Int J Biometeorol (2009) 53:167–175
DOI 10.1007/s00484-008-0200-5

ORIGINAL PAPER

Climate impact on suicide rates in Finland from 1971 to 2003

Reija Ruuhela · Laura Hiltunen · Ari Venäläinen · Pentti Pirinen · Timo Partonen

Received: 10 April 2008 / Revised: 16 November 2008 / Accepted: 24 November 2008 / Published online: 20 December 2008

Abstract Seasonal patterns of death from suicide are well-documented and have been attributed to climatic factors such as solar radiation and ambient temperature. However, studies on the impact of weather and climate on suicide are not consistent, and conflicting data have been reported. In this study, we performed a correlation analysis between nationwide suicide rates and weather variables in Finland during the period 1971–2003. The weather parameters studied were global solar radiation, temperature and precipitation, and a range of time spans from 1 month to 1 year were used in order to elucidate the dose-response relationship, if any, between weather variables and suicide. Single and multiple linear regression models show weak associations using 1-month and 3-month time spans, but robust associations using a 12-month time span. Cumulative global solar radiation had the best explanatory power, while average temperature and cumulative precipitation had only a minor impact on suicide rates. Our results demonstrate that winters with low global radiation may increase the risk of suicide. The best correlation found was for the 5-month period from November to March; the inter-annual variability in the cumulative global radiation for that period explained 40 % of the variation in the male suicide rate and 14 % of the variation in the female suicide rate, both at a statistically significant level. Long-term variations in global radiation may also explain, in part, the observed increasing trend in the suicide rate until 1990 and the decreasing trend since then in Finland.

Keywords Climate impact · Global solar radiation · Season · Suicide · Weather impact

R. Ruuhela (✉) · A. Venäläinen · P. Pirinen
Climate Change Research, Finnish Meteorological Institute,
P.O. Box 503, 00101 Helsinki, Finland
e-mail: reija.ruuhela@fmi.fi

L. Hiltunen · T. Partonen
National Public Health Institute,
Helsinki, Finland

Introduction

Suicide is a public health problem in many European countries, with an average suicide rate of 17.5 per 100,000 in the WHO European Region (WHO 2005). In Finland, the average suicide rate was 20.3 per 100,000 in 2004 as compared, for example, with 13.2 per 100,000 in Sweden in 2002, 11.5 per 100,000 in Norway in 2004, and 34.3 per 100,000 in Russia in 2004. To visualise the impact, suicide was ranked as the fourth leading cause of death among both men and women of working age in Finland in 2006. In other words, in 2006, there were 663 and 206 deaths from suicide, representing 8.9% and 6.5% of all deaths of individuals aged 15 to 64 years. Suicide mortality varies between men and women in different parts of Finland, being highest for men in northern and north-eastern areas, and highest for women in the south of Finland, since the 1970s (Partonen et al. 2003).

Suicide is a complex phenomenon, usually having more than one risk factor such as mental illness, unemployment, low income and a family history of suicide (Qin et al. 2003; Mann et al. 2005). In addition, suicidal behaviour follows a seasonal pattern, with a peak in the spring and early summer in both the northern and southern hemispheres (Näyhä 1981; Hakko et al. 1998a; Rock et al. 2003; Partonen et al. 2004a; Rocchi et al. 2004; Bridges et al. 2005; Zonda et al. 2005). For women, there seems to be a second peak in the autumn (Meares et al. 1981; Näyhä

1982; Micciolo et al. 1989). In addition, violent methods of death from suicide appear to have a more seasonal pattern than other forms (Hakko et al. 1998b; Räsänen et al. 2002).

Weather varies from season to season, and influences populations living under these conditions. Weather has an impact on individuals in their habitat at the social, psychological and physiological levels, and this may be seen in a range of behaviours (Voracek et al. 2007). So far, however, no specific meteorological condition can be labelled as "suicide weather" (Dixon and Shulman 1983; Yan 2000; Deisenhammer 2003; Lee et al. 2006). Higher temperatures appear to increase the risk of suicide (Lee et al. 2006; Page et al. 2007; Preti et al. 2007), but negative correlations have also been found (Souêtre et al. 1987, 1989), as well as no correlation at all (Partonen et al. 2004b; Dixon et al. 2007). In Finland, drops in temperature on successive days during spring have been found to be related to suicide rates in northern Finland (Partonen et al. 2004c).

Daily sunshine duration has a positive correlation with suicide rates (Souêtre et al. 1987; Petridou et al. 2002; Lambert et al. 2003), contributing in part to the seasonal effect on suicide mortality, which increases with increasing latitudes (Parker et al. 2001; Heerlein et al. 2006). Sunlight might possibly act as a trigger for suicide (Papadopoulos et al. 2005), because an increase in daylight is specifically able to stimulate the production of serotonin in the brain (Lambert et al. 2002), and among suicide victims there are indeed some abnormalities in serotonin metabolism in the brain (Dwivedi et al. 2001; Pandey et al. 2002). However, negative correlations between daily sunshine duration and suicide rates have also been reported (Stoupel et al. 1995; Preti 1998).

Most studies in this field analyse daily sunshine duration, whereas solar radiance has been used for analysis in only one earlier study, reporting data from Greece (Papadopoulos et al. 2005). The conflicting results from earlier studies, as summarised above, thus gave a rationale for the present study, and data on global solar radiation is an added feature of this analysis.

