The effects of sunshine duration and ambient temperature on suicides in Hungary

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Background: A couple of studies suggest that sunshine duration and ambient temperature contribute to suicide. Few studies have happened in East-Central European area. **Objective:** We scrutinized the daily suicide rates and other measured meteorological parameters spanning from 1971 to 2013 in the region of Hungary exhibiting the highest suicide rate. **Methods:** The meteorological parameters measured in the area signified the independent variables of the statistical model, while the observed suicide rate connoted the dependent variable. Dynamic Regression, a time series analytical method was employed for creating the model. **Results:** Three meteorological parameters displayed a weak, yet statistically significant relationship with suicide rates. 1/ Daily sunshine duration has shown an immediate, significant positive correlation, 2/ daily changes in temperature at ground level also exhibited a significant relationship, albeit it followed a complex transient profile overarching three days. Tropopause height was also significant in the model: an immediate positive effect was followed by a negative effect six days later. **Conclusions:** We estimated consistent and immediate positive associations between daily suicide and daily change of elevated ambient temperature and duration of sunshine in a high rated area of Hungary.

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Keywords: sunshine duration, ambient temperature, suicide, time series analysis

INTRODUCTION

Since the dawn of time, humans have strived to find connections between unruly nature and subjective, experiential phenomena. Seasons, the changing parameters of weather have produced several psychological changes in humans over the course of millennia, yet the underlying mechanisms of these effects are still mostly unknown. The effect of weather parameters on affective states is a well-established observation, especially concerning impulsivity, which in turn is closely related to the risk of suicide. As early as the 19th century, several explanations were put forward with regard to bioclimatic influences on suicide (and other aggressive acts) (Esquirol, 1938; Morselli,1881; Durkheim,1982). However, because of the technological limitations of that age, these "classic" theories were not effective in demonstrating causation.

More sophisticated studies of suicide rates and meteorological phenomena were possible only in the second half of the 20th century. Data were collected, and many meteorological parameters were examined for their association with suicide. Two of them have been shown to have an effect in almost all cases: *ambient temperature* (and its changes) (Page et al. 2007; Likhvar et al. 2011; Kim et al.2011; Tsai and Cho 2012; Kim et al. 2016) and the *duration of sunshine* (Petridou et al. 2002; Lambert et al. 2003; Papadopoulps et al. 2005) Vyssoki et al. 2014; Makris et al. 2015). A few studies have found an effect of both temperature and sunshine (Linkowski et al. 1992; Maes et al. 1994; Salib and Gray 1997). It has also been shown that these two

parameters have a positive relationship with suicides using *violent* methods while, for suicides using non-violent methods, this correlation is non-existent (Souêtre et al. 1990; Maes et al. 1993; Lin et al. 2008). At first, most studies were based on monthly data but, subsequently, *daily* data were used.

The first Hungarian study investigated the *monthly* hours of sunshine and the number of violent and non-violent suicides in both sexes over a 30-year period between 1971-2000. This analysis found no significant relationship between the *monthly hours of sunshine* and the number of suicides, even for suicides using violent methods (Bozsonyi et al. 2017). A second study (Törő et al. 2009) found that the number of suicides increased during warm weather with low relative humidity (dry anticyclones). Seregi et al. (2016) investigated the hours of sunlight per day and the number of suicides in Hungary and found a weak association between the duration of sunshine and the number of suicides, most clearly for males using violent methods for suicides.

The present study sought to use *daily* meteorological data in order to clarify the relationship of the meteorological parameters and suicides in Hungary.

METHOD

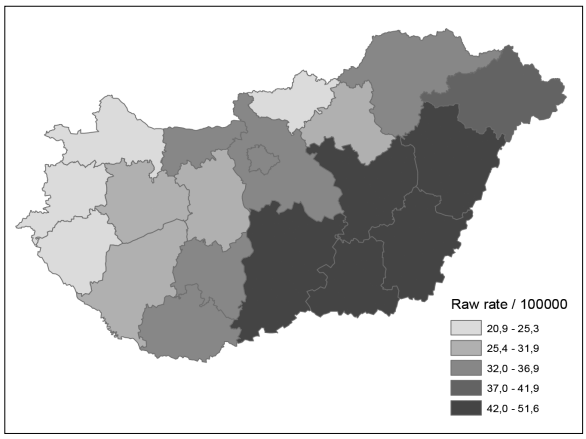
Hungary covers a large area, so it was decided to focus on a small geographical area, Southeast Hungary containing the six darkest counties. This area was chosen because it had the highest suicide rate in Hungary and because this geographical aggregate can be adequately characterized by a single meteorological parameter for daily data (Figure 1).

