

The reason why föhn winds should affect health is uncertain, although various postulates have been promulgated in the literature.14 23 24 One theory suggests that these winds increase the proportion of positive ions in the atmosphere, which, in turn, adversely affects our endocrine, vegetative and autonomous nerve systems.16 25 26 Increased SIDS incidence could thus occur directly, through increased positive ion exposure, or indirectly, through altered infant care practices in response to föhn wind conditions (such as caregiver irritability or headaches).

Wind is undoubtedly an important environmental factor. The question that arises is how much influence does climatic wind have on infants’ SIDS risk? The purpose of this study was to examine and identify relations between wind and SIDS on data collected over 30 years from 1968 to 1997 in Christchurch, New Zealand.

Methods

The objective is to examine and identify relations between SIDS and environmental wind once trend components and ambient temperature measures have been accounted for in the statistical model.

CHRISTCHURCH METEOROLOGICAL DATA

The New Zealand Meteorological Service supplied hourly recorded meteorological data, for the years 1968–1997, collected from...
A quadratic model.

dashed line gives the first order linear model, and the solid curve gives the second order

Figure 2 Y early SIDS deaths in Canterbury per 1000 live births from 1968 to 1989. The meteorological data were recorded.

illustrates the 20 km radius where 90% of the SIDS deaths occurred, and the airport where flows over the Southern Alps and across the Canterbury Plains. The Christchurch map is located in the central South Island of New Zealand. The northwesterly, a föhn wind, was recorded on the hour and measured to the nearest degree Celsius (°C), wind direction was derived by averaging the recorded directions over the previous 10 minutes and measured to the nearest 10 degrees, and wind speed was derived by averaging recorded speeds over the previous 10 minutes and measured to the nearest knot. No wind direction measurement was recorded if the wind speed was zero.

Measurement instrumentation was upgraded by the Meteorological Service at the beginning of 1993. The new equipment was sensitive to lighter winds.

CHRISTCHURCH SIDS DATA

All postneonatal infant deaths occurring within the greater Christchurch region since 1968 have been systematically examined and classified.27 Deaths classified as SIDS with date of death on or between 1 January 1968 and 31 December 1997 were included for analysis. Most (90%) of these deaths occurred within a 20 km radius of Christchurch Airport (the site of meteorological measurement), as depicted in figure 1.

Pathology records and parental interview notes were used to ascertain the date and time that SIDS victims were discovered. Nelson et al, studying postneonatal mortality in this region, reported that two thirds of parents last saw their infants alive within six hours of the time that the infant was subsequently found dead.28 Few deaths (5.0%) were discovered before 5 30 am, implying that only a small proportion of the dates of death would have been misclassified. A further 33% of SIDS deaths were discovered between 5 30 am and 8 30 am, 22% were discovered between 8 30 am and midday, while the remaining 40% of SIDS deaths were discovered between midday and midnight.

TEMPERATURE VARIABLE SPECIFICATION

Using these data over the 1968–1989 period, a previous study2 related SIDS to ambient temperature and found two significant components, namely:

(1) a seasonal effect, measured by averaging the minimum temperature recorded on the nominated day and the preceding 30 days; and

(2) a day effect, measured by averaging the hourly changes in temperature over the course of the nominated day.

A day was defined to contain 24 hourly observations beginning from midnight. These temperature measures were calculated for each day of the study and embodied into the statistical model.

WIND VARIABLE SPECIFICATION

Hourly wind direction was resolved into nine groupings (in degrees from true north): N (337.5–22.5), NE (22.5–67.5), E (67.5–112.5), SE (112.5–157.5), S (157.5–202.5), SW (202.5–247.5), W (247.5–292.5), NW (292.5–337.5) and Calm (wind speed equalled zero). On days where one particular wind direction group predominated then, this was recorded as the wind direction for that day (91.0% of days), otherwise the wind direction variable was designated as being Mixed (9.0% of days). Two other daily wind direction variables were considered, namely: the average hourly change; and, the maximum hourly change. The first variable measures the variability in daily wind direction, while the second variable facilitates the examination of dramatic wind direction changes (such as the passage of fronts or thunderstorms).

