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

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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.**

***Setting*—Christchurch, New Zealand, between 1968 and 1997 inclusively.**

***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.**

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Sudden infant death syndrome (SIDS) is the leading cause of postneonatal infant mortality in many developed countries, including New Zealand.[1] Despite extensive international research, much remains unknown about the exact causes or mechanisms that lead to such deaths.

One of the consistent epidemiological features of SIDS found throughout the world is that of seasonality, with SIDS occurring more frequently in colder months.[2–6] Various day and lagged day ambient temperature effects have also been associated with SIDS.[2–6] The significance of these temperature measures has prompted speculation that other localised meteorological patterns may also affect SIDS incidence.

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.[7–12] Internationally, this type of wind has many nomenclatures, including: the föhn (or foehn) wind in Switzerland and Germany[13]; the Santa Ana or witches wind in the USA[11]; the Sirocco in south eastern Europe[10]; the Chinook in Canada[8]; the Zonda in the Andes; and, the Sharav in Israel.[14] Föhn winds have been associated with increased irritability, headaches and heart problems.[10 13 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.[18–20]

Few studies have specifically related meteorological patterns, other than ambient 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 undoubtably 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

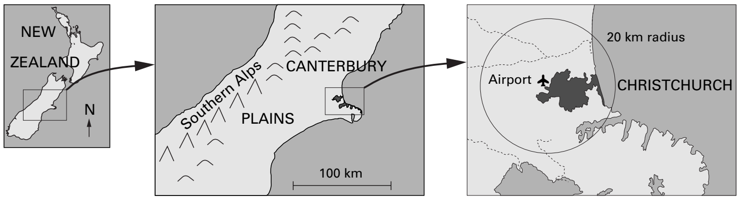

Figure 1 Maps of New Zealand, Canterbury and Christchurch. The region of Canterbury is located in the central South Island of New Zealand. The northwesterly, a föhn wind, flows over the Southern Alps and across the Canterbury Plains. The Christchurch map illustrates the 20 km radius where 90% of the SIDS deaths occurred, and the airport where the meteorological data were recorded.

Christchurch Airport (fig 1); a well exposed site that is considered to be representative of the weather conditions in greater Christchurch.

Each hourly observation consisted of several variables including temperature, wind direction, and wind speed. Temperature 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.

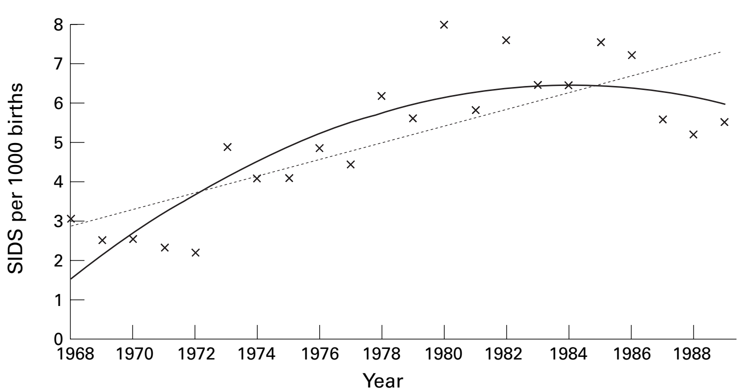

Figure 2 Yearly SIDS deaths in Canterbury per 1000 live births from 1968 to 1989. The dashed line gives the first order linear model, and the solid curve gives the second order quadratic model.

TEMPERATURE VARIABLE SPECIFICATION

Using these data over the 1968–1989 period, a previous study[2] 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.[2–6] 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