One reason for the contradictions in earlier studies on the climate dependence of suicides may be that they have been performed in different climatic conditions. Finland, situated in northern Europe, has a strong seasonal variation determined mainly by temporal variations in the solar radiation energy received in the area. Most of the solar radiation is received in the summer, when the monthly sum of global radiation is about 600 MJ/m^2, while in the winter months the monthly global radiation is typically only one-tenth of summer-time values. The annual global solar radiation varies from 2,800 MJ/m^2 in the north to 3,400 MJ/m^2 in southern Finland. The monthly duration of sunshine in Lapland varies on average from 270 h in June to a period of darkness in the winter. In southern Finland, the sun shines on average 300 h in June and only 30 h in December. The annual mean temperature varies between −2°C in northern Lapland to +5°C in southern Finland, and the annual precipitation from 500 mm in northern Lapland to 650 mm in southern Finland. The winter (December–February) is usually cold, and the mean temperature varies from −4°C in southern Finland to −16°C in northern Lapland. The summer (June–August) mean temperature varies from 12 to 16°C; precipitation during summer months exceeds that in winter (Drebs et al. 2002).

Our aims were to test whether global solar radiation (hereafter, global radiation) explains the inter-annual and intra-seasonal variation in suicide rates better than daily sunshine duration (hereafter, sunshine hours) and, if so, is global radiation the most informative of the explanatory weather parameters. In addition, we hypothesised that climate may have a cumulative impact on suicide rate. Longer periods, i.e. season(s) to year(s), of climatic anomalies might have an effect on the number of potential suicide candidates, whereas shorter periods of days to week(s) might act as a trigger for the actual decision to commit suicide.

Methods

Our material contained data on all the 43,393 deaths from suicide (33,993 men and 9,400 women) in Finland (which has a population of approximately 5 million), over the 35-year period from 1969 to 2003, both years inclusive. The data, derived from official death certificates, were obtained from Statistics Finland (www.stat.fi) and contained the following information for each case: the date of death, date of birth, sex, and residence. The codes of death from suicide according to the World Health Organization's International Classifications of Diseases include X60-X84 and Y87.0 (ICD-10), E950A-E959X (ICD-9) and E950.9-E959.9 (ICD-8). The detailed content of the Finnish death certificate provides excellent accuracy and reliability of information on the cause of death. Finnish law requires a medico-legal (forensic) investigation of the cause and the manner of death whenever it has been unnatural, or is suspected to be so, or whenever it has been sudden or unexpected. The proportion of investigations for suicide has been stable for many decades (Näyhä 1981), and the overall autopsy rate has remained relatively high, both of which allow for reliable conclusions on suicide trends over time.

Daily climate data from the Finnish Meteorological Institute (www.fmi.fi) were used in this study. For temperature and precipitation, we used data that have been interpolated from weather observations onto a grid of 10 km×10 km. For global radiation, grid-based data are not available, so we used data that were measured at a weather station located at Jokioinen, in south-western

Finland, this being well enough representative of the variability in global radiation in the most densely populated (southern and central) areas of Finland, where 80% of suicides take place. Global radiation is measured with a pyranometer at 1-min intervals. Daily cumulative observations of radiation were available in the database from 1971 onwards, which thus defined the study period for analysis.

Suicide rates and weather variables were analysed using time frames ranging from the monthly to the annual level. For each time frame, the cumulative values of suicide rate, global radiation, sunshine hours and precipitation were calculated as the sum of daily values for the period in question, whereas temperature was averaged over the whole period. The definition of the four seasons used in our analysis was as follows: spring is from March to May, summer is from June to August, autumn is from September to November, and winter is from December to February. Suicide rates were analysed for the total population as well as for men and women separately.

Statistics

Both simple and multivariate linear regression analyses were performed. Linear univariate regression models were calculated using the suicide rate as the dependent variable and measured global radiation, sunshine hours, average temperature or precipitation as explanatory variables. For the multivariate models the measured global radiation, average temperature and precipitation were included stepwise as explanatory variables. Sunshine hours were not used, since this parameter can no longer be considered to be an independent variable when global radiation is included in the model. The model follows Eq. 1:

$$\mathrm{SR} = \mathrm{a} + \mathrm{b(G)} + \mathrm{c(Tavg)} + \mathrm{d(RR)} \quad (1)$$

where SR is suicide rate (per 100,000 persons); *a*, *b*, *c*, and *d* are regression coefficients; *G* is cumulative global radiation (MJ/m^2); T_{avg} is average temperature (°C); and *RR* is accumulated precipitation (mm). The regression analysis was executed using a range of time spans from the monthly to the annual level. In order to study the effect of the long-term variation in climate factors, a regression analysis was first performed with the data including trends and then with the residual data after removing the effect of trends. The trends were filtered by fitting linear trends both to the suicide and weather data for two sub-periods, i.e. the periods of increasing suicide rates from 1971 to 1990 and of decreasing suicide rates from 1991 to 2003; the regression was analysed using the residual of suicide rate as the dependent variable and the residuals of the weather parameters as the explanatory variables.

Results

Annual suicide rates and weather parameters

There was a marked inter-annual variability in suicide and weather variables (Fig. 1). Concerning global radiation, there is both inter-annual and long-term variability with no clear trend, but a decreasing trend can be interpreted for the period of 1971–1990 and an increasing trend thereafter. The current climate change can be discerned in the annual mean temperature, but the inter-annual variability is even stronger. As a sign of ongoing climate change, we noted that since 1989 no years have been as cold as they still were in the 1970s and 1980s, and that there is an increasing trend (+0.2°C in 10 years) in the annual mean temperature in the 1990s. At the annual level there is no precipitation trend.

