Cyclicity of Suicides May Be Modulated by Internal or External ≈11-Year Cycles: An Example of Suicide Rates in Finland

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Abstract. Multicomponent cyclicity in monthly suicides (periods T = 18, 46 and 198 months) was found and close similarity with heliogeophysical activity (HGA) suggested by Dimitrov in 1999. The current report aimed at scrutinizing the results on suicide annual cyclicity (seasonality) in Slovenia as reported by Oravecz et al in 2007 as well as at analyzing suicide data from Finland in this regard. We postulated that: (i) trans-year (12-24 months) or far-trans-year long-term cycles of suicides might interfere with their seasonality; and (ii) associations to environmental factors with alike cyclicity (e.g. HGA, temperature) could exist. Annual suicide incidence from Oulu, Finland over years 1987-1999 was analyzed. Annual data on solar activity (sunspot index Rz or Wolf number), planetary geomagnetic activity (*aa*-index) and local daily mean temperatures were used. The exploration of underlying chronomes (time structures) was done by periodogram regression analysis with trigonometric approximation. We analyzed temporal dynamics, revealed cyclicity, decomposed and reconstructed significant cycles and correlated the time series data. Suicide seasonality in Slovenia during the years 1971-2002 (n=384 months, peak May-June) was considered and, although some discrepancies and methodological weaknesses were suspected, we further hypothesized about trans-year and/or longer (far-trans-year) cyclic components. Suicide incidence data from Finland indicated that the 12.5-year cyclic component (or trend) was almost parallel (coherent) to the cyclic heliogeophysical parameters and similar to local decreasing temperature dynamics. Also, 8-year and 24.5-year cycles were revealed. A correlation between the 12.5-year suicide cycle and 11-year solar cycle was found (R=0.919, p=0.000009). Above findings on cyclicity and temporal correlations of suicides with cyclic environmental factors, even being still preliminary, might not only allow for further more specific analyses. They might also corroborate to improved forecasting and prevention and confer a better understanding of suicide dynamics and aetiology.

Keywords: suicides, seasonality, cyclicity, heliogeophysical activity (HGA), temperature

Introduction

The increase of suicides has promoted the issue of their high socio-economic importance and further need for new measures for forecasting and prevention. Precise forecasting of incidence trends and better allocation of resources are invaluable for national health systems worldwide in terms of screening, early identification of risk factors and planning of preventive measures. Earlier we described a multicomponent cyclicity in temporal variations of monthly suicides [1] and suggested that its chronome (time structure) contains cycles that are similar to and could be associated with environmental factors such as cyclic heliogeophysical activity (HGA). HGA is a natural ecological cyclic multicomponent factor consisting of interrelated physico-chemical processes and irradiations of cosmic (space/solar or earth) origin, with fluctuations of their amplitudes at various frequencies (from hours, days to tenth of years). It is mainly represented by such phenomena as sunspots activity and geomagnetic fluctuations, but it may also refer to a number of other photic or non-photic events (e.g., solar UV radiation, solar wind, 10.7-cm solar radio flux, earth-ionosphere cavity or Schumann resonances, etc.) indicated by various parameters or indices (sunspot Rz-index, geomagnetic *aa*-index, ozone concentration, etc.). Ambient temperature is also a physical factor that is related to heliogeophysical variations. Most of these phenomena have been known, observed and measured since antiquity and, although showing notable fluctuations, they have been relatively constant (permanently present) as events in the human environment [2]. Most exhibit an established seasonality (annual cyclicity) but their chronomes are often multicomponent, with trans-year (periods of 12-24 months) or far-trans-year cycles such as the 11-year cycle of the sunspot index (Rz-index or Wolf number) which has been a consistent observation over hundreds of years [1, 3].

Incidence rates of suicides have increased in many countries over the last 5-6 decades and some of them show stabilization or decrease recently, however, no causes on a macro-scale, except associations with unemployment trends, were postulated. Usually, forecasting of incidence trends relies on linear regression models over time but such simple extrapolation has shown very often big discrepancies between estimates and real values. The recently published paper by Oravecz et al. [4] on suicides in Slovenia assessed the changes of seasonal variations (mainly, the 12-month cycle) in monthly suicide rates over the interval 1971-2002 (n=384 months) in Slovenia (latitude ≈ 46^{0}N). Notably, beyond an increase till mid 80-ies and a following decrease (inverse U-shaped curve) of the suicide incidence, they found a significant seasonal peak in May-June along a decreasing seasonality with an amplitude being positively related to the mean monthly rates, but only in females. However, despite the thorough methodological approach, with more details given in their previous paper [5], some of their assumptions and interpretations seem unfounded, or at least, problematic.