Daily wind speed measures considered were average speed, the maximum recorded speed and the standard deviation of the recorded speeds.

Several studies have identified associations between lagged daily temperature and SIDS.6 Correspondingly, wind variables recorded on the designated day and over the eight preceding days were investigated. We define day 0 to denote the designated day, while day 1 represents the preceding day, day 2 is the day preceding day 1, and so forth. Similarly, four between day wind variables were also considered.

ANALYSIS

As this study was principally exploratory, many meteorological variables were considered. To reduce the chance of reporting spuriously significant associations, the large dataset was cleaved into two—the first used for variable investigation and the second for variable...
validation. Before 1990, New Zealand had one of the highest rates of SIDS recorded in the developed world.30 In an attempt to redress this situation, various national and regional SIDS prevention campaigns were started.30 31 Since the commencement of these programmes, the New Zealand SIDS rate has decreased by more than two thirds.31 Thus, data collected before the SIDS prevention campaigns were used for the determination of the significant wind variables (1968–1989) and the data collected since these campaigns were used for variable validation (1990–1997).

Poisson regression with a log-link function, using the “reference cell coding” method, into the Statistical Analysis System (SAS), was used to examine the meteorological variables. Initially, a baseline model was constructed that accounted for polynomial trends and the significant ambient temperature associations within the data. Each wind variable was then added to the baseline model to determine whether it was significantly associated with SIDS. Variables were considered important if they significantly improved the log-likelihood statistic, approximated by the χ² distribution, on September 15, 2023 by guest. Protected by copyright.

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Table 1 Description of wind variables grouped by SIDS event and no-SIDS days