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

Day effects	*(ave se)*	*day 0*	*day 1*	*day 2*	*day 3*	*day 4*	*day 5*	*day 6*	*day 7*	*day 8*
Proportion of predominantly N days										
SIDS		0.051	0.042	0.037	0.040	0.035	0.031	0.029	0.026	0.040
No-SIDS		0.033	0.034	0.034	0.034	0.034	0.035	0.035	0.035	0.034
Proportion of predominantly NE days										
SIDS		0.160	0.149	0.127	0.150	0.156	0.141	0.141	0.134	0.134
No-SIDS		0.141	0.141	0.143	0.141	0.141	0.142	0.142	0.143	0.143
Proportion of predominantly E days										
SIDS		0.187	0.204	0.242	0.217	0.193	0.189	0.204	0.176	0.174
No-SIDS		0.233	0.232	0.229	0.231	0.233	0.233	0.233	0.235	0.235
Proportion of predominantly SE days										
SIDS		0	0	0	0	0	0	0	0	0
No-SIDS		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Proportion of predominantly S days										
SIDS		0.055	0.042	0.055	0.042	0.072	0.064	0.070	0.064	0.050
No-SIDS		0.079	0.080	0.079	0.080	0.078	0.079	0.078	0.079	0.080
Proportion of predominantly SW days										
SIDS		0.167	0.152	0.154	0.138	0.154	0.152	0.171	0.156	0.169
No-SIDS		0.146	0.147	0.147	0.148	0.147	0.147	0.146	0.147	0.146
Proportion of predominantly W days										
SIDS		0.059	0.077	0.070	0.068	0.072	0.062	0.062	0.066	0.055
No-SIDS		0.059	0.058	0.058	0.059	0.058	0.059	0.059	0.059	0.059
Proportion of predominantly NW days										
SIDS		0.059	0.048	0.061	0.040	0.072	0.068	0.051	0.073	0.072
No-SIDS		0.063	0.063	0.062	0.064	0.062	0.062	0.063	0.061	0.062
Proportion of mixed wind direction days										
SIDS		0.088	0.103	0.064	0.099	0.061	0.081	0.077	0.083	0.084
No-SIDS		0.091	0.089	0.092	0.090	0.093	0.091	0.091	0.091	0.091
Proportion of predominantly windless days										
SIDS		0.174	0.183	0.191	0.206	0.187	0.211	0.194	0.222	0.222
No-SIDS		0.155	0.154	0.154	0.153	0.154	0.152	0.153	0.151	0.151
Mean of average hourly wind speed (knots)										
SIDS	(0.162)	8.178	7.761	7.597	7.556	7.719	7.724	7.763	7.746	7.843
No-SIDS	(0.043)	8.214	8.244	8.257	8.260	8.247	8.245	8.242	8.243	8.236
Mean of maximum wind speed (knots)										
SIDS	(0.253)	16.10	15.45	15.25	15.16	15.68	15.36	15.51	15.35	15.68
No-SIDS	(0.067)	16.10	16.15	16.16	16.17	16.13	16.15	16.14	16.15	16.13
Mean of standard deviation of hourly wind speed (knots)										
SIDS	(0.069)	4.415	4.290	4.227	4.254	4.381	4.267	4.314	4.274	4.344
No-SIDS	(0.019)	4.459	4.468	4.473	4.471	4.461	4.469	4.465	4.468	4.463
Mean of average hourly change in wind direction (degrees)										
SIDS	(0.343)	17.55	17.79	17.92	17.66	17.93	17.85	17.84	17.44	17.83
No-SIDS	(0.092)	17.98	17.96	17.95	17.97	17.95	17.95	17.95	17.98	17.95
Mean of maximum hourly change in wind direction (degrees)										
SIDS	(2.121)	104.7	104.4	105.4	103.3	103.8	103.9	107.0	103.8	104.9
No-SIDS	(0.572)	105.6	105.6	105.5	105.6	105.6	105.6	105.4	105.6	105.5

Between day effects	*(ave se)*	*day 0–1*	*day 1–2*	*day 2–3*	*day 3–4*	*day 4–5*	*day 5–6*	*day 6–7*	*day 7–8*
Mean absolute difference in the predominance of windless days									
SIDS	(0.018)	0.229	0.206	0.242	0.239	0.237	0.240	0.262	0.279
No-SIDS	(0.005)	0.201	0.203	0.201	0.201	0.201	0.201	0.199	0.198
Mean absolute difference in average daily wind speed (knots)									
SIDS	(0.108)	3.049	3.000	3.036	3.086	3.095	3.115	3.194	3.424
No-SIDS	(0.030)	3.156	3.160	3.158	3.154	3.154	3.152	3.146	3.129
Mean absolute difference in standard deviation of daily wind speed (knots)									
SIDS	(0.181)	4.883	4.991	4.972	4.945	5.029	4.903	5.204	5.266
No-SIDS	(0.049)	5.011	5.003	5.005	5.007	4.999	5.008	4.985	4.980
Mean absolute difference in average daily change in wind direction (degrees)									
SIDS	(0.271)	8.141	8.056	7.846	7.628	7.550	8.108	8.017	7.862
No-SIDS	(0.072)	7.903	7.910	7.923	7.938	7.942	7.901	7.908	7.918