At the annual level, global radiation correlated best with suicide rates, with the correlation being stronger than that for sunshine hours (Table 1). The correlation coefficient (*R*) between sunshine hours and global radiation was only 0.839. Global radiation is a parameter that measures the amount of energy received at ground level from both the direct and diffuse solar radiation. It gives a more valid estimate of luminance than sunshine hours, because sunshine hours accumulate only when there are no clouds or only thin high-level clouds in front of the sun. Global radiation is often strong in situations of changing cumulus or scattered middle-level altocumulus clouds. In addition, an altostratus cloud cover may let a large proportion of radiation through to the ground.

Regression analyses show that statistically significant ($P<0.01$) models for both the total suicide rate and the male suicide rate were achieved using only global radiation as the independent variable, and in these models R^2 was as great as 0.23 (Table 2). Temperature or precipitation alone made no significant contribution to the suicide rates (data not shown). However, using temperature and precipitation together with global radiation as the independent variables, the model explained a greater proportion of the variation ($R^2=0.32$) in the suicide rates (Table 2). Because the female suicide rate was lower than the male suicide rate, the stochastic variations in suicide incidence may be larger.

Next, the regression analysis was computed separately for the periods of increasing (1971–1990) and decreasing (1991–2003) suicide rates. The dependence on weather was more robust for the former period (Table 2). For the latter period, any dependence on the weather disappeared (Table 2). It is important to note that the results from these different periods are not totally comparable because the smaller number of observations in the latter period makes the statistical significance weaker.

In view of these trends, the suicide rates and weather variables were analysed further using the residuals after

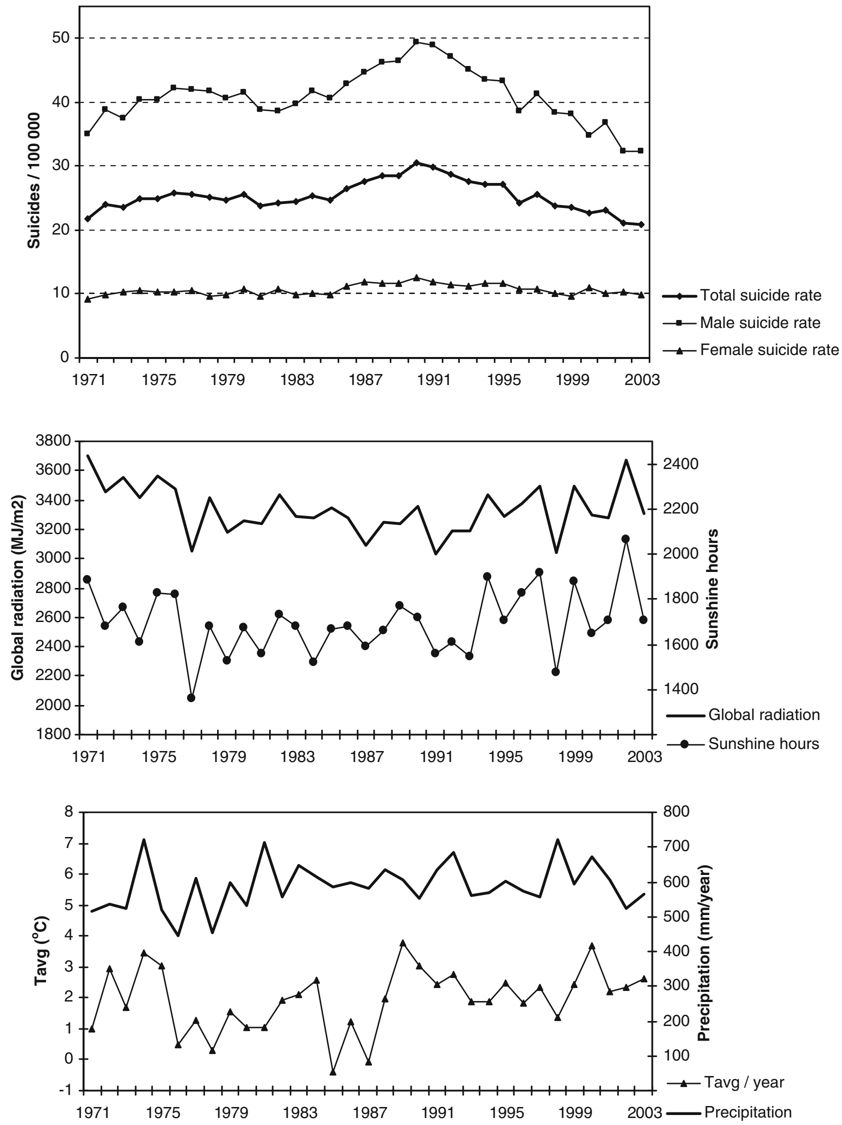

Fig. 1 Total, male and female suicide rates (*top panel*), annual global solar radiation and sunshine hours at Jokioinen (*middle panel*), and annual mean temperature and precipitation (*bottom panel*) in Finland from 1971 to 2003

fitting the trends to the data, even though this was rather hypothetical in the case of the weather data. In this way we sought to discover whether the variation in the weather variables correlated with the variation in the suicide rates (Table 3).