<table>
<thead>
<tr>
<th>Day effects</th>
<th>(case se)</th>
<th>day 0</th>
<th>day 1</th>
<th>day 2</th>
<th>day 3</th>
<th>day 4</th>
<th>day 5</th>
<th>day 6</th>
<th>day 7</th>
<th>day 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of predominantly N days</td>
<td>SIDS</td>
<td>0.051</td>
<td>0.042</td>
<td>0.037</td>
<td>0.040</td>
<td>0.035</td>
<td>0.031</td>
<td>0.029</td>
<td>0.026</td>
<td>0.026</td>
</tr>
<tr>
<td>No-SIDS</td>
<td>0.033</td>
<td>0.034</td>
<td>0.034</td>
<td>0.034</td>
<td>0.034</td>
<td>0.035</td>
<td>0.035</td>
<td>0.035</td>
<td>0.035</td>
<td>0.035</td>
</tr>
<tr>
<td>Proportion of predominantly NE days</td>
<td>SIDS</td>
<td>0.160</td>
<td>0.149</td>
<td>0.127</td>
<td>0.150</td>
<td>0.156</td>
<td>0.141</td>
<td>0.141</td>
<td>0.134</td>
<td>0.134</td>
</tr>
<tr>
<td>No-SIDS</td>
<td>0.141</td>
<td>0.141</td>
<td>0.143</td>
<td>0.141</td>
<td>0.141</td>
<td>0.142</td>
<td>0.142</td>
<td>0.143</td>
<td>0.143</td>
<td>0.143</td>
</tr>
<tr>
<td>Proportion of predominantly E days</td>
<td>SIDS</td>
<td>0.187</td>
<td>0.204</td>
<td>0.242</td>
<td>0.217</td>
<td>0.193</td>
<td>0.189</td>
<td>0.204</td>
<td>0.176</td>
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<tr>
<td>No-SIDS</td>
<td>0.233</td>
<td>0.232</td>
<td>0.229</td>
<td>0.231</td>
<td>0.233</td>
<td>0.233</td>
<td>0.233</td>
<td>0.235</td>
<td>0.235</td>
<td>0.235</td>
</tr>
<tr>
<td>Proportion of predominantly S days</td>
<td>SIDS</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>No-SIDS</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Proportion of predominantly SW days</td>
<td>SIDS</td>
<td>0.167</td>
<td>0.152</td>
<td>0.154</td>
<td>0.138</td>
<td>0.154</td>
<td>0.152</td>
<td>0.171</td>
<td>0.156</td>
<td>0.169</td>
</tr>
<tr>
<td>No-SIDS</td>
<td>0.146</td>
<td>0.147</td>
<td>0.147</td>
<td>0.148</td>
<td>0.147</td>
<td>0.147</td>
<td>0.146</td>
<td>0.147</td>
<td>0.146</td>
<td>0.146</td>
</tr>
<tr>
<td>Proportion of predominantly W days</td>
<td>SIDS</td>
<td>0.059</td>
<td>0.077</td>
<td>0.070</td>
<td>0.068</td>
<td>0.072</td>
<td>0.062</td>
<td>0.062</td>
<td>0.066</td>
<td>0.055</td>
</tr>
<tr>
<td>No-SIDS</td>
<td>0.059</td>
<td>0.058</td>
<td>0.058</td>
<td>0.059</td>
<td>0.058</td>
<td>0.059</td>
<td>0.059</td>
<td>0.059</td>
<td>0.059</td>
<td>0.059</td>
</tr>
<tr>
<td>Proportion of predominantly NW days</td>
<td>SIDS</td>
<td>0.059</td>
<td>0.048</td>
<td>0.061</td>
<td>0.040</td>
<td>0.072</td>
<td>0.068</td>
<td>0.051</td>
<td>0.073</td>
<td>0.072</td>
</tr>
<tr>
<td>No-SIDS</td>
<td>0.063</td>
<td>0.063</td>
<td>0.062</td>
<td>0.064</td>
<td>0.062</td>
<td>0.062</td>
<td>0.063</td>
<td>0.061</td>
<td>0.062</td>
<td>0.062</td>
</tr>
<tr>
<td>Proportion of mixed wind direction days</td>
<td>SIDS</td>
<td>0.088</td>
<td>0.103</td>
<td>0.064</td>
<td>0.099</td>
<td>0.061</td>
<td>0.081</td>
<td>0.077</td>
<td>0.083</td>
<td>0.084</td>
</tr>
<tr>
<td>No-SIDS</td>
<td>0.091</td>
<td>0.089</td>
<td>0.092</td>
<td>0.090</td>
<td>0.093</td>
<td>0.091</td>
<td>0.091</td>
<td>0.091</td>
<td>0.091</td>
<td>0.091</td>
</tr>
<tr>
<td>Proportion of predominantly windless days</td>
<td>SIDS</td>
<td>0.174</td>
<td>0.183</td>
<td>0.191</td>
<td>0.206</td>
<td>0.187</td>
<td>0.211</td>
<td>0.194</td>
<td>0.222</td>
<td>0.222</td>
</tr>
<tr>
<td>No-SIDS</td>
<td>0.155</td>
<td>0.154</td>
<td>0.154</td>
<td>0.153</td>
<td>0.154</td>
<td>0.152</td>
<td>0.153</td>
<td>0.151</td>
<td>0.151</td>
<td>0.151</td>
</tr>
<tr>
<td>Mean of average hourly wind speed (knots)</td>
<td>SIDS</td>
<td>8.128</td>
<td>7.761</td>
<td>7.597</td>
<td>7.556</td>
<td>7.219</td>
<td>7.724</td>
<td>7.763</td>
<td>7.746</td>
<td>7.843</td>
</tr>
<tr>
<td>Mean of maximum wind speed (knots)</td>
<td>SIDS</td>
<td>16.10</td>
<td>15.45</td>
<td>15.25</td>
<td>15.16</td>
<td>15.68</td>
<td>15.36</td>
<td>15.51</td>
<td>15.35</td>
<td>15.68</td>
</tr>
<tr>
<td>Mean of absolute hourly change in wind direction (degrees)</td>
<td>SIDS</td>
<td>3.156</td>
<td>3.160</td>
<td>3.158</td>
<td>3.154</td>
<td>3.154</td>
<td>3.152</td>
<td>3.146</td>
<td>3.129</td>
<td></td>
</tr>
<tr>
<td>Mean absolute difference in standard deviation of daily wind speed (knots)</td>
<td>SIDS</td>
<td>5.011</td>
<td>5.003</td>
<td>5.000</td>
<td>5.007</td>
<td>4.999</td>
<td>5.008</td>
<td>4.985</td>
<td>4.980</td>
<td></td>
</tr>
<tr>
<td>No-SIDS</td>
<td>5.049</td>
<td>5.011</td>
<td>5.003</td>
<td>5.000</td>
<td>5.007</td>
<td>4.999</td>
<td>5.008</td>
<td>4.985</td>
<td>4.980</td>
<td></td>
</tr>
<tr>
<td>Mean absolute difference in average daily wind direction (degrees)</td>
<td>SIDS</td>
<td>7.846</td>
<td>8.056</td>
<td>7.846</td>
<td>7.628</td>
<td>7.550</td>
<td>8.108</td>
<td>8.017</td>
<td>7.862</td>
<td></td>
</tr>
<tr>
<td>No-SIDS</td>
<td>7.922</td>
<td>7.903</td>
<td>7.910</td>
<td>7.923</td>
<td>7.938</td>
<td>7.942</td>
<td>7.901</td>
<td>7.908</td>
<td>7.918</td>
<td></td>
</tr>
</tbody>
</table>