Beyond the particular approach of Oravecz and collaborators [4, 5], other approaches in modeling and forecasting the suicide rates are needed, with minimal standards as the following: (1) Non-linear regression modeling over time; (2) Linear and non-linear regression modeling to independent variables with deterministic temporal patterns (seasonality, cyclicity). Currently, the relationship of heliogeophysical cycles to suicide dynamics is of increasing importance in the view of the new 11-year solar cycle No. 24 that has started recently, on 4-th January 2008 (http://www.physorg.com/news119271347.html).

The aim of this paper was (i) to scrutinize earlier findings on seasonality of suicides and restate cyclicity as a deterministic pattern of their incidence variations; (ii) to consider multicomponent trans-year (infra-annual) cycles in monthly data of incidence and their eventual relationships with seasonality; (iii) to assess possibilities for similarities to and associations of suicides with HGA and other environmental (temperature) cycles.

Materials and methods

Time series datasets consist of annual suicide incidence rates in Oulu, Finland as taken from Table 1 of the paper by Partonen et al. [6]. The solar activity index (Rz) and the planetary geomagnetic index (*aa*) were taken from the Prompt Reports of NOAA, USA (1992); currently also online (e.g., http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotnumber.html) even on a monthly and daily basis (http://www.dxlc.com/solar/). Daily mean temperature data were obtained from the official statistical databases in Finland and average annual data computed. All original datasets are public and/or are available from the authors upon written request.

Different statistical methods for time-series analyses and modeling were used, as follows: descriptive statistics, linear and non-linear regression over time, periodogram regression analysis (PRA) with trigonometric approximations (TA), linear phase-correlation analysis (PCA) and statistical tests with 95% confidence limits. PRA was previously described elsewhere [1, 7]. The regression equation of periodic mode for the derivation of cosine-sine estimates of original values (e.g., incidence rates, etc.) is:

$$F(t) = a_0 + \sum_{i=1}^{2} \left(A_i \cos \frac{2\pi t}{T_i} + B_i \sin \frac{2\pi t}{T_i} \right),$$

where a_0 is the mean of the value *f(n)* in the sample, *A* and *B* are coefficients of the regression line, T is the length of a 95% statistically significant period, *t* is the current moment of time (a serial number of the year: 0, 1, 2, 3, ..., n-1), and *n* is the total number of values in the series of data. The PRA, whether using basic, detrended or decycled time series, also allows a description of 'hypercycles' (defined as such because the length of their period T_H exceeds the length of the time series); these hypercycles may also be included in TA modeling when able to improve the forecasting power, as appropriate. The TA (cosine-sine) approach relies on a prognostic index (PI) whereas PI should be above 0.25-0.30 to allow 25% of data series length forecasting ahead [7, 8]. The linear PCA, as described also recently elsewhere, has been successfully applied in analyzing the relationship between the solar activity and melanoma incidence dynamics. When there is a significant correlation, for instance, the lag-period dT with which this correlation is most likely to appear is ***null*** (dT=0) if the correlated time series are coherent (phase-locked) and it is *positive* (dT>0) if the extremes of the incidence rate dynamics follow the extremes of the sunspot index Rz [9].

Results

Graphical (visualization) analysis of suicides in Slovenia

We considered the recent data on suicides in Slovenia as presented by Oravecz et al. [4, 5]. However, without a formal testing of the distributions for normality over the studied interval of 32 years on annual (or monthly) discretization, the interpretation of the graphical visualization on their charts may question the appropriateness of the linear and quadratic parametric models and *t*-test statistics that were applied to find the best fit. Unfortunately, no original data in a table format per year were published in both papers. Thus, we were not able to test the above patterns, but it may seem from the charts that the temporal distributions of suicides may be better described by other nonlinear (e.g., cubic) and/or higher-order functions with low-frequency (trans-year) cyclical components [1, 3, 7, 10].

Statistical analyses of suicides in Oulu, Finland

To provide evidence on the above conjectures, we present here recent, although preliminary results that we obtained on the suicide incidence data from Oulu, Finland (65^{o}N) (Fig.1). We revealed a main cycle of 12.5 years as well as two other cyclic components - a cycle with period T of 8 years and a hypercycle with period T_H of 24.5 years. Similar cyclicity was found in the heliogeophysical activity (T = 11 years) and the temperature dynamics - period T = 11.8 years (Fig.2). We extracted and reconstructed the estimates of the above cyclic components. Notably, the dynamics of the main 12.5-year cyclic component of annual suicide rates appeared almost parallel (coherent) to the similar cyclic component in the global heliogeophysical parameters (Rz sunspot number, *aa*-index) and the local daily mean temperature dynamics, even on the background of the decreasing temperature tendency (Fig.3).