SUICIDAL AND METEOROLOGICAL DATA

The suicide data were obtained from the National Institute of Statistics which gathers data on all suicides in Hungary after a sociological and medico-legal examination. For the period between January 1st, 1971 and December 31st, 2013, here were 91,509 suicides in this region. Suicide rates for each day of the year were calculated based on the population on January 1st of each year. Because of the low daily numbers of suicides, it was not possible to examine subgroups formed on the basis of gender, age, or method used for suicide.

The data for meteorological data were obtained from the National Meteorological Service.

Figure 1. The distribution of raw suicide rates by counties between 1971-2013



STATISTICAL ANALYSIS

The well-known monthly and weekly seasonal trends had to be removed along with the long-term non-monotonous trend components. Detrended and de-seasoned ratios formed the basis of the model's dependent variable. The long-term trend was modelled by fitting an analytic parabolic trend component while the monthly seasonality was modelled by fitting a sinus function. Further on, after the OLS fitting of the following equation:

$$Y_t = \alpha t^2 + \beta t + \gamma \sin\left(\frac{2\pi t}{365{,}25} + \varphi\right) + C + Res_t$$

The Res_t time series served as the dependent variable in dynamic regression models. Filtering out of season component was also performed with the help of another procedure by using 11 monthly (January, February, March, April, May, June, July, August, September, October, November) dummy variables (December served as the reference month). Since this method did not alter our results significantly, in the final model we retained the solution based on the sinus function.

The independent variables were meteorological parameters which were calculated as the averages of the daily data deriving from the meteorological stations located in the area. The meteorological parameters examined in the model were the following: temperature at ground level, atmospheric pressure at ground level, daily duration of sunshine, atmospheric temperature at the tropopause[1], atmospheric

[1] Tropopause in the atmosphere is a transitional boundary between the troposphere (the lowest layer of the atmosphere) and the stratosphere. It is located at a height of 8-12 kilometres from ground level, depending on geographical latitude. Its temperature is around −42 °C.

Table 1. Fit statistics of the model

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
Cleaned suicide rate	3	0,094	20,937	16	0,181	0

Table 2. Parameters and significance values of the parameters of the fitted model

			Parameter	SE.	t statistic	Sig. t
	Constant		-,011	,004	-2,631	,009
	AR	Lag 1	,997	,001	1225,199	,000
	MA	Lag 1	,972	,002	405,560	,000
Height of tropopause level from ground level	Numerator	Lag 0	4,353E-7	1,778E-7	2,448	,014
		Lag 6	-4,527E-7	1,761E-7	-2,571	,010
First difference of air temperature on ground level	Numerator	Lag 0	,001	,000	8,639	,000
	Denominator	Lag 1	1,346	,077	17,491	,000
		Lag 2	-,393	,074	-5,306	,000
Daily duration of sunshine	Numerator	Lag 0	3,78E-4	1,08E-4	3,535	,000

pressure at the tropopause, height of the tropopause from ground level, and the daily changes in these parameters (first differences). The effects of monthly, seasonal and long-term trend components were also removed from the independent variables. Removing trend and seasonal components from the independent variables was performed by the same procedure as in the case of the dependent variables. This step was needed because, on the one hand, ARIMA models require that the analysed time series be stationary as trend and/or seasonal components present in the time series damage stationarity. On the other hand, trend/seasonal filtering only removed those components from the changes of meteorological data which had already been known to us. However, we were seeking to identify relationships between suicide data and meteorological characteristic which cannot be explained by seasonal variation. After the trend and seasonal filtering of the datasets, the Dynamic Regression model was able to show precisely whether meteorological characteristics and suicide data move together outside the well-known seasonal and trend paths.

We identified additive trend and seasonal components for both the dependent and independent variables and, after separating these time-series components, the cleaned residual stochastic time-series formed the basis for the modelling. *Dynamic regression*, a time-series analytical method, was employed for creating the model. This model type was examined with the aid of the Time Series Modeler algorithm in the SPSS 21.0 software package.