After trend filtering, the coefficients for global radiation became smaller and less significant (Tables 2, 3). On the other hand, the changes in the coefficients for temperature and precipitation were small, but they became more significant. Thus, the impact of temperature and precipita-

Table 1 Pearson correlation matrix for annual suicide rates and weather parameters in Finland in the period 1971–2003

	Suicide rate	Male suicide rate	Female suicide rate	Global radiation	Sunshine hours	Average temperature	Precipitation
Suicide rate	1.000						
Male suicide rate	0.991	1.000					
Female suicide rate	0.814	0.729	1.000				
Global radiation	−0.475	−0.475	−0.349	1.000			
Sunshine hours	−0.276	−0.317	−0.047	0.839	1.000		
Average temperature	0.071	0.016	0.278	0.096	0.138	1.000	
Precipitation	0.108	0.094	0.121	−0.572	−0.527	0.312	1.000

Table 2 Regression coefficients for annual global radiation (G), average temperature (T_{avg}), and precipitation (RR) explaining annual suicide rates

		Total suicide rate		Male suicide rate		Female suicide rate	
		Coefficient	P	Coefficient	P	Coefficient	P
Suicide rates explained by global radiation							
1971–2003	G	−0.007*	0.005*	−0.012*	0.005*	−0.002*	0.047*
	R^2	0.23		0.23		0.12	
1971–1990	G	−0.006*	0.027*	−0.011*	0.020*	−0.002	0.115
	R^2	0.24		0.27		0.13	
1991–2003	G	−0.008	0.093	−0.015	0.083	−0.001	0.302
	R^2	0.24		0.245		0.10	
Suicide rates explained by global radiation, temperature and precipitation							
1971–2003	G	−0.010*	0.001*	−0.018*	0.001*	−0.003*	0.006*
	T_{avg}	0.609	0.140	0.833	0.259	0.364*	0.016*
	RR	−0.014	0.075	−0.023	0.087	−0.004	0.102
	Multiple R^2	0.32		0.31		0.29	
	P		0.010*		0.013*		0.018*
1971–1990	G	−0.010*	0.003*	−0.017*	0.002*	−0.003*	0.026*
	T_{avg}	0.829*	0.032*	1.320*	0.035*	0.355	0.051
	RR	−0.013	0.066	−0.022	0.056	−0.004	0.171
	Multiple R^2	0.47		0.48		0.33	
	P		0.016*		0.013*		0.084
1971–1990	G	−0.011	0.065	−0.019	0.156	−0.003	0.233
	T_{avg}	−0.051	0.154	−0.448	0.882	0.328	0.487
	RR	−0.014	0.976	−0.024	0.572	−0.005	0.471
	Multiple R^2	0.27		0.29		0.17	
	P		0.389		0.364		0.619

*P<0.05

Table 3 Regression coefficients for the residuals of weather parameters explaining suicide rates after fitting linear trends for the years of 1971–1990 and 1991–2003

	Suicide rate total		Suicide rate male		Suicide rate female	
	Coeffient	P	Coeffient	P	Coeffient	P
Suicide rates explained by radiation, temperature and precipitation in 1971–2003						
G	−0.004*	0.019*	−0.006*	0.014*	−0.001	0.336
T_{avg}	0.627*	0.002*	0.960*	0.005*	0.307*	0.006*
RR	−0.010*	0.004*	−0.017*	0.005*	−0.004	0.052
Multiple R^2	0.35		0.32		0.26	
P		0.005*		0.010*		0.033*
Suicide rates explained by radiation, temperature and precipitation in 1971–1990						
G	−0.004	0.061	−0.008*	0.041*	−0.001	0.400
T_{avg}	0.692*	0.009*	1.102*	0.001*	0.299*	0.034*
RR	−0.012*	0.013*	−0.020*	0.011*	−0.004	0.103
Multiple R^2	0.42		0.43		0.28	
P		0.028*		0.027*		0.149
Suicide rates explained by radiation, temperature and precipitation in 1991–2003						
G	−0.001	0.497	−0.003	0.526	0.000	0.870
T_{avg}	0.365	0.373	0.307	0.710	0.428	0.121
RR	−0.003	0.563	−0.004	0.696	−0.002	0.557
Multiple R^2	0.05		0.05		0.26	
P		0.914		0.914		0.410

*P<0.05

tion on the suicide rate appeared similar, whereas the impact of global radiation raised new questions.

Monthly and seasonal suicide rates and weather parameters

The significant associations found at the annual level raised the question of whether there is any particular period of the year during which these correlations are at their strongest. In other words, is the dependence on weather parameters constant throughout the year, and does the relative impact of weather parameters change during the course of the year? To that end, we wanted to analyse these relationships at the monthly and seasonal (3-month) levels. The monthly and seasonal suicide rates, global radiation, mean temperature and precipitation were modelled in a similar way to those at the annual level.

Analysis of the monthly weather data yielded few significant associations. The male suicide rate was related to global radiation in March (b=−0.004, P=0.050) and September (b=−0.006, P=0.015). The female suicide rate was related to global radiation (b=−0.011, P=0.026) and mean temperature (c=0.046, P=0.005) in November.

Next, seasonal analysis using 3-month cumulative values yielded no significant correlation between the suicide rates and the weather parameters for spring or summer. For autumn, there was a negative correlation between global radiation and the suicide rate for both men (R^2=0.17; b=−0.012, P=0.017) and women (R^2=0.20; b=−0.004, P=0.009). In the winter, there was a positive correlation between mean temperature and the suicide rate for men (R^2=0.16; c=0.16, P=0.022) only. Multiple regression with global radiation, mean temperature and precipitation as the independent variables improved the explanatory power of the findings in autumn but not those in winter.