To confirm the above observation, formally, we applied linear PCA [9]. We associated the reconstructed estimates of the revealed 12.5-year cyclic component (curve with rhomboids, Fig.3) with, for instance, the estimates of the 11-year sunspot index Rz (curve with circles, Fig.3) and found a very significant phase-locked correlation (dT = 0 years, R=0.919, p=0.000009, n=13).

Discussion

Descriptive and visualization analyses have indicated clearly that cyclic patterns, beyond seasonality, may exist in the considered suicide time series. For instance, finding and removing the best fit according to the particular distribution is important since Oravecz et al. [4] reported to have had analyzed only detrended data (see their p.212, right column, top). They have reported the presence of seasonal (intra-annual) components by this part of the total variance they were able to explain (e.g., 26.54%) by 12-month harmonic peak in females for 1971-1978 [5]. It is known that the better the fit, the less variance or variations remain unexplained (regular or random). Thus, there is an obvious discrepancy between the overall regression results about the seasonal amplitude dependencies (decreasing rates lead to lower seasonal amplitude in females only, Table 1, p.213) and the higher, almost 2-fold to 3-fold rates in males, with higher seasonality (i.e., more seasonal variance in males, Table 1). To note, seasonality in both genders has been described on the background of above underlying quadratic trends and this surely needs further clarifications or, at least, further investigation on the relationships between such non-linear trends and seasonal patterns.

Second, from methodological viewpoint, Oravecz et al. [4, 5] had divided *a priori* the whole study period of 32 years into four, 8-year intervals, but the reasons behind this approach are unclear. It is possible that such *a priori* stacking of monthly suicide rates had "masked" important underlying patterns of suicide rate dynamics. Moreover, it not only decreased the sample size within each interval, but it may have also exposed the yearly and half-yearly rhythms (12-month and 6-month cycles) to "beating" by longer, existing but hidden, far-trans-year cycles (≈10- or ≈11-year components) that may have been missed during the analyses. For instance, when using monthly data on suicides from Bulgaria (latitude ≈43°N) without *a priori* stacking of the original data during the years 1929-1945 (204 months, see [1]), we had found multicyclic dynamics not only of seasonal, intra-annual range, but also trans-year and far-trans-year cyclicity (periods T = 18, 46 and 198 months). Notably, Cornelissen and Halberg [3] have also emphasized that the most complete description of the suicide chronome (time structure) may be better revealed if the stacking is done after the chronomics. They have indicated that the presence of a yearly rhythm, with an eventual parallel presence of a near-trans-year candidate (i.e., 12-24-month cycle), might be both amenable to modulations by ≈11-year cycle(s) of internal and/or external origins. Beyond confirming our earlier results on multicomponent suicide cyclicity [1] by their data on the time of occurrence of suicides in Minnesota, USA (43-49°N, periods T = 0.5, 1.0, 1.7 and 1.3 years), Cornelissen and Halberg [3] have also provided evidence on such multicyclic patterns of suicides by month of birth in England and Wales (51-54°N) before stacking (periods T = 0.42, 0.5, 0.73, 1.0, ≈2.2 and ≈7.5 years). They stated clearly that in order to better resolve the various sources of variation in suicide rates, mainly records covering a decade or longer should be analyzed [10]. In this sense, within the framework of our study, it is also interesting to note that, by retrospectively analyzing birthdates of 6662 cases with psychotic diseases and suicides *vs*. 9393 controls from France, Germany and Ukraine, Grigoryev et al. [11] have recently established that the 2nd week after conception of the cases *(12-18 days post-conception)* coincided with a statistically significant minimum of mean weekly values of the *aa*-index of geomagnetic activity. To note, possibly as a putative patho-physiological mechanism of (helio)geophysical influences on a predisposition to a cyclic appearance of suicides in the later, adult life, it is known that the nervous system structures are formed during the first 2-3 weeks post-conception [11] and, therefore, they are most vulnerable (even to weak external factors) during this initial time period of intrauterine development. Further, we may postulate that similar co-existence of seasonality with longer, far-trans-year cycles (as noted above [1, 3]) may be eventually revealed also in the data from Slovenia, but before the 8-year interval stacking is done and/or by exploring somewhat longer time intervals (e.g., time slots of minimum duration of 11-16 years).