---

Poisson regression with a log-link function, conducted using the GENMOD procedure in the Statistical Analysis System (SAS), was used to examine the meteorological variables. Initially, a baseline model was constructed that accounted for polynomial trends and the significant ambient temperature associations within the data. Each wind variable was then added to the baseline model to determine whether it was significantly associated with SIDS. Variables were considered important if they significantly improved the log-likelihood statistic, approximated by the χ² distribution, on September 15, 2023 by guest. Protected by copyright.
### Results

**BASELINE MODEL DETERMINATION**

Over the 22 years, 1968–1989, (8036 days) there were 545 days (6.8%) on which one or more SIDS occurred: no SIDS occurred on 7491 days (93.2%); one SIDS occurred on 523 days (6.5%); and two SIDS occurred on 22 days (0.3%). The empirical dispersion index (variance to mean ratio) equaled 1.007, indicating that these data were not over-dispersed.

A plot of annual SIDS rates per 1000 live births over the years 1968–1989 is presented in figure 2.

It was evident from this figure that SIDS rates followed a polynomial progression. Introduction of a linear trend component significantly reduced the log-likelihood statistic ($\chi^2=50.2, df=1, p<0.001$), as did the introduction of a quadratic term ($\chi^2=6.2, df=1, p=0.013$). Figure 2 also depicts these polynomial terms.

The two previously identified significant temperature variables were then introduced into the model. As before, the seasonal temperature variable significantly reduced the log-likelihood statistic ($\chi^2=68.4, df=1, p<0.001$) as did the day temperature variable

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#### Table 2  Univariate analysis of wind variables in addition to the baseline model

