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Research paper

Examining for any impact of climate change on the association between seasonality and hospitalization for mania

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ABSTRACT

Background: Studies have established higher rates of hospitalization for mania in spring and summer and posit various explanatory climatic variables. As the earth's climate is changing, we pursue whether this is reflected in the yearly seasonal variation in hospitalizations for mania. This would be indicated by the presence of secular changes in both the hospitalization seasonal pattern and climatic variables, and associations between both variable sets.

Methods: Data were obtained for 21,882 individuals hospitalized to psychiatric hospitals in the Australian state of New South Wales (NSW) over a 14-year period (2000–2014) with ICD-diagnosed mania – and with NSW population figures and salient climatic variables collected for the same period. Regression analyses were conducted to examine the predictive value of climate variables on hospital admissions.

Results: Data quantified a peak for manic admissions in spring of the southern hemisphere, in the months of October and November. There was a significant linear increase in manic admissions (0.5%/year) over the 14-year time period, with significant variation across years. In terms of climatic variables, there was a significant linear trend over the interval for solar radiation, although the trend indicated a decrease rather than an increase. Seasonal variation in admissions was most closely associated with two climate variables – evaporation in the current month and temperature in the previous month.

Limitations: Hospitalization rates do not necessarily provide an accurate estimate of the onset of manic episodes and findings may be limited to the southern hemisphere, or New South Wales.

Conclusions: While overall findings do not support the hypothesis that climate change is leading to a higher seasonal impact for manic hospital admissions in the southern hemisphere, analyses identified two climate/weather variables – evaporation and temperature – that may account for the yearly spring excess.

1. Introduction

Bipolar disorder has long been recognized as showing a seasonal pattern in non-equatorial regions where there are higher seasonal variations in temperature. While some studies have not quantified a seasonal effect, the majority of northern hemisphere studies have reported that admissions to hospital for mania peak in spring and summer (see Geoffroy et al., 2014). A similar pattern has been reported in southern hemisphere countries such as New Zealand (Mulder et al., 1990; Sayer et al., 1991), and the Australian states of Tasmania (Jones et al., 1995) and New South Wales (NSW; Parker and Walter, 1982) – although the NSW study quantified a peak for spring only. Although determinants remain unclear, potential factors include climatic variables, such as hours of sunlight (or day length), rate of increase in bright sunshine (luminance), solar/ultraviolet radiation (Parker and Walter, 1982), temperature (Silverstone and Romans-Clarkson, 1989), air ionisation, barometric pressure and relative humidity (Mawson and Smith, 1981) as well as snow cover and rain (Geoffroy et al., 2014). In addition, consideration has been given to social and psychological determinants, such as cultural factors (Christmas in the southern hemisphere) and sleep deprivation with increasing temperatures (Wehr et al., 1987) leading to increased rates of mania.

If climate variables effect hospitalizations for mania, any general climate change might effect the seasonal distribution of hospitalization rates for mania. There is increasing international recognition of the effect of climate change on the planet – including, but not limited to, global increases in temperature, higher frequency and severity of extreme weather conditions and greater ultra-violet radiation (Climate Council, 2015; McMichael et al., 2006) – and so include many of the climate variables implicated in the seasonal pattern of

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admissions for mania. We therefore undertook a study using longitudinal data with the aim of examining whether specific climatic changes are linked with changes in the seasonal pattern of admissions for mania. Support for such a hypothesis would require demonstration of (i) a secular change in admissions over the period of review, (ii) a secular change in one or more of the putative climatic variables and (iii) a correlational association between those two sets of variables – although any association between those variables would not necessary imply causality. Only one such study has been previously undertaken. Medici et al. (2016) examined for an overall seasonal pattern in hospitalization rates for more than 24,000 admissions for mania in Denmark over an extended period (i.e. 1995–2012), and examined for any secular change in admissions and climatic variables. Their cohort quantified peak admissions occurring in summer, and with higher rates being associated with increases in sunshine, ultraviolet radiation, temperature and snow. However, over the 18-year period there were no significant temporal changes in the amplitude of the seasonal peak and no significant changes in the climatic variables, effectively negating a 'climate change' hypothesis.

In studies evaluating seasonal variations in hospitalizations for mania, it is generally assumed that climatic variables have a relatively immediate impact, although some authors (e.g. Myers and Davies, 1978) concede that there may be a lag between the onset of mania and the subsequent hospitalization of the individual. In this seasonality study we also indirectly examine this possibility.