Third, Oravecz et al. [4, 5] claimed both counteracting (to mental disease treatments) and vanishing of links between the seasonal recurrence of suicides and meteorological factors, including increasing surface temperatures (global warming?), but this seems inconsistent. Moreover, no their own analyses of parallel meteo-temperature data from Slovenia were done to support such statements. If such positive links to increasing temperatures exist, they can counteract preventive measures. But if such links decrease and vanish over years, they cannot subsequently counteract therapeutic improvements because both are acting at the same decreasing direction. Rather, such disappearing seasonality and links to meteorological factors on a monthly basis could be regarded as a sensible marker, on a long-term, of successive interventions in preventing suicides. However, the decrease and disappearance of the seasonal variations (as being of lower, subordinate level) cannot exclude the existence of long-term cyclic components (of higher, dominant level, with yearly periods) in suicide dynamics that may have links/coherence to environmental factors with similar cyclicity, on a macro-scale. For instance, there is a clear relationship between increasing number of sunspots (11-year cyclic factor) and increasing suicides in Thailand on a yearly basis (even at low latitudes of 13-15°N) where expressed seasonal patterns of suicides would not be expected [2].

However, our phase-correlation analysis (not shown) revealed a link between the suicides and HGA that are similar to the results about the effect of sunspots on suicides in Finland (1979-1999, n=27469 cases) as reported by Partonen and his colleagues. In the same time, interestingly, we revealed that the seasonal, 12-month cycle was most pronounced when the number of suicides was rather low than elevated as shown by the authors' own analyses [12].

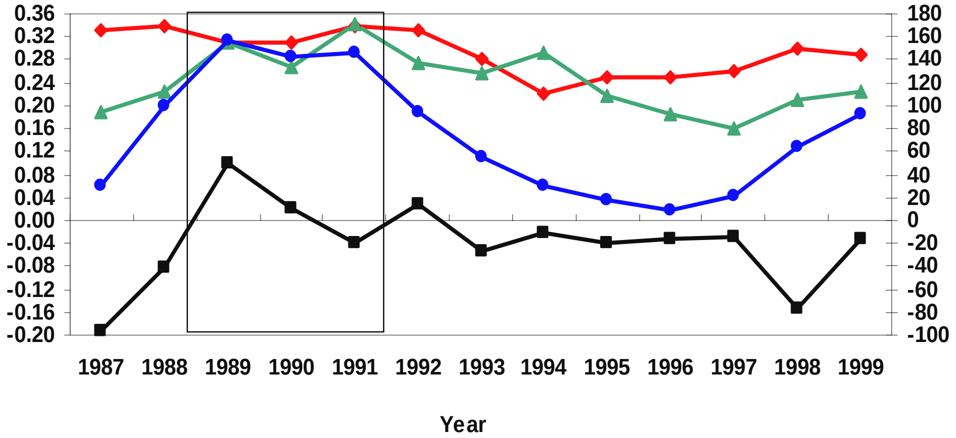

Fig.1. ***Suicide incidence and temperature in Oulu, Finland with indexes of heliogeomagnetic activity (1987-1999).*** *Decreasing tendencies of original suicide incidence, local temperature, solar and geomagnetic indexes (n=13).* Legend: *X-axis: year; Y-axes {left}: suicide rate per 1000 person (red rhomboids), daily mean temperature (℃, x0.1/12.1, black squares) and geomagnetic index* ***aa*** *(x1/100, green triangles); {right}: sunspot index Rz (blue circles); black rectangle: coherent occurrence of maximal values around the time interval 1989-1991.*