Cumulative suicide rates and global radiation

Finally, we wanted to test whether a lack of global radiation results in a gradual increase in suicide rates. To address this question we analysed the cumulative effect using a range of time periods. For this purpose we computed correlations between suicide rates and global radiation starting from November, which is the beginning of the darkest, and therefore potentially the most depressing period of the year. From November onwards, daylight time is short (less than 9 h, even in southern Finland) and the weather is quite often cloudy and rainy, which reduces solar radiation on the ground. It is noteworthy that the selection of a "suicide year" as the 12-month period of November to October had an influence on the results, with those based on the calendar year presented in Table 2 being slightly different.

The analysis of cumulative global radiation showed that the longer the cumulative period, the stronger the association of suicide rates with global radiation (Table 4). The best correlation was found for the period of November to March, especially for the male suicide rate; 40% of the variation in this rate was explained by cumulative global radiation.

From April onwards, the impact of the cumulative global solar radiation on the suicide rates decreased, being at its lowest for the period of November to July. After summer, these negative correlations between suicide rates and cumulative global solar radiation again reached significance.

Discussion

Our key finding was that global solar radiation from November to March had an influence on the subsequent number of deaths from suicide in Finland. The less global

Table 4 Dependence of suicide rates on cumulative global radiation (*Glob*) by period, starting from November onwards. Data for this analysis: time period November 1971–October 2003, nationwide suicide rates, global solar radiation from the Jokioinen weather station

	Suicide rate total			Suicide rate male			Suicide rate female		
Time period	Coefficient Glob	R^2	P	Coefficient Glob	R^2	P	Coefficient Glob	R^2	P
November	−0.012	0.08	0.123	−0.014	0.04	0.306	−0.011*	0.14*	0.036*
November-December	−0.013	0.07	0.157	−0.018	0.04	0.274	−0.008	0.08	0.108
November-January	−0.011	0.03	0.312	−0.011	0.01	0.556	−0.011	0.12	0.058
November-February	−0.012	0.06	0.176	−0.017	0.04	0.260	−0.006	0.07	0.071
November-March	−0.015*	0.39*	0.0001*	−0.026*	0.40*	0.0001*	−0.004*	0.14*	0.035*
November-April	−0.007*	0.23*	0.005*	−0.013*	0.23*	0.006*	−0.002	0.08	0.112
November-May	−0.005	0.12	0.051	−0.008	0.11	0.064	−0.001	0.06	0.188
November-June	−0.004	0.10	0.075	−0.007	0.09	0.106	−0.001	0.07	0.138
November-July	−0.003	0.03	0.333	−0.005	0.03	0.326	−0.000	0.004	0.728
November-August	−0.004	0.07	0.137	−0.007	0.07	0.138	−0.001	0.02	0.425
November-September	−0.006*	0.17*	0.018*	−0.011*	0.18*	0.017*	−0.006*	0.17*	0.018*
November-October	−0.011*	0.17*	0.019*	−0.011*	0.17*	0.019*	−0.006*	0.17*	0.021*

*P<0.05

radiation there is during the winter, the higher the risk of suicide will be, from November to March in particular. These results do not contradict, but rather extend a series of earlier findings regarding suicidal behaviour from nationwide study samples in Finland. In Finland, the incidence of attempted suicide is lowest in December and highest in April (Haukka et al. 2008), whereas the risk of death from suicide is greatest in May. The latter is not only associated with high levels of solar radiation but is also most pronounced in springs of longer-term periods, which have relatively low suicide rates (Partonen et al. 2004b). For violent suicides there is a clear spring peak, whereas non-violent suicides are more likely to occur in the autumn (Hakko et al. 1998a). However, by analysing time spans from 1 month to a year, we found no positive correlation between the suicide rate and global radiation, and no further support for the view that the spring peak in suicide mortality is due to increases in the amount of sunlight. Concerning suicide mortality from April to June in particular, analysis of time spans shorter than a month may be of added value but is beyond the scope of our current report.

Global solar radiation is unique among meteorological variables as an independent risk factor, since it explained the suicide rates in a significant way. However, after trend filtering, its impact was lessened and was statistically less significant in our analysis. Longer-term trends in suicide mortality have been considered to be due to socio-economic or psychological factors. As health authorities became concerned at the increasing mortality due to suicide in the 1970s, a nationwide suicide-prevention program was started in Finland in 1986, leading to a decreasing trend after 1990 (Beskow et al. 1999). This change specifically parallels the decrease seen in violent suicides (Hakko et al. 1998b). Here, on the basis of our results, the long-term trends seen in suicide mortality may not just be an outcome of the sum of the aforementioned factors; longer-term variability in global solar radiation may also be relevant. A limitation of our analysis, however, is that individual data concerning the age, education, civil status, socio-economic status or mental illness were not available and therefore not taken into account as risk factors. It also needs to be noted that variations in physical factors such as sunshine hours may result in changes in people's social activities and, if these changes end in difficulties in social relationships and associated negative outcomes, contribute to suicide rates.