<table>
<thead>
<tr>
<th>Day effects</th>
<th>Day 0</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
<th>Day 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predominantly N days</td>
<td>0.510* (0.210)</td>
<td>0.203 (0.232)</td>
<td>0.021 (0.245)</td>
<td>0.141 (0.226)</td>
<td>0.058 (0.245)</td>
<td>-0.196 (0.254)</td>
<td>-0.096 (0.256)</td>
<td>-0.515 (0.283)</td>
<td>-0.038 (0.233)</td>
</tr>
<tr>
<td>Predominantly NE days</td>
<td>0.086 (0.151)</td>
<td>0.068 (0.148)</td>
<td>-0.150 (0.155)</td>
<td>-0.043 (0.146)</td>
<td>0.095 (0.147)</td>
<td>-0.157 (0.148)</td>
<td>-0.020 (0.150)</td>
<td>-0.225 (0.147)</td>
<td>-0.146 (0.146)</td>
</tr>
<tr>
<td>Predominantly E days</td>
<td>-0.143 (0.152)</td>
<td>-0.014 (0.142)</td>
<td>0.166 (0.136)</td>
<td>0.011 (0.137)</td>
<td>-0.005 (0.144)</td>
<td>-0.190 (0.144)</td>
<td>0.009 (0.141)</td>
<td>-0.321* (0.142)</td>
<td>-0.270 (0.142)</td>
</tr>
<tr>
<td>Predominantly S days</td>
<td>-0.167 (0.209)</td>
<td>-0.494* (0.232)</td>
<td>-0.182 (0.206)</td>
<td>-0.570* (0.235)</td>
<td>0.139 (0.188)</td>
<td>-0.119 (0.192)</td>
<td>-0.006 (0.194)</td>
<td>-0.235 (0.195)</td>
<td>-0.470* (0.214)</td>
</tr>
<tr>
<td>Predominantly SW days</td>
<td>-0.026 (0.155)</td>
<td>-0.098 (0.148)</td>
<td>-0.093 (0.144)</td>
<td>-0.195 (0.145)</td>
<td>-0.039 (0.145)</td>
<td>-0.211 (0.145)</td>
<td>0.017 (0.143)</td>
<td>-0.227 (0.139)</td>
<td>-0.120 (0.136)</td>
</tr>
<tr>
<td>Predominantly W days</td>
<td>-0.247 (0.203)</td>
<td>0.066 (0.179)</td>
<td>-0.079 (0.185)</td>
<td>-0.206 (0.189)</td>
<td>-0.043 (0.186)</td>
<td>-0.203 (0.185)</td>
<td>-0.109 (0.187)</td>
<td>-0.284 (0.185)</td>
<td>-0.498* (0.204)</td>
</tr>
<tr>
<td>Predominantly NW days</td>
<td>-0.016 (0.206)</td>
<td>-0.180 (0.215)</td>
<td>0.007 (0.197)</td>
<td>-0.434 (0.226)</td>
<td>0.248 (0.183)</td>
<td>-0.344 (0.191)</td>
<td>-0.187 (0.211)</td>
<td>0.012 (0.181)</td>
<td>-0.008 (0.184)</td>
</tr>
<tr>
<td>Mixed wind direction days</td>
<td>-0.024 (0.178)</td>
<td>0.105 (0.186)</td>
<td>-0.297 (0.190)</td>
<td>0.013 (0.166)</td>
<td>-0.374 (0.199)</td>
<td>-0.164 (0.173)</td>
<td>-0.148 (0.180)</td>
<td>-0.245 (0.173)</td>
<td>-0.246 (0.175)</td>
</tr>
<tr>
<td>Predominantly windless days (reference category)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Average hourly wind speed (knots)</td>
<td>0.012 (0.011)</td>
<td>-0.013 (0.012)</td>
<td>-0.022 (0.012)</td>
<td>-0.026* (0.012)</td>
<td>-0.013 (0.012)</td>
<td>-0.015 (0.012)</td>
<td>-0.011 (0.012)</td>
<td>-0.014 (0.012)</td>
<td>-0.005 (0.011)</td>
</tr>
<tr>
<td>Maximum wind speed (knots)</td>
<td>0.010 (0.007)</td>
<td>-0.007 (0.007)</td>
<td>-0.012 (0.007)</td>
<td>-0.016* (0.008)</td>
<td>0.000 (0.007)</td>
<td>-0.010 (0.007)</td>
<td>-0.006 (0.007)</td>
<td>-0.012 (0.007)</td>
<td>-0.002 (0.007)</td>
</tr>
<tr>
<td>Standard deviation of hourly wind speed (knots)</td>
<td>0.032 (0.027)</td>
<td>0.053 (0.027)</td>
<td>0.045 (0.028)</td>
<td>0.036 (0.027)</td>
<td>0.011 (0.027)</td>
<td>-0.036 (0.027)</td>
<td>-0.017 (0.027)</td>
<td>-0.033 (0.027)</td>
<td>-0.013 (0.027)</td>
</tr>
<tr>
<td>Average hourly change in wind direction (degrees)</td>
<td>-0.001 (0.006)</td>
<td>-0.002 (0.005)</td>
<td>-0.001 (0.005)</td>
<td>-0.005 (0.005)</td>
<td>-0.001 (0.005)</td>
<td>-0.001 (0.005)</td>
<td>-0.001 (0.005)</td>
<td>-0.001 (0.005)</td>
<td>-0.002 (0.005)</td>
</tr>
<tr>
<td>Maximum hourly change in wind direction (degrees)</td>
<td>0.001 (0.001)</td>
<td>0.000 (0.001)</td>
<td>0.000 (0.001)</td>
<td>0.000 (0.001)</td>
<td>0.000 (0.001)</td>
<td>0.000 (0.001)</td>
<td>0.000 (0.001)</td>
<td>0.000 (0.001)</td>
<td>0.000 (0.001)</td>
</tr>
</tbody>
</table>

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*Denotes $0.01<p<0.05$. 