validation. Before 1990, New Zealand had one of the highest rates of SIDS recorded in the developed world.[29] 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.[32] 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, 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 χ^2 distribution, over the baseline model.[33] The polytomous wind direction variable was transformed, using the "reference cell coding" method, into a set of design variables each representing one wind direction category.[33] The design variable corresponding to predominantly windless (or calm) days was taken as the reference group.

The presence of first order autocorrelations was tested using the Durbin-Watson *d* statistic. For the purposes of this paper, an α level of 5% was used to determine statistical significance.

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) equalled 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 (χ^2=50.2, df=1, p<0.001), as did the introduction of a quadratic term (χ^2=6.2, df=1, p=0.013). Figure 2 also depicts these polynomial terms.

KEY POINTS

- The incidence of sudden infant death syndrome (SIDS) exhibits environmental temperature seasonality and various day effects but was unaffected by föhn 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.

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 (χ^2=68.4, df=1, p<0.001) as did the day temperature variable

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

Day effects	*day 0*	*day 1*	*day 2*	*day 3*	*day 4*	*day 5*	*day 6*	*day 7*	*day 8*
Predominantly N days									
est	0.510*	0.203	0.021	0.141	0.058	−0.196	−0.096	−0.515	−0.038
(se)	(0.210)	(0.232)	(0.245)	(0.226)	(0.245)	(0.254)	(0.256)	(0.283)	(0.233)
Predominantly NE days									
est	0.086	0.068	−0.150	−0.043	0.095	−0.157	−0.020	−0.225	−0.184
(se)	(0.151)	(0.148)	(0.155)	(0.146)	(0.147)	(0.148)	(0.150)	(0.147)	(0.146)
Predominantly E days									
est	−0.143	−0.014	0.166	0.011	−0.005	−0.190	0.009	−0.321*	−0.270
(se)	(0.152)	(0.142)	(0.136)	(0.137)	(0.144)	(0.141)	(0.142)	(0.143)	(0.142)
Predominantly S days									
est	−0.167	−0.494*	−0.182	−0.570*	0.139	−0.119	−0.006	−0.235	−0.470*
(se)	(0.209)	(0.232)	(0.206)	(0.233)	(0.188)	(0.192)	(0.194)	(0.195)	(0.214)
Predominantly SW days									
est	−0.026	−0.098	−0.093	−0.195	−0.039	−0.211	0.017	−0.227	−0.120
(se)	(0.155)	(0.148)	(0.144)	(0.145)	(0.145)	(0.143)	(0.141)	(0.139)	(0.136)
Predominantly W days									
est	−0.247	0.066	−0.079	−0.206	−0.043	−0.203	−0.109	−0.284	−0.498*
(se)	(0.203)	(0.179)	(0.185)	(0.189)	(0.186)	(0.185)	(0.187)	(0.185)	(0.204)
Predominantly NW days									
est	−0.016	−0.180	0.007	−0.434	0.248	−0.044	−0.187	0.012	−0.008
(se)	(0.206)	(0.215)	(0.197)	(0.226)	(0.183)	(0.191)	(0.211)	(0.181)	(0.184)
Mixed wind direction days									
est	−0.024	0.105	−0.297	0.013	−0.374	−0.164	−0.148	−0.245	−0.246
(se)	(0.178)	(0.168)	(0.190)	(0.166)	(0.199)	(0.173)	(0.180)	(0.173)	(0.175)
Predominantly windless days (reference category)									
est	0	0	0	0	0	0	0	0	0
Average hourly wind speed (knots)									
est	0.012	−0.013	−0.022	−0.026*	−0.013	−0.015	−0.011	−0.014	−0.005
(se)	(0.011)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.011)
Maximum wind speed (knots)									
est	0.010	−0.007	−0.012	−0.016*	0.000	−0.010	−0.006	−0.012	−0.002
(se)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Standard deviation of hourly wind speed (knots)									
est	0.032	−0.023	−0.045	−0.036	0.011	−0.036	−0.017	−0.033	−0.013
(se)	(0.027)	(0.027)	(0.028)	(0.027)	(0.027)	(0.028)	(0.027)	(0.027)	(0.027)
Average hourly change in wind direction (degrees)									
est	−0.001	−0.002	−0.001	−0.005	−0.001	−0.001	−0.001	−0.008	−0.002
(se)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Maximum hourly change in wind direction (degrees)									
est	0.001	−0.000	−0.000	−0.001	−0.001	−0.000	0.001	−0.001	0.000
(se)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