Papadopoulos et al. (2005) reported that solar radiance during the preceding day increased the risk of suicide by 2% per each MW/m^2. The finding seems to contradict ours, as we found that the less solar radiance there was during the winter, the higher the risk of suicide, but the two studies applied different time spans in that Papadopoulos et al. focussed on time spans shorter than a month whereas we analysed those longer than a month. In the data from Greece, however, the past solar radiance was related on average to risk of suicide on a daily level, indicating that there might be a mechanism with a duration effect. Our results from Finland support the finding that there was a duration effect. They also found that longer sunshine exposure was needed in men to trigger suicide. In this study, we demonstrate the magnitude of the weather impact on suicide occurrence by applying coefficients from Table 2 (suicide rates explained by global radiation) for the Finnish population. A variability of twice the standard deviation (of 180 MJ/m^2) in global radiation would mean a variation of 130 suicide cases per year. Even the smaller coefficients of global radiation (from Table 3) would mean a variation of 65 suicide cases per year. To conclude, variability in global radiation has a marked influence on suicide mortality and is therefore of interest to public health and suicide prevention programs. Precipitation and mean temperature also have an effect, though smaller (71 and 66 suicide cases, respectively).

Another of our key findings was that the dose-response period of time may be shorter for women. For women, the significant correlation between suicide rate and global radiation disappears early in March, whereas for men the correlation remains stronger for a longer period. Interestingly, these negative correlations were stronger for men than women, indicating that men might be more sensitive to variability in global radiation than women. On the other hand, the mean temperature was more strongly related to the suicide rate for women than for men, thereby suggesting that both men and women react to climate, but in a different way.

The impact of climate on the suicide rates, and the relative value of each weather parameter to explain variation, fluctuates over the year. Using the 1-month time span there is no relationship between suicide rates and weather for most months. One reason may be that the stochastic variability is greater at the monthly than at the annual level. Therefore, a calendar month may not be a valid frame for estimation of the impact of weather on suicide. In addition, the dose-response effect may lead to a nonsensical correlation if the suicides rates of a given month are compared with the weather parameters of the same month, and any possible lag is ignored.

Our current results indicate that the period of autumn and winter months having a lack of global solar radiation, in other words being relatively dark, increases the number of people at risk of committing suicide. Our monthly and seasonal time span analysis showed that the mean temperature had a positive correlation with the female suicide rate in November and with the male suicide rate in winter (December to February). These findings support the results from two recent studies (Ajdacic-Gross et al. 2007; Preti et al. 2007) suggesting that it may not be the heat as such but the lack of cold that is related to suicide occurrence.

The suicide peak in spring has often been attributed to sudden increases in luminance and sunshine. However, in this study, using 1-month or 3-month time spans we found no positive correlation between suicide and global radiation during spring. On the contrary, there were negative correlations only at the annual, seasonal (autumn) and monthly (March, September, November) levels.

There are some limitations to our analysis. First, the spatial resolution of our temperature and precipitation data are high, but for global radiation we used measurements from only one weather station at Jokioinen. However, this particular station is located in the middle of the most densely populated (south-western) part of Finland and therefore the weather impact is very similar if the number of suicides completed near Jokioinen is used as the dependent variable. Therefore, in order to generalise the results, we decided to use nationwide suicide rates for our analysis. Second, the characteristics of weather and climate that impact on suicide might have been elucidated in more detail by using longer cumulative periods to analyse whether weather affects the number of people at risk of committing suicide, and by using shorter study periods to study whether weather is a short-acting trigger for suicide. We also need to keep in mind the fact that weather parameters are not truly independent. However, our results suggest that weather and climate factors may be significant and worthy of further studies in suicide research.

Our finding regarding the negative association of annual global radiation levels with suicide rates is of continuing interest, and may be a key to suicide mortality statistics at the global level. Suicide rates tend to be higher at higher latitudes than at lower latitudes (Lester 1970; Terao et al. 2002; Lawrynowicz and Baker 2005). Our results now show that there is a significant association between suicide rates and global radiation, and thus suggest that a lack of short-wave radiation, especially during the winter time in higher latitudes, may make a difference to suicide mortality. The relative importance of global radiation and other climate factors additionally raises the question of whether the current climate change is having an effect on suicide mortality. In Finland, there has been a decreasing trend in suicide mortality since 1990, with male and female suicide rates being reduced by 39% and 24%, respectively, to 2006. Due to projected climate change, however, global radiation is likely to be reduced in winter because of increasing precipitation and cloudiness, and shorter periods with snow cover. For northern Europe, winter (December–February) precipitation is projected to increase by 9–25% by the end of this century (Christensen et al. 2007), and the number of days with snow cover to decrease by 30–40% on average as compared with the current climate (Jylhä et al. 2008). The worst scenario is that the positive development in suicide prevention and mental health promotion will come to a halt to be replaced by an increasing trend in suicide in the next decades.

In conclusion, our results show that global solar radiation gives a more accurate representation of the impact of climate on suicide rates than sunshine hours. Cumulative periods ranging across seasons rather than the commonly used calendar months give a more robust association of weather parameters with suicide rates. Variability in annual global radiation explains a large proportion of the suicide occurrence at the annual level and may also closely reflect long-term trends in suicide rates.

Acknowledgement This study was supported in part by the grants #201097 and #210262 (to T.P.) from the Academy of Finland.