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### Key Points

- The incidence of sudden infant death syndrome (SIDS) exhibits environmental temperature seasonality and various day effects but was unaffected by fohn winds.
- It seems unlikely that changes to the atmospheric proportion of positive ions, as caused by wind direction or speed, either directly or indirectly affects SIDS incidence.
- Evidence for the effects of wind direction and wind speed on SIDS occurrence, on the day of death or over the preceding eight days, was tenuous and small.
Table 3  Results of the variable validation analysis

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SIDS</td>
<td>No-SIDS</td>
<td>OR (95% CI)</td>
<td>SIDS</td>
</tr>
<tr>
<td>Predominantly N on day 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no</td>
<td>517 (94.9)</td>
<td>7241 (96.8)</td>
<td>1.00</td>
<td>70 (92.1)</td>
</tr>
<tr>
<td>yes</td>
<td>28 (5.1)</td>
<td>240 (3.3)</td>
<td>1.74 (1.19, 2.52)</td>
<td>6 (7.9)</td>
</tr>
<tr>
<td>Predominantly S on day 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no</td>
<td>522 (95.8)</td>
<td>6890 (92.0)</td>
<td>1.00</td>
<td>69 (90.8)</td>
</tr>
<tr>
<td>yes</td>
<td>23 (4.2)</td>
<td>601 (8.0)</td>
<td>0.61 (0.40, 0.92)</td>
<td>7 (9.2)</td>
</tr>
<tr>
<td>Predominantly S on day 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no</td>
<td>522 (95.8)</td>
<td>6890 (92.0)</td>
<td>1.00</td>
<td>72 (94.7)</td>
</tr>
<tr>
<td>yes</td>
<td>23 (4.2)</td>
<td>601 (8.0)</td>
<td>0.60 (0.40, 0.91)</td>
<td>4 (5.3)</td>
</tr>
<tr>
<td>Predominantly E on day 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no</td>
<td>449 (82.4)</td>
<td>5734 (76.5)</td>
<td>1.00</td>
<td>60 (78.9)</td>
</tr>
<tr>
<td>yes</td>
<td>96 (17.6)</td>
<td>1757 (23.5)</td>
<td>0.87 (0.69, 1.08)</td>
<td>16 (21.1)</td>
</tr>
<tr>
<td>Predominantly S or W on day 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no</td>
<td>488 (89.5)</td>
<td>6449 (86.1)</td>
<td>1.00</td>
<td>62 (81.6)</td>
</tr>
<tr>
<td>yes</td>
<td>57 (10.5)</td>
<td>1042 (13.9)</td>
<td>0.70 (0.54, 0.92)</td>
<td>14 (18.4)</td>
</tr>
<tr>
<td>Average hourly wind speed on day 3 (knots)</td>
<td>mean (se)</td>
<td></td>
<td></td>
<td>mean (se)</td>
</tr>
<tr>
<td>no</td>
<td>7.56 (0.16)</td>
<td>8.26 (0.04)</td>
<td>0.97 (0.95, 0.99)</td>
<td>7.83 (0.33)</td>
</tr>
<tr>
<td>yes</td>
<td>15.16 (0.24)</td>
<td>16.17 (0.07)</td>
<td>0.98 (0.97, 0.99)</td>
<td>14.84 (0.51)</td>
</tr>
<tr>
<td>Absolute difference in predominance of windlessness on day 7–8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no</td>
<td>393 (72.1)</td>
<td>6011 (80.2)</td>
<td>1.00</td>
<td>70 (92.1)</td>
</tr>
<tr>
<td>yes</td>
<td>152 (27.9)</td>
<td>1480 (19.8)</td>
<td>1.27 (1.05, 1.51)</td>
<td>6 (7.9)</td>
</tr>
</tbody>
</table>

\( (\chi^2=5.4, \text{df}=1, \ p=0.020) \). No significant first order autocorrelation was found in the residuals of the model containing the trend and temperature variables \( (\chi^2=2.0, \ p=0.632) \). Therefore, the model containing constant, linear and quadratic terms and the two temperature components was taken as the baseline meteorological model for subsequent analyses.

