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Weak associations between the daily number of suicide cases and amount of daily sunlight

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ABSTRACT

Several environmental factors with periodic changes in intensity during the calendar year have been put forward to explain the increase in suicide frequency during spring and summer. In the current study we investigated the effect of averaged daily sunshine duration of periods with different lengths and 'lags' (i.e. the number of days between the last day of the period for which the averaged sunshine duration was calculated and the day of suicide) on suicide risk.

We obtained data on daily numbers of suicide cases and daily sunshine duration in Hungary from 1979 to 2013. In order to remove the seasonal components from the two time series (i.e. numbers of suicide and sunshine hours) we used the *differencing* method. Pearson correlations ($n = 22{,}950$) were calculated to reveal associations between sunshine duration and suicide risk.

The final sample consisted of 122,116 suicide cases. Regarding the entire investigated period, after *differencing*, sunshine duration and number of suicides on the same days showed a distinctly weak, but highly significant positive correlation in the total sample ($r = 0.067$; $p = 1.17{*}10^{-13}$). Positive significant correlations ($p < 0.0001$) between suicide risk on the index day and averaged sunshine duration in the previous days (up to 11 days) were also found in the total sample.

Our results from a large sample strongly support the hypothesis that sunshine has a prompt, but very weak increasing effect on the risk of suicide (especially violent cases among males). The main limitation is that possible confounding factors were not controlled for.

1. Introduction

According to various estimations, currently approximately 800,000–1 million people die by suicide in the world every year (Turecki and Brent, 2016; WHO, 2014). Annual suicide rates of Hungary were unexpectedly high in the previous century and currently – despite a marked decrease from the late 1980s – Hungary has the second-third highest suicide rate in the EU28 group and its suicide rate ranked in the global top 10 in the first decade of the third millennium (Rihmer et al., 2013; Varnik, 2012; WHO (http://data.euro.who.int/hfadb/)).

Suicide is a multicausal behaviour and several interrelated factors (e.g. psychiatric and chronic physical disorders, age, gender, personality characteristics, genetic predisposition and epigenetic factors, stressful life events, infections, lithium content of tap water, access to means) determine the probability of its occurrence (Hawton and van Heeringen, 2009; Turecki and Brent, 2016; Vita et al., 2015). The investigation of the possible pathoplastic effects of environmental factors has a long tradition in medicine. Already the ancient Greek physician Hippocrates in his book entitled "On Airs, Waters and Places" stated that 'Whoever wishes to pursue the science of medicine in a direct manner must first investigate the seasons of the year and what occurs in them' (cited by Torrey et al. (2000)). The need to study the role of environmental factors in evoking suicidal behaviour is substantiated by the observation that suicide cases are unevenly distributed during the calendar year (Christodoulou et al., 2012; Woo et al., 2012b). The fact that more suicide cases occur in the spring and early summer than during autumn and winter was already described by the founders of classic suicidology (Durkheim, 2005 (first published 1897, Paris); Morselli, 1882) and it was later confirmed and replicated by several investigations from various countries in both the Northern and Southern hemispheres (including Hungary) (Christodoulou et al., 2012; Muller et al., 2011; Rihmer et al., 2013; White et al., 2015; Woo et al., 2012b). It has been proposed that various physical (e.g. sunshine duration, temperature, atmospheric pressure, rainfall), chemical (e.g. air pollutants) and biological (e.g.

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infections, pollens) factors are responsible for this phenomenon (Kim et al., 2016; Linkowski et al., 1992; Tsai and Cho, 2012; Vyssoki et al., 2014; Woo et al., 2012b), but there are still contradictory findings concerning the exact role of these (Dixon et al., 2007; Kim et al., 2016; Linkowski et al., 1992; Souetre et al., 1990; Tsai and Cho, 2012; Woo et al., 2012a; Woo et al., 2012b). For example, some research has found that ambient temperature has no remarkable effect on suicide risk, while other studies have found that high or – on the contrary – low ambient temperature is associated with an elevated risk of suicide (Dixon et al., 2007; Dixon et al., 2014; Kim et al., 2016; Linkowski et al., 1992; Souetre et al., 1990).