Between day effects	*day 0–1*	*day 1–2*	*day 2–3*	*day 3–4*	*day 4–5*	*day 5–6*	*day 6–7*	*day 7–8*
Absolute difference in predominance of windlessness								
est	0.004	−0.132	0.061	0.037	0.044	0.061	0.166	0.241*
(se)	(0.104)	(0.106)	(0.100)	(0.101)	(0.101)	(0.100)	(0.098)	(0.096)
Absolute difference in average daily wind speed (knots)								
est	−0.030	−0.031	−0.029	−0.023	−0.018	−0.016	−0.006	0.024
(se)	(0.017)	(0.017)	(0.017)	(0.017)	(0.016)	(0.016)	(0.016)	(0.015)
Absolute difference in standard deviation of daily wind speed (knots)								
est	−0.015	−0.013	0.040	0.000	−0.016	−0.021	0.018	−0.000
(se)	(0.034)	(0.034)	(0.033)	(0.034)	(0.034)	(0.034)	(0.033)	(0.034)
Absolute difference in average daily change in wind direction (degrees)								
est	0.008	0.003	−0.003	−0.007	−0.009	0.006	0.003	−0.002
(se)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)

*Denotes 0.01<p≤0.05.

Table 3 Results of the variable validation analysis

	1968–1989			*1990–1997*		
	SIDS	*No-SIDS*	*OR (95% CI)*	*SIDS*	*No-SIDS*	*OR (95% CI)*
Predominantly N on day 0						
no	517 (94.9)	7241 (96.8)	1.00	70 (92.1)	2727 (95.8)	1.00
yes	28 (5.1)	249 (3.3)	1.74 (1.19, 2.52)	6 (7.9)	119 (4.2)	1.73 (0.73, 4.05)
Predominantly S on day 1						
no	522 (95.8)	6890 (92.0)	1.00	69 (90.8)	2608 (91.6)	1.00
yes	23 (4.2)	601 (8.0)	0.61 (0.40, 0.92)	7 (9.2)	238 (8.4)	1.14 (0.52, 2.50)
Predominantly S on day 3						
no	522 (95.8)	6890 (92.0)	1.00	72 (94.7)	2606 (91.6)	1.00
yes	23 (4.2)	601 (8.0)	0.60 (0.40, 0.91)	4 (5.3)	240 (8.4)	0.61 (0.22, 1.68)
Predominantly E on day 7						
no	449 (82.4)	5734 (76.5)	1.00	60 (78.9)	2190 (77.0)	1.00
yes	96 (17.6)	1757 (23.5)	0.87 (0.69, 1.08)	16 (21.1)	656 (23.0)	1.07 (0.62, 1.85)
Predominantly S or W on day 8						
no	488 (89.5)	6449 (86.1)	1.00	62 (81.6)	2345 (82.4)	1.00
yes	57 (10.5)	1042 (13.9)	0.70 (0.54, 0.92)	14 (18.4)	501 (17.6)	0.99 (0.56, 1.78)
Average hourly wind speed on day 3 (knots)						
mean (se)	7.56 (0.16)	8.26 (0.04)	0.97 (0.95, 0.99)	7.83 (0.33)	7.89 (0.06)	1.00 (0.93, 1.08)
Maximum wind speed on day 3 (knots)						
mean (se)	15.16 (0.24)	16.17 (0.07)	0.98 (0.97, 0.99)	14.84 (0.51)	15.06 (0.10)	0.99 (0.95, 1.04)
Absolute difference in predominance of windlessness on day 7–8						
no	393 (72.1)	6011 (80.2)	1.00	70 (92.1)	2622 (92.1)	1.00
yes	152 (27.9)	1480 (19.8)	1.27 (1.05, 1.51)	6 (7.9)	224 (7.9)	0.91 (0.37, 2.19)

(χ^2=5.4, df=1, p=0.020). No significant first order autocorrelation was found in the residuals of the model containing the trend and temperature variables (*d*=2.01, 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 INVESTIGATION

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 föhn 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 pursuant 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: 1.05, 1.54), compared with days without such wind changes.