**WIND VARIABLE VALIDATION**

Table 1 includes descriptive statistics for each examined wind variable, grouped by days where at least one SIDS death occurred (545 days), labelled “SIDS”, and days free from SIDS deaths (7491 days), labelled “no-SIDS”.

Perusal of table 1 shows that the predominant Christchurch wind blew from an E direction, followed by SW and NE winds. Christchurch’s fohn wind predominated on approximately 6% of days and on another 16% of days, the city was predominantly becalmed. It is also evident from table 1 that predominantly SE wind direction days occurred infrequently. To enhance computational performance and alleviate problems with parameter bias and over-smoothing, SE and Mixed groupings were amalgamated for subsequent analyses.

Univariate results from the introduction of each wind variable into the baseline model are included in table 2. Compared with predominantly windless days (the reference category), predominantly N wind days were associated with a significantly increased risk for SIDS, estimated odds ratio (OR)\(=1.67 \) (95% CI: \(1.10, 2.51\)). Conversely, predominantly S winds on day 1, day 3 and day 8 had significantly decreased SIDS risks; OR\(=0.61 \) (95% CI: \(0.39, 0.96\)), OR\(=0.57 \) (95% CI: \(0.36, 0.89\)), and OR\(=0.63 \) (95% CI: \(0.41, 0.95\)), respectively. Other statistically significant wind direction variables were E winds on day 7, having decreased SIDS risk OR\(=0.73 \) (95% CI: \(0.55, 0.96\)), and W winds on day 8, having decreased SIDS risk OR\(=0.61 \) (95% CI: \(0.41, 0.91\)).

Both the average daily wind speed and maximum daily wind speed recorded three days before were significantly associated with SIDS. For every knot increase in average daily wind speed the SIDS risk decreased by a factor of \(0.97 \) (95% CI: \(0.95, 0.99\)), and for every knot increase in maximum daily wind speed the SIDS risk decreased by a factor of \(0.98 \) (95% CI: \(0.97, 0.99\)). Both wind speed variables were highly correlated (Pearson’s \(r=0.84\)).

Lastly, days that were predominantly calm on day 7 but windy on day 8, or predominantly calm on day 8 but windy on day 7, were associated with increased SIDS risk, OR\(=1.27 \) (95% CI: \(0.95, 0.99\)), compared with days without such wind changes.

There was no evidence of significant first order residual autocorrelation in any of the models examined.
Statistically significant wind variables identified in the 1968–1989 period were examined over the 1990–1997 periods, assuming an identical baseline meteorological model but with parameters re-estimated over the latter time frame. Table 3 includes the results from these analyses.

None of the variables included in table 3 was statistically significant over the 1990–1997 period. However, the magnitude and sign of the estimated effect was similar for predominately N winds on day 0 (OR\textsubscript{1968–1989}=1.74 vs OR\textsubscript{1990–1997}=1.73) and predominately S winds on day 3 (OR\textsubscript{1968–1989}=0.60 vs OR\textsubscript{1990–1997}=0.61).

**Discussion**

Motivation for this study stemmed from the possible association of wind and SIDS, as wind has been previously shown to influence health, and another climatic variable, temperature, has been associated with SIDS.1–6

Analysis was conducted using Poisson regression. The Poisson distribution efficaciously models counts of events over time but is constrained by having a theoretical dispersion index (the variance to mean ratio) equal to one. The empirical dispersion indices for the SIDS data over 1968–1989 and 1990–1997 periods were 1.007 and 1.075, respectively. Therefore, no evidence existed to suggest that the dispersion of these data deviated from unity and cast significant doubt over the Poisson assumption.

Among the strengths of this study is the utilisation of hourly meteorological data spanning some three decades. The size and accuracy of these data enabled a thorough and comprehensive investigation into wind and SIDS in Christchurch, New Zealand. Moreover, the localisation of SIDS deaths around the site of meteorological data collection ensures that infants’ actually experienced, at least indirectly, the weather that was recorded. Nearly all SIDS deaths occurred within a 20 km radius of the meteorological station. Some temperature studies have extrapolated measurements from one site homogeneously over an entire country or region.5–6 Such assumptions could potentially lead to a substantial degree of variable misclassification, particularly if adopted for variables such as wind.