In this study we chose sunshine duration from the above variables, since it is well known that light from either natural or artificial sources has significant impacts on mood (see, for example, the use of light therapy in the treatment of mood disorders) and also on the activity of the serotonergic system (one of the most important neurobiological systems regulating mood, impulsiveness and aggression, each of which plays a role in the background of suicidal behaviour) (Praschak-Rieder et al., 2008; Spindelegger et al., 2012; Vyssoki et al., 2014). At the same time, the effect of sunshine duration (using slightly different indicators of it, e.g. solar irradiance measured in MW/m^2 per day (Papadopoulos et al., 2005); duration of *direct* solar irradiance with an intensity higher than 120 W/m^2 per day (Kadotani et al., 2014; Vyssoki et al., 2014); sum and maximum daily *global* radiation in Wh/m^2 (Muller et al., 2011)) on suicide risk is equivocal. For instance, Papadopoulos et al. (2005) found that in the total population, even after controlling for ambient temperature (and month and year), solar radiances on the day before suicide and also on the four days before the day of suicide (but not sunshine on the day of suicide) were significantly associated with increased risk of suicide (Papadopoulos et al., 2005). On the other hand, there was a significant negative association between solar radiance during the sixth day before the day of the suicide and the risk of suicide (although the authors concluded that this finding may be a statistical artefact) (Papadopoulos et al., 2005). The authors found that solar radiance in some respects has a different effect on suicide risk in males and females (e.g. in males longer sunshine exposure is needed to trigger suicide than in females) (Papadopoulos et al., 2005). A recent paper from Austria also reported (after removing the seasonal components from the time series of suicide and sunshine duration) that in the total sample there is a small yet significant positive correlation between the number of suicides and direct sunshine duration for the day of suicide and up to 10 days before it. Furthermore, in the total population the authors also found a significant negative effect of sunshine duration during the period lasting from 14 to 60 days before the suicide on suicide risk (Vyssoki et al., 2014). The authors of this study highlighted that the effect of sunshine duration on suicide is significantly different between males and females and between violent and nonviolent subgroups of suicide victims (Vyssoki et al., 2014). After correcting for season, using daily suicide data, Müller et al. (Muller et al., 2011) found that higher *global* radiation (day maximum and daily sum), which is somewhat different from the *direct* radiation measured by Vyssoki et al. (2014), on the day of suicide and on the day before suicide was associated with a higher risk of suicidality (the sample of this study consisted of both suicide attempters and victims) (Muller et al., 2011; Vyssoki et al., 2014; White et al., 2015). On the contrary, a study from Japan found that railway suicides are more frequent after 3-day or 7-day periods with *less* sunshine (but suicide risk was not associated with sunshine duration on the day of the suicide) (Kadotani et al., 2014). Similarly, Linkowski et al. (1992) reported that sunshine duration was *negatively* associated with violent suicides in both genders (Linkowski et al., 1992). Finally, some papers were unable to confirm an effect of sunshine on suicidal risk. For instance, Tsai and Cho (2012) demonstrated that ambient temperature increase is significantly associated with suicide rates while sunshine is not (Tsai, 2015; Tsai and Cho, 2012). In another recently published paper, the authors used three data sets (from Greece, Australia and Norway; total $n = 31{,}060$) to disentangle the possible effect of sunshine on suicide risk (White et al., 2015). Based on data from 2 of their 3 data sets (the Greek and the Australian) and using a very similar methodology to that applied by Vyssoki et al. (2014) they were unable to confirm the main results of the Austrian paper; after correction for multiple testing they did not find that daily sunshine duration has any effect on daily suicide risk (White et al., 2015). After removing seasonality, the authors were also unable to find evidence for a correlation between average *monthly* sunshine duration and *monthly* suicide rates (White et al., 2015). Another recent study from Sweden using *monthly* sunshine and suicide data did not find significant associations between these two variables after adjusting for seasonal effects (however, in a small subsample of those victims who received SSRI medication there was a significant positive association between the two variables) (Makris et al., 2016).

Taking into account the contradictory results on effects of daily sunshine duration on the risk of suicide, the aim of the current study was to investigate this issue in a considerably large sample of individuals who committed suicide during a 35-year period.

2. Methods

2.1. Data

The daily numbers of suicide victims grouped by gender and suicide type (i.e. violent and nonviolent ones) were taken from the Death Register of the Hungarian Central Statistical Office. This database has existed since 1970, but because meteorological data were available from 1979 we only used data on daily suicide numbers from 1 January 1979 to 31 December 2013. In accordance with previous literature, an individual whose International Classification of Diseases-8/9 (***ICD-8/9***) or ***ICD-10*** code in the paragraph "cause of death" was one of the following was considered as a suicide completer: ***ICD-8/9***: E950 to E958; ***ICD-10***: X60 to X84. The total sample of suicide completers was grouped according to method of suicide into violent (***ICD-8/9***: E953–E958; ***ICD-10***: X70–X84) and nonviolent (***ICD-8/9***: E950–E952; ***ICD-10***: X60–X69) subgroups (Bjorkenstam et al., 2013; Hulten et al., 2001; Lin et al., 2008; Preti and Miotto, 1998; Ruljancic et al., 2013; Salmeron et al., 2013; Vyssoki et al., 2014; Vyssoki et al., 2012). In line with our aims (i.e. to investigate the effect of sunshine duration during a given period (with or without a *time lag*) on the number of suicides on a particular day), our database did not include those 16 subjects who died due to "late effects" of suicide (***ICD-8/9***: E959; ***ICD-10***: Y87.0) between 1979 and 2013. Furthermore, we excluded those few suicide victims from the calculations whose exact day of death was undetermined ($n = 12$). In addition, due to the problem caused by leap years in our calculations (for further details, see the subchapter "Data Analysis and Statistical Methods"), we also excluded those subjects ($n = 74$) who committed suicide on 29 February. For technical reasons we excluded the first 99 days (the sum of the lengths of the maximum *time window* and the maximum *time lag*) of the years 1979 and 1980 from the calculations; consequently those 1217 subjects who committed suicide during this 99-day period from 1 January 1980 to 9 April 1980 and those 1093 subjects who committed suicide during this 99-day period from 1 January 1979 to 9 April 1979 were excluded as well.

Data on sunshine duration were retrieved on 07/01/2015 from the "ERA-Interim" database produced by the European Centre for Medium-Range Weather Forecasts (ECMWF; http://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/) (Dee et al., 2011). In this database "sunshine duration" is defined "as the number of seconds since the start of the forecast that the direct downwelling solar flux into a *horizontal* plane at the surface exceeded 120 W/m^{-2}". Unfortunately, this definition somewhat differs from the widely used definition of "sunshine duration", which is the same but for direct solar flux into a plane *perpendicular to the sun* (Hogan). However, we do not believe that these two "types" of "sunshine duration" are likely to evoke relevantly different physiological effects. The grid points from which the