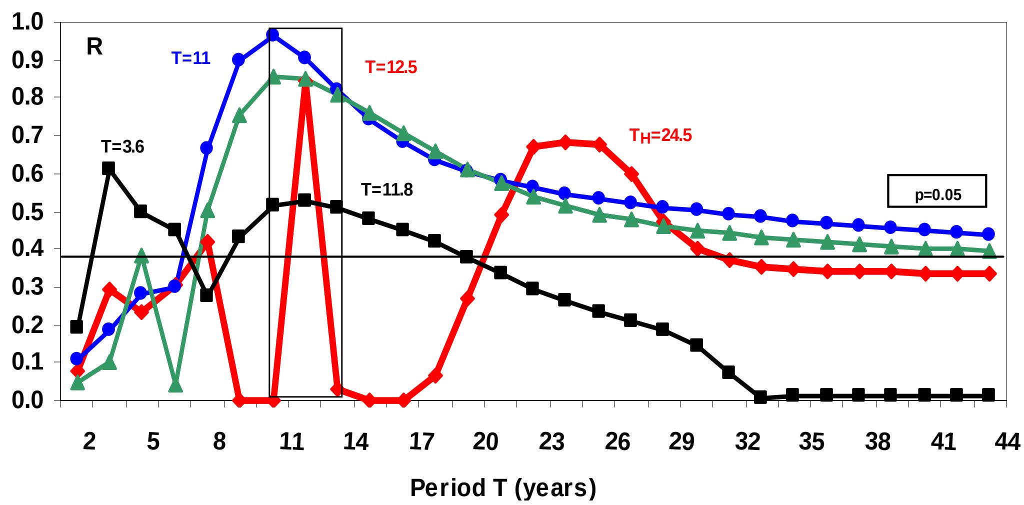

Fig.2. ***Periodogram regression analysis (PRA) of variations in the original time series (1987-1999).*** *The cyclic patterns of variations are presented by the spectra (periodograms) of the coefficients of correlation R for each period T (discretization of 1.5 years). The peaks above the horizontal black line (R_T=0.44) indicate the statistically significant periods of cycles revealed by the periodograms. Legend: X-axis: period T (years). Y-axis: coefficient of correlation R for the periodograms of variations in the suicide incidence rate (periods T=12.5 and T_H=24.5 years, rhomboids, red), geomagnetic activity index aa (T=11 years, triangles, green), daily mean temperature (T=3.6 and T=11.8 years, squares, black) and solar (sunspot) activity index Rz (T=11 years, circles, blue). Vertical black rectangle: similarity of the periods (range 11-12 years) in the variations of time series. Horizontal black rectangle & line: p-value of 0.05 as significance level of the theoretical coefficient of correlation R_T at variance F≈2σ (RT=0.44, F≈2σ, p=0.05, n=13).*

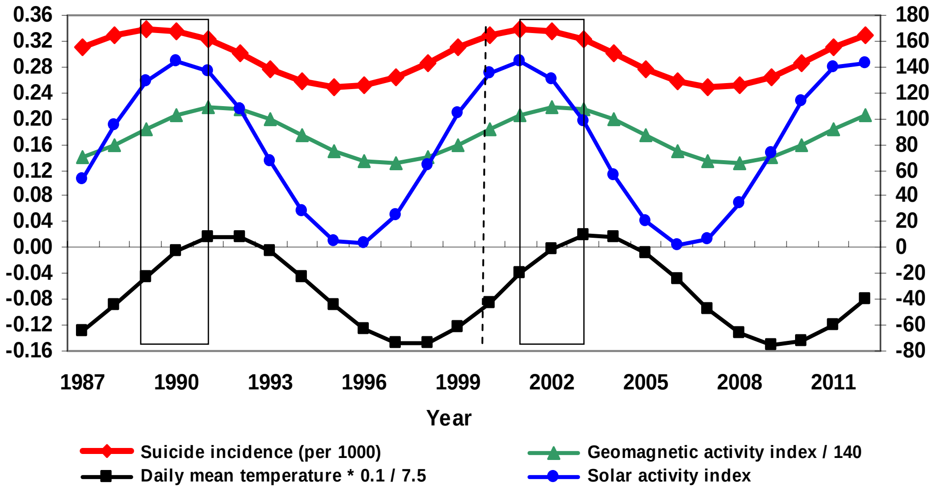

Fig.3. ***Reconstructed ≈11-12-year cyclic components of time series (1987-2011).*** *Model curves of the 11-12-year variation in the time series after trigonometric approximation by using only the estimates of the cyclic components. The curves demonstrate more clearly the peaks and falls over time. The area on the right side of the vertical dotted line indicates the model estimates as forecasted ahead (prognostic interval 2000-2011). Legend: X-axis: calendar year. Y-axes, left: suicide incidence rate per 1000 person-years (rhomboids, red), geomagnetic activity index aa (scaled x 1/140, triangles, green), daily mean temperature (^{0}C scaled x 0.1/7.5, squares, black); right: solar (sunspot) activity index Rz (Wolf number, circles, blue). Vertical dotted line: end of year 1999 (end of the 13-year observation interval). Black rectangles: coherent occurrence of maximal values around the time slots 1989-1991 and 2001-2003.*

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