There was no evidence of significant first order residual autocorrelation in any of the models examined.

WIND VARIABLE VALIDATION

Over the eight years, 1990–1997, (2922 days) there were 76 days (2.6%) on which one or more SIDS occurred: no SIDS occurred on 2846 days (97.4%); one SIDS occurred on 74 days (2.5%); two SIDS occurred on one day (0.0%); and three SIDS occurred on another day (0.0%). The empirical dispersion index equalled 1.075.

The proportion of predominantly windless days for the period 1990–1992 was 13.4%, no different from the 15.6% recorded over the 1968–1989 period (χ^2=3.61, df=1, p=0.058). However, with the change to more sensitive wind speed measurement instrumentation in 1993, predominantly windless days were recorded significantly less frequently. The proportion of predominantly windless days for the period 1993–1997 was 0.6% compared with 15.4% recorded over the 1968–1992 period (χ^2=297.14, df=1, p<0.001). Consequently, the continued use of predominantly windless days as the reference group would introduce large standard error and bias. To reduce both error and bias, wind direction cells were collapsed into dichotomous categories.

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 predominantly N winds on day 0 ($OR_{1968-1989}$=1.74 *v* $OR_{1990-1997}$=1.73) and predominantly S winds on day 3 ($OR_{1968-1989}$=0.60 *v* $OR_{1990-1997}$=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,[7–10 12–15 22] and another climatic variable, temperature, has been associated with SIDS.[2–6]

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 disputation 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 homogenously over an entire country or region.[3–6] 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.[34] Indeed, table 2 reported results from 149 separate analyses that, when using the conventional α=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 α level needed to be α=0.05/149.[34] None of the results reported in table 2 was statistically significant at this level of α. However, it is widely recognised that the Bonferroni method is conservative.[34] 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 föhn 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: $OR_{1968-1989}$=0.61 *v* $OR_{1990-1997}$=1.14; and, S or W on day 8: $OR_{1968-1989}$=0.70 *v* $OR_{1990-1997}$=0.99), the importance of the associated 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 föhn 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.