References

Ajdacic-Gross V, Lauber C, Sansossio R, Bopp M, Eich D, Gostynski M, Gutzwiller F, Rössler W (2007) Seasonal associations between weather conditions and suicide—evidence against a classic hypothesis. Am J Epidemiol 165:561–569. doi:10.1093/aje/kwk034

Beskow J, Kerkhof A, Kokkola A, Uutela A (1999) Suicide prevention in Finland 1986–1996: external evaluation by an international peer group. Ministry Soc Aff Health Copies 1999:2. Ministry of Social Affairs and Health, Helsinki

Bridges FS, Yip PS, Yang KC (2005) Seasonal changes in suicide in the United States, 1971 to 2000. Percept Mot Skills 100:920–924

Christensen JH, Hewitson B, Busuioc A, Chen A, Gao X, Held I, Jones R, Kolli RK, Kwon W-T, Laprise R, Magaña Rueda V, Mearns L, Menéndez CG, Räisänen J, Rinke A, Sarr A, Whetton P (2007) Regional climate projections. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate Change 2007: the physical science basis. contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK

Deisenhammer EA (2003) Weather and suicide: the present state of knowledge on the association of meteorological factors with suicidal behaviour. Acta Psychiatr Scand 108:402–409. doi:10.1046/j.0001-690X.2003.00209.x

Dixon KW, Shulman MD (1983) A statistical investigation into the relationship between meteorological parameters and suicide. Int J Biometeorol 27:93–105. doi:10.1007/BF02185738

Dixon PG, McDonald AN, Scheitlin KN, Stapleton JE, Allen JS, Carter WM, Holley MR, Inman DD, Roberts JB (2007) Effects of temperature variation on suicide in five U.S. counties, 1991–2001. Int J Biometeorol 51:395–403. doi:10.1007/s00484-006-0081-4

Drebs A, Nordlund A, Karlsson P, Helminen J, Rissanen P (2002) Climatological statistics of Finland 1971–2000 (in Finnish). Finnish Meteorological Institute, Helsinki

Dwivedi Y, Rizavi HS, Roberts RC, Conley RC, Tamminga CA, Pandey GN (2001) Reduced activation and expression of ERK1/2 MAP kinase in the post-mortem brain of depressed suicide subjects. J Neurochem 77:916–928. doi:10.1046/j.1471-4159.2001.00300.x

Hakko H, Räsänen P, Tiihonen J (1998a) Seasonal variation in suicide occurrence in Finland. Acta Psychiatr Scand 98:92–97. doi:10.1111/j.1600-0447.1998.tb10048.x

Hakko H, Räsänen P, Tiihonen J (1998b) Secular trends in the rates and seasonality of violent and nonviolent suicide occurrence in Finland during 1980–95. J Affect Disord 50:49–54. doi:10.1016/S0165-0327(98)00031-7

Haukka J, Suominen K, Partonen T, Lönnqvist J (2008) Determinants and outcomes of serious attempted suicide: a nationwide study in Finland, 1996–2003. Am J Epidemiol 167:1155–1163. doi:10.1093/aje/kwn017

Heerlein A, Valeria C, Medina B (2006) Seasonal variation in suicidal deaths in Chile: its relationship to latitude. Psychopathology 39:75–79. doi:10.1159/000090596

Jylhä K, Fronzek S, Tuomenvirta H, Carter TR, Ruosteenoja K (2008) Changes in frost, snow and Baltic sea ice by the end of the twenty-first century based on climate model projections for Europe. Clim Change 86:441–462. doi:10.1007/s10584-007-9310-z

Lambert GW, Reid C, Kaye DM, Jennings GL, Esler MD (2002) Effect of sunlight and season on serotonin turnover in the brain. Lancet 360:1840–1842. doi:10.1016/S0140-6736(02)11737-5

Lambert G, Reid C, Kaye D, Jennings G, Esler M (2003) Increased suicide rate in the middle-aged and its association with hours of sunlight. Am J Psychiatry 160:793–795. doi:10.1176/appi.ajp.160.4.793

Lawrynowicz AEB, Baker TD (2005) Suicide and latitude in Argentina: Durkheim upside-down. Am J Psychiatry 162:1022. doi:10.1176/appi.ajp.162.5.1022

Lee HC, Lin HC, Tsai SY, Li CY, Chen CC, Huang CC (2006) Suicide rates and the association with climate: a population based study. J Affect Disord 92:221–226. doi:10.1016/j.jad.2006.01.026

Lester D (1970) Completed suicide and latitude. Psychol Rep 27:818

Mann JJ, Apter A, Bertolote J, Beautrais A, Currier D, Haas A, Hegerl U, Lonnqvist J, Malone K, Marusic A, Mehlum L, Patton G, Phillips M, Rutz W, Rihmer Z, Schmidtke A, Shaffer D, Silverman M, Takahashi Y, Varnik A, Wasserman D, Yip P, Hendin H (2005) Suicide prevention strategies: a systematic review. JAMA 294:2064–2074. doi:10.1001/jama.294.16.2064

Meares R, Mendelsohn FAO, Milgrom-Friedman J (1981) A sex difference in the seasonal variation of suicide rate, a single cycle for men, two cycles for women. Br J Psychiatry 138:321–325. doi:10.1192/bjp.138.4.321

Micciolo R, Zimmermann-Tansella C, Williams P, Tansella M (1989) Seasonal variation in suicide: is there a sex difference? Psychol Med 19:199–203

Näyhä S (1981) Short and medium-term variations in mortality in Finland: a study on cyclic variations, annual and weekly periods and certain irregular changes in mortality in Finland during period 1868–1972. Scand J Soc Med 8(Suppl 21):1–101