2. Methods

2.1. Study sample characteristics

Data were obtained from the NSW Department of Health for 21,882 individuals hospitalized in the Australian state of New South Wales (NSW) mental health units from 2000 to 2014 for ICD-10 diagnosed mania. To calculate admissions for mania, data included the categories for mania without psychotic symptoms (ICD classification F30.1), mania with psychotic symptoms (F30.2), other manic episodes (F30.8), manic episode unspecified (F30.9), bipolar affective disorder, current episode manic without psychotic symptoms (F31.1), and bipolar affective disorder, current episode manic with psychotic symptoms (F31.2). Population figures for NSW over that interval (range =6,486,213–7,511,774) were obtained and used to define a population-adjusted number of admissions (i.e. generating a mean population of 6,915,218 for the study period). The population-adjusted admissions were further adjusted to what they would be if each month had 30 days.

2.2. Study variables

The following climate variables were obtained for the same 2000–2014 period: EVAP (mean daily evaporation), HSUN (hours of bright sunshine), RAIN (average rainfall), TEMP (average temperature), GSOL (global solar radiation) and SOIX (Southern Oscillation Index, a gauge of the strengths of El Niña and La Niña events). These daily recorded variables were consolidated for the purpose of the current study into monthly average scores. Seasonal average scores were created by calculating the average score for the requisite months of each season.

2.3. Study analyses

We initially report raw data on admissions and climate variables, before focusing on secular changes and any associations between admission patterns and changes in climate variables. Our regression analyses for admissions and climate variables used orthogonal polynomials to examine if the values showed (i) a linear increase/decrease over time (linear trend), (ii) an increase/decrease followed by a decrease/increase (quadratic trend) and/or (iii) an additional increase/decrease to the quadratic trend (cubic trend). As many climate variables display a clear yearly cycle, these were further modelled by fitting curves which address the pattern of increase/decrease across the year (usually called cosinor models). As noted, we also examined for any impact of there being a lag in seasonality effects (i.e. determining if there might be a delayed relationship between the climatic variables and hospitalization). Two-sided significance testing was used with a significance level of $p < 0.05$.

To analyze climatic variables, we used regression models that assume normally-distributed data, while for admissions we used Poisson regression which handles non-normally distributed counts of the numbers of events (individuals admitted with mania). Akaike (AIC) and Bayesian (BIC) information criteria statistics were used to compare models. When reporting differences between observed values and those expected by our models we used deviance residuals (Hilbe, 2014) which provide a standardized measure of the differences.

3. Results

A test for a linear trend across the 2000-14 review period indicated a significant increase in yearly admissions for mania corresponding to approximately 0.5% per year. Table 1 reports (i) the aggregated admissions for each month totaled across all years from 2000 to 2014, (ii) the differences from the expected (the expected value for each month is equal to 1,794 due to their adjustment as 30-d months), and (iii) the associated residuals (or differences between observed and expected data). There was moderate monthly variation, with fewer admissions than expected from March to June (i.e. autumn, early winter), particularly in April (9.4% fewer) and June (8.9%), and then a change to more admissions than expected from July (mid-winter), with the largest numbers above expectation occurring in late spring (8.3% more in November and 6.2% more in October). Fig. 1 shows residuals representing the difference between totals by year and the expected yearly total. While there are some years with likely significant departures from the expected (residuals with absolute values > 2), there is no strong pattern over time.

Fig. 2 plots the residuals for each year by each of the four seasons, as well as a line representing the modelled linear and quadratic trend (combined) and the p values associated with each trend. While the values for season show variation, apart from a borderline linear increase in winter (p=0.052), there was no evidence of any systematic

Table 1
Observed numbers of hospitalizations for mania (totaled over the whole review period), differences from expected admissions, and the corresponding residuals, quantified by month and season.

	Autumn			Winter			Spring			Summer		
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Obs.	1726	1626	1729	1634	1880	1833	1826	1906	1943	1801	1800	1829
Obs. – Exp.	−68	−168	−65	−160	86	39	32	112	149	7	6	35
Residual	−1.63	−4.04	−1.55	−3.85	2.00	0.91	0.74	2.61	3.46	0.16	0.13	0.81

Obs. = Observed; Exp. = expected.