RESULTS

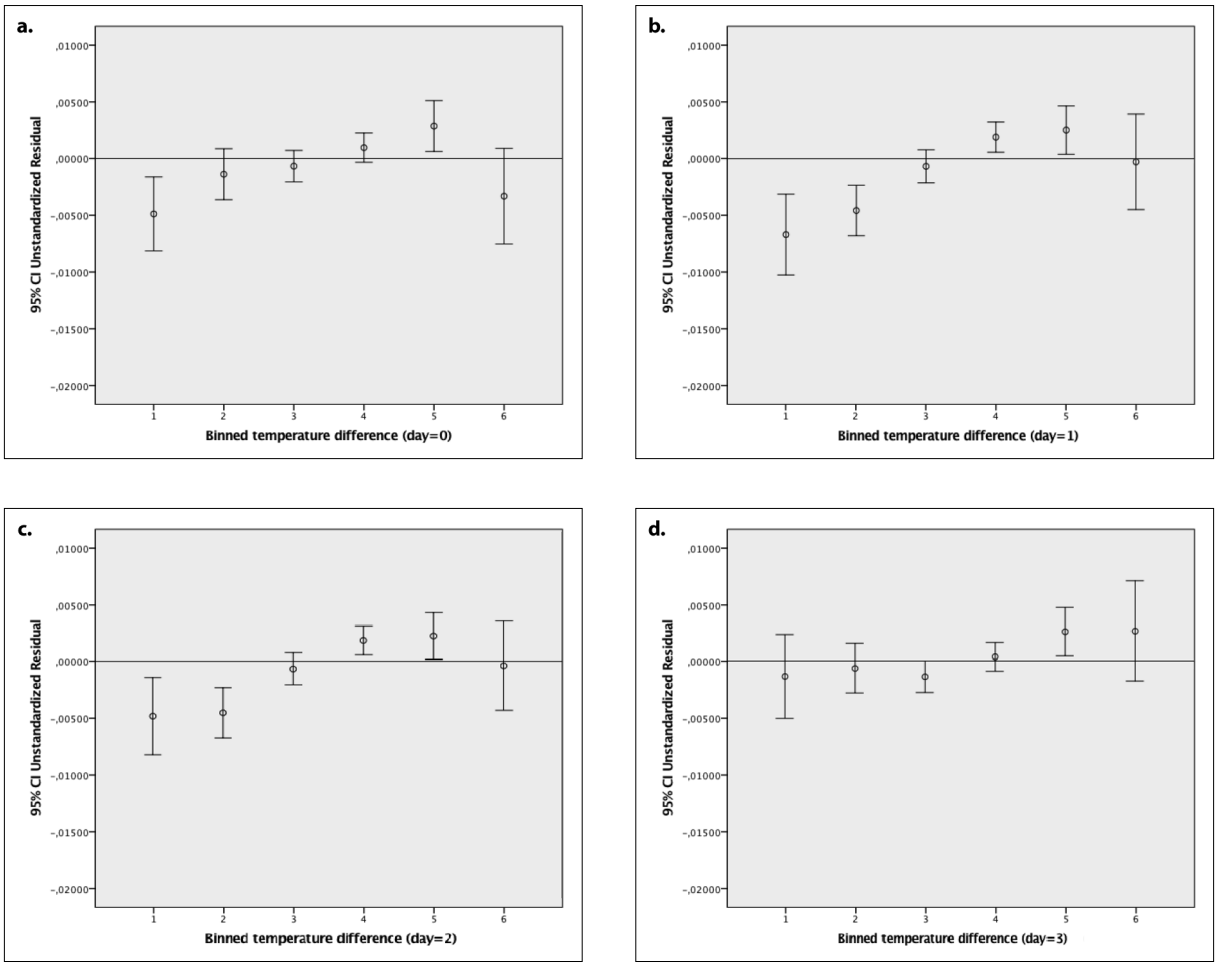
The ARIMA (1,0,1) procedure fitted with three exogenous variables was the best fit for the cleaned suicide data. The fit statistics of the model are reported in Table 1. As shown, the Ljung-Box statistics calculated for the residual time series, after fitting the ARIMA model, was not significant. Therefore, the residual time series contained no significant auto-correlation. The R^2 value of 0.094 indicated a weak, but significant model fit.

As it can be seen in Table 2, three of the meteorological parameters showed a weak, but significant relationship with the daily suicide rates. The effects of each meteorological parameter are described in detail below.

Daily sunshine duration had a significant, immediate positive relationship with the daily suicide rates. This result indicates that, even after filtering for seasonal effects and taking the ARIMA processes of the time-series into consideration, there was still a significant relationship between the frequency of suicides and daily sunshine duration.

Changes in surface temperature (first difference) also showed a significant relationship, although following a transient profile over a three-day period described by a complicated transfer function. There were positive and negative phases in this transient profile, meaning that, although the daily temperature did not exhibit a relationship with the daily suicide rate, the magnitude of changes in temperature from day-to-day did. If the temperature increased significantly from one day to

Figure 2. Transient effect of the temperature difference on daily suicide rates[2]



the next, it brought about an *immediate increase* in the daily suicide rate which continued the next day. However, on the third day of temperature increase, there was a slight drop in the daily suicide rate. The transient relationship of the magnitude of temperature change and suicide rates is displayed in the figures below.