The exploratory nature of this study necessitated the investigation of a large number of wind variables. Consequently, some of the reported significant results may simply be Type I errors.4 Indeed, table 2 reported results from 149 separate analyses that, when using the conventional \( \alpha=0.05 \), implied that 7.45 spurious significant associations could be expected by chance alone. In table 2, nine significant results were reported. Using the Bonferroni method to “adjust for multiple comparisons”, a global 95% confidence region obtained from overlapping the 149 single intervals implied that a single interval \( \alpha \) level needed to be \( \alpha=0.05/149.4 \).

None of the results reported in table 2 was statistically significant at this level of \( \alpha \). However, it is widely recognised that the Bonferroni method is conservative.4 Instead, we preferred to validate tentatively significant results using data from a second set.

This variable validation approach suffered from two weaknesses. Firstly, SIDS occurred less frequently during the 1990–1997 period and so the power to establish statistically significant results for the effect sizes given by the 1968–1989 results was small. Secondly, the meteorological measuring instrumentation modification in 1993 meant wind variables lacked consistency across the 1990–1997 period. The combination of these events reduced the probability of replicating the significant results demonstrated for the 1968–1989 period.

Another potential weakness of study was associated with the variable specification of wind predominance on day 0, as 38% of deaths were discovered before 8:30 am and 60% of deaths were discovered between midnight and midday. This implies that a number of infants may have died before being exposed to the predominant wind of that day. However, should infant caregivers respond to actual or anticipated wind patterns, then it may be immaterial whether the infant actually experienced the predominant wind conditions of that day. This premise of indirect exposure has been used to account for the relation between climatic temperature and SIDS.

Over the 1968–1989 period, Christchurch’s fohn wind, the northwesterly, predominated on approximately 6% of days. There was no evidence to suggest that this wind was associated with increased SIDS risk on the day of death or over the preceding eight days.

Six wind direction variables were associated with SIDS over the 1968–1989 period, namely: northerly winds on the day of death; southerly winds on the preceding day, three days and eight days; easterly winds seven days preceding a death; and westerly winds eight days preceding a death. When compared with corresponding variables for the period 1990–1997, only the northerly wind on the day of death and the southerly wind three days before a SIDS death had estimated associations with similar effect size and sign. Given that the two other tentatively significant southerly wind variables gave such disparate results between periods (S on day 1: OR\textsubscript{1968–1989}=0.61 vs OR\textsubscript{1990–1997}=1.14; and, S or W on day 8: OR\textsubscript{1968–1989}=0.70 vs OR\textsubscript{1990–1997}=0.99), the importance of the association between southerly wind lagged three days and SIDS must also be queried.

Perhaps the only non-spurious wind direction variable was that of the predominance of northerly winds on the day of SIDS death. In both sets of analyses, the increased risk of SIDS on northerly days compared with non-northerly days was estimated at OR=1.7. However, this result also requires further confirmation as the confidence intervals for this variable were large and included unity for the 1990–1997 dataset.

None of the wind speed variables considered was consistently associated with SIDS incidence over both time frames, nor were any of the between day effect variable that were examined.

In conclusion, the relations identified between SIDS incidence and wind in Christchurch, after...
controlling for the effects of temperature and trend, were tenuous and relatively small. No evidence was found to suspect that foehn winds influenced SIDS occurrence. Accumulation of more data is necessary to substantiate whether northerly winds on the day of death or southerly winds occurring three days before a death are truly associated with SIDS.

We acknowledge Maria Ackerman for proposing and motivating this research, and Roche for financial support. We thank the referees for their helpful suggestions and comments. Philip Schütler was supported by the Canterbury Cot Death Fellowship.

Conflicts of interest: none.

1 Theor MP. Cot death: rich factors and prevention in the Nether-
2 Schütler PJ, Ford RPK, Brown J, et al. Weather temperatures and
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4 Campbell MJ. Time series regression for counts: an investi-
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