Näyhä S (1982) Autumn incidence of suicides pre-examined: data from Finland by sex, age and occupation. Br J Psychiatry 141:512–517. doi:10.1192/bjp.141.5.512

Page LA, Hajat S, Kovats RS (2007) Relationship between daily suicide counts and temperature in England and Wales. Br J Psychiatry 191:106–112. doi:10.1192/bjp.bp.106.031948

Pandey GN, Dwivedi Y, Rizavi HS, Ren X, Pandey SC, Pesold C, Roberts RC, Conley RR, Tamminga CA (2002) Higher expression of serotonin 5-HT 2A receptors in the postmortem brains of teenage suicide victims. Am J Psychiatry 159:419–429. doi:10.1176/appi.ajp.159.3.419

Papadopoulos FC, Frangakis CE, Skalkidou A, Petridou E, Stevens RG, Trichopoulos D (2005) Exploring lag and duration effect of sunshine in triggering suicide. J Affect Disord 88:287–297. doi:10.1016/j.jad.2005.08.010

Parker G, Gao F, Machin D (2001) Seasonality of suicide in Singapore: data from the equator. Psychol Med 31:549–553

Partonen T, Haukka J, Lönnqvist J (2003) Suicide mortality in Finland 1979–2001 (in Finnish). Duodecim 119:1827–1834

Partonen T, Haukka J, Pirkola S, Isometsä E, Lönnqvist J (2004a) Time patterns and seasonal mismatch in suicide. Acta Psychiatr Scand 109:110–115. doi:10.1046/j.0001-690X.2003.00226.x

Partonen T, Haukka J, Nevanlinna H, Lönnqvist J (2004b) Analysis of the seasonal pattern in suicide. J Affect Disord 81:133–139. doi:10.1016/S0165-0327(03)00137-X

Partonen T, Haukka J, Viilo K, Hakko H, Pirkola S, Isometsä E, Lönnqvist J, Särkioja T, Väisänen E, Räsänen P (2004c) Cyclic time patterns of death from suicide in northern Finland. J Affect Disord 78:11–19. doi:10.1016/S0165-0327(02)00236-7

Petridou E, Papadopoulos FC, Frangakis CE, Skalkidou A, Trichopoulos D (2002) A role of sunshine in the triggering of suicide. Epidemiology 13:106–108. doi:10.1097/00001648-200201000-00017

Preti A (1998) The influence of climate on suicidal behaviour in Italy. Psychiatry Res 78:9–19. doi:10.1016/S0165-1781(97)00154-6

Preti A, Lentini G, Maugeri M (2007) Global warming possibly linked to an enhanced risk of suicide: data from Italy, 1974–2003. J Affect Disord 102:19–25. doi:10.1016/j.jad.2006.12.003

Qin P, Agerbo E, Mortensen PB (2003) Suicide risk in relation to socioeconomic, demographic, psychiatric, and familial factors: a national register-based study of all suicides in Denmark, 1981–1997. Am J Psychiatry 160:765–772. doi:10.1176/appi.ajp.160.4.765

Räsänen P, Hakko H, Jokelainen J, Tiihonen J (2002) Seasonal variation in specific methods of suicide: a national register study of 20,234 Finnish people. J Affect Disord 71:51–59. doi:10.1016/S0165-0327(01)00411-6

Rocchi MB, Miotto P, Preti A (2004) Seasonal variation in suicides and in deaths by unintentional illicit acute drug intoxications. Addict Biol 9:255–263. doi:10.1080/13556210412331292587

Rock D, Greenberg DM, Hallmayer JF (2003) Increasing seasonality of suicide in Australia 1970–1999. Psychiatry Res 120:43–51. doi:10.1016/S0165-1781(03)00165-3

Souêtre E, Salvati E, Belugou JL, Douillet P, Braccini T, Darcourt G (1987) Seasonality of suicides: environmental, sociological and biological covariations. J Affect Disord 13:215–225. doi:10.1016/0165-0327(87)90040-1

Souêtre E, Wehr TA, Douillet P, Darcourt G (1989) Influence of environmental factors on suicidal behavior. Psychiatry Res 32:253–263. doi:10.1016/0165-1781(90)90030-9

Stoupel E, Petrauskiene J, Kalediene R, Abramson E, Sulkes J (1995) Clinical cosmobiology: the Lithuanian study 1990–1992. Int J Biometeorol 38:204–208. doi:10.1007/BF01245390

Terao T, Soeda S, Yoshimura R, Nakamura J, Iwata N (2002) Effect of latitude on suicide rates in Japan. Lancet 360:1892. doi:10.1016/S0140-6736(02)11761-2

Voracek M, Tran US, Sonneck G (2007) Facts and myths about seasonal variation in suicide. Psychol Rep 100:810–814. doi:10.2466/PR0.100.3.810-814

WHO (2005) Mental Health: facing the challenges, building solutions, suicide prevention. Report from the WHO European Ministerial Conference. World Health Organization, Geneva, pp 75–82

Yan YY (2000) Geophysical variables and behavior: LXXXXIX. The influence of weather on suicide in Hong Kong. Percept Mot Skills 91:571–577. doi:10.2466/PMS.91.6.571-577

Zonda T, Bozsonyi K, Veres E (2005) Seasonal fluctuation of suicide in Hungary between 1970-2000. Arch Suicide Res 9:77–85. doi:10.1080/13811110590512967