A pronounced drop in temperature (a decrease of more than 4 degrees Celsius from one day to the next) on day zero reduced the daily suicide rate by approximately 8%, while a pronounced rise in temperature (an increase between 2-4 degrees Celsius) increased the daily suicide rate. However, an increase of more than 4 degrees Celsius no longer had a significant effect on the daily suicide rate (Figure 2). Figures 2a, 2b and 2c display the formation of the transient effect, while Figure 2d shows that all significant effects cease on day 3.

The height of the tropopause from ground level was also significant in the model. An instant positive effect was followed by a delayed negative effect six days later. The tropopause can be described as the border of the stratosphere which is always present, but its height increases and decreases depending on different meteorological conditions.

The significant effect of the tropopause height seems to exist, but there is no widely accepted explanation regarding the specific details of how this effect is exerted.

DISCUSSION

Many research studies have reported an association between daily sunshine duration and the warm ambient temperature with an increase suicide. It has also been reported that there is an enhanced

[2] Categorization of temperature differences: decrease of more than 4 degrees=1, decrease between 4-2 degrees=2, decrease between 2-0 degrees=3, increase between 0-2 degrees=4, increase between 2-4 degrees=5, increase of more than 4 degrees=6.

association between sunshine and suicide *among those with SSRI medication*, even after adjusting for seasonal effects (Makris et al. 2015). It may be that sunshine has a "triggering effect on suicide" (Petridou et al. 2002), and the hypothesis that sunshine acts as a natural antidepressant which first improves motivation and later improves mood, creating a potential short-term increased risk of suicide (Papadopoulos et al. 2005). There are no agreed-upon biological mechanisms to explain the association between ambient temperature and sunshine duration and an increased suicide rate. It has been hypothesized that higher suicide rates in the spring and early summer may reflect seasonal variations in serotonin, a neurotransmitter that may influence impulsiveness and aggression, possibly leading to suicide (Mann 2013).

The results of the present study confirm that daily sunshine duration has a weak, yet significant positive effect, on suicide rates, even when the deterministic components and autoregressive behavior of the time-series was taken into consideration during the modeling. This supports previous research on this association in Hungary. The present study, however, used, for the first time, daily Hungarian data.

The complex, dynamic effects of temperature changes extending over time offer evidence for the influence of weather fronts on the occurrence of suicide. However, these effects depended on the direction and magnitude of temperature changes, and they followed a complicated transient profile over a period of days.

The present results may have interesting theoretical and clinical implications if the relationship between sunshine duration and/ changes of ambient temperature and increased suicide risk are replicated in subsequent research. Clinicians may have to rethink the antidepressant therapeutic protocol for depression and suicide prevention in the Spring and early Summer if sunshine does act as a natural antidepressant.

Limitations: The results presented in our study were based on aggregate, ecological data, so there is no way to detect individual causal relationships. The significant correlations found can be considered as indirect evidence of the relationship between the meteorological parameters and suicide investigated. However, this indirect evidence underpins further research on the subject. According to the authors, natural experiments can be successfully designed based on the results of their present work, which can convincingly clarify the causal mechanisms between the examined variables.

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Napfénytartam és egyéb meteorológia tényezők hatása az öngyilkosságokra Magyarországon

Háttér: Magyarország legmagasabb öngyilkossági rátával rendelkező régióját elemeztük 1971 és 2013 közötti időszakban, napi szintű öngyilkossági adatok és mért meteorológiai paraméterek segítségével. **Módszer:** A statisztikai modell független változói a területen mért egyes meteorológiai paraméterek voltak. A függő változó pedig a területen megfigyelt öngyilkossági ráta. A modellezés az idősor modellek közé sorolható dinamikus regresszió (dynamic regression) módszerével történt. **Eredmények:** A meteorológiai paraméterek közül három mutatott gyenge, de határozottan szignifikáns kapcsolatot az öngyilkossági rátákkal: A napi napfény mennyisége szignifikáns, azonnali pozitív együtt járást mutatott az öngyilkossági rátával. A földfelszíni hőmérséklet egyik napról másikra történő megváltozása szintén mutatott szignifikáns kapcsolatot, de ez a kapcsolat egy bonyolult három napon átívelő tranziens profilt követett. A tropopauza magassága szintén szignifikáns volt a modellben; itt egy azonnali pozitív hatást egy hat nappal késleltetett negatív követett. **Következtetés:** Konzisztens azonnali pozitív összefüggést találtunk a napi öngyilkosság és az emelkedett hőmérséklet napi változása és a napfénytartam között.

Kulcsszavak: napfénytartam, hőmérséklet, öngyilkosság, idősorelemzés