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1 l'Hoir MP. *Cot death: risk factors and prevention in the Netherlands in 1995–1996.* [Ph.D thesis]. Utrecht: University Hospital Utrecht, 1998.
2 Schluter PJ, Ford RPK, Brown J, *et al*. Weather temperatures and sudden infant death syndrome: a regional study over 22 years in New Zealand. *J Epidemiol Community Health* 1998;**52**:27–33.
3 Julious SA. There is still seasonality in sudden infant death syndrome in England and Wales. *J Epidemiol Community Health* 1997;**51**:101–02.
4 Campbell MJ. Time series regression for counts: an investigation into the relationship between sudden infant death syndrome and environmental temperature. *Journal of the Royal Statistical Society, Series A* 1994;**157**:191–208.
5 Murphy MFG, Campbell MJ. Sudden infant death syndrome and environmental temperature: an analysis using vital statistics. *J Epidemiol Community Health* 1987;**41**:63–71.
6 McGlashan ND, Grice AC. Sudden infant deaths and seasonality in Tasmania, 1970–1976. *Soc Sci Med* 1983;**17**: 885–8.
7 Rose MS, Verhoef MJ, Ramcharan S. The relationship between Chinook conditions and women's illness-related behaviours. *Int J Biometeorol* 1995;**38**:156–60.
8 Verhoef MJ, Rose MS, Ramcharan S. The relationship between Chinook conditions and women's physical and mental well-being. *Int J Biometeorol* 1995;**38**:148–51.
9 Miric D, Rumboldt Z, Rumboldt Z. The impact of meteorological factors on the onset of myocardial infarction in the coastal region of middle Dalmatia. *G Ital Cardiol* 1993;**23**:655–60.
10 Miric D, Ljutic D, Eterovic D, *et al*. The sirocco wind increases the onset of paroxysmal atrial fibrillation in patients in the central Dalmatian coastal region. *Lijec Vjesn* 1992;**114**:93–5.
11 Richards W, Azen S, Weiss J, *et al*. Los Angeles air pollution and asthma in children. *Ann Allergy* 1981;**47**:348–54.
12 Daubert K. Medical meteorologic problems of the Fohn. *Hippokrates* 1970;**41**:517–19.
13 Novak V. Pathogenesis and surgical therapy of migraine attacks caused by weather (Foehn) and menstruation. *Rhinology* 1984;**22**:165–70.
14 Sulman FG, Levy D, Pfeifer Y, *et al*. Effects of the Sharav and Bora on urinary neurohormone excretion in 500 weather-sensitive females. *Int J Biometeorol* 1975;**19**:202–9.
15 Piorecky J, Becker WJ, Rose MS. Effect of Chinook winds on the probability of migraine headache occurrence. *Headache* 1997;**37**:153–8.
16 Sulman FG, Levy D, Lunkan L, *et al*. New methods in the treatment of weather sensitivity. *Fortschr Med* 1977;**95**:746–52.
17 Carey MJ, Cordon I. Asthma and climatic conditions: experience from Bermuda, an isolated island community. *BMJ* 1986;**293**:843–4.
18 Khot A, Burn R, Evans N, *et al*. Biometeorological triggers in childhood asthma. *Clin Allergy* 1988;**18**:351–8.
19 Gnecchi Ruscone T, Crosignani P, Micheletti T, *et al*. Meteorological influences on myocardial infarction in the metropolitan area of Milan. *Int J Cardiol* 1985;**9**:75–80
20 Dubs R, Primault B. Meteorological observations concerning haemorrhages after tonsillectomy. *Laryngol Rhinol Otol (Stuttg)* 1975;**54**:755–61.
21 Auliciems A, Barnes A. Sudden infant deaths and clear weather in a subtropical environment. *Soc Sci Med* 1987;**24**:51–6.
22 Kraus AS, Steele R, Langworth JT. Sudden unexpected death in infancy in Ontario: part 2, findings regarding season, clustering of death and specific days and weather. *Can J Publ Health* 1967;**58**:364–71.
23 Vetulani J, Marona-Lewicka D, Michaluk J, *et al*. Stability and variability of locomotor responses of laboratory rodents. III. Effect of environmental factors and lack of catecholamine receptor correlates. *Pol J Pharmacol Pharm* 1988;**40**:273–80.
24 Li Vecchi M, Frada GJ, Di Lorenzo G. Hormone changes during the sirocco. *Arch Sci Med (Torino)* 1981;**138**:269–71.
25 Sulman FG. Migraine and headache due to weather and allied causes and its specific treatment. *Ups J Med Sci Suppl* 1980;**31**:41–4.
26 Krueger AP, Reed EJ. Biological impact of small air ions. *Science* 1976;**24**:1209–13.
27 Beckwith JB. Discussion of terminology and definition of the sudden infant death syndrome. In: Bergman A, Beckwith J, Ray C, eds. *Proceedings of the second international conference on causes of sudden death in infants*. Seattle: University of Washington Press, 1970:14–22.
28 Nelson EAS, Williams SM, Taylor BJ, *et al*. Postneonatal mortality in south New Zealand: necropsy data review. *Paediatr Perinat Epidemiol* 1989;**3**:375–85.
29 Ford RPK. Postneonatal mortality in Christchurch. *N Z Med J* 1986;**99**:939–41.
30 Mitchell E, Aley P, Eastwood J. The national cot death prevention program in New Zealand. *Aust J Public Health* 1992;**16**:158–61.
31 Cowan S. *The contribution of information leaflets to advice and practice in infants care in a region of high cot death*. [M Ed thesis]. Christchurch: University of Canterbury, 1991.
32 Health Information Services. *Infant mortality statistics-1998.* Wellington: Department of Health, 1999.
33 Hosmer DW, Lemeshow S. *Applied logistic regression*. New York: Wiley, 1989.
34 Rothman KJ, Greenland S. *Modern epidemiology*. 2nd ed. Philadelphia: Lippincott-Raven, 1998.