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The relationship between daylight hours and suicides seasonality in Russia

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Abstract

Researchers from various countries across the globe have found suicidal behaviour to exhibit seasonality. In Russia and other countries located in the northern hemisphere it is observed that the number of suicides spikes during the spring to summer period and drops in winter. Researching the seasonal fluctuations of suicide mortality will allow us to better understand this phenomenon and, consequently, to develop effective measures of suicide prophylaxis, which help prevent future suicide cases.

In this article we research whether the seasonality of suicide levels in Russian countries is related to the daylight hours in different months. To achieve this, seasonality indices for suicides and daylight hours have been constructed for 8 Russian cities located across different latitudes. For these indices Pearson's correlation coefficient has been computed. Granger causality test has been performed for the Russian suicide mortality data obtained for the years from 2000 to 2021. The authors have also attempted to estimate the real number of suicides by including some other causes of death, which were classified as events of undetermined intent.

The results of the study show significant high positive correlation between the seasonality indices of suicides and daylight hours (ranging between 0.74 and 0.9 depending on the city) as well as the presence of Granger causality for all researched cities when using 2 and 3 lags, which might imply a potential influence of the daylight hours on the suicidal behaviour in Russia.

This research contributes to academic literature on the seasonal patterns in suicides and their potential causes.

Keywords
Correlation, daylight hours, events of undetermined intent, Granger causality, suicidal behaviour, suicides estimate.

Introduction

Suicides are a disturbing problem which is highly relevant in today's society. Every 45 seconds a person takes his own life, while the annual number of suicides amounts to a devastating 700 thousand people (Suicide 2023). Every case of suicide is a tragedy and a strong blow to the families, communities and even entire countries, causing a lasting negative impact. The World Health Organization considers suicide prevention as one of their top priorities in the domain of public health. Especially alarming is the data for suicides among young people aged 15 to 29, where suicide ended up being the fourth most common cause of death (Suicide 2023).

The suicide levels in Russia exceed those of many other countries, which shows why this problem is especially relevant for it. In 2019 the Russian Federation became the top 4 country by the suicide cases per 100 thousand persons (Ranking of countries by suicide rate 2019). On top of that, according to the Investigative Committee of Russia, in 2021 the number of child suicides increased to 37.4% compared to the previous year (Maria Lvova-Belova presented the 2021 work results 2022).

Suicides in Russia have a strongly apparent seasonality with the highest number of cases during spring and summer months and the lowest in winter (Vishnevsky 2017). In order to develop effective

measures of prophylaxis and international collaboration in suicide prevention it is vital to research the seasonal behaviour of suicide mortality coefficients and to explain the nature of those fluctuations.

The aim of this research article is to determine the relationship between daylight hours and suicides seasonality in Russia.

The object of this research is the suicides seasonality in Russia.

The subject is the relationship between daylight hours and suicides seasonality in Russia.

Methodology

Anonymized data on individual death reports was obtained for the analysis from Rosstat for 8 Russian countries for the years from 2000 to 2021 with the following ICD-10 causes:

1) Intentional self-harm (X60-84)
2) Poisoning, undetermined intent, except for narcotics and psychedelics (Y10-11, Y13-19)
3) Hanging, strangulation and suffocation, undetermined intent (Y20)
4) Firearm discharge, undetermined intent (Y22-24)
5) Falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent (Y30-31)

Using this data, monthly mortality coefficients have been computed for 22 years as the number of deaths divided by the person-years in the current month.

For this study only cities in Russia with a population of over 500 000 people and located at different latitudes with a difference no less than 2° ± 0,08° have been considered. This is because the latitude affects the daylight hours of a given city. The sample contains 8 Russian cities (Table 1).

Table 1. The list of cities chosen in the study and their characteristics for the year 2021.

#	City name	Population size, people	Latitude (degrees)
1	Vladivostok	603 519	43°11,55’N
2	Krasnodar	1 099 344	45°03,54’N
3	Khabarovsk	617 441	48°48,02’N
4	Saratov	901 361	51°53,35’N
5	Tolyatti	684 709	53°50,78’N
6	Moscow	12 552 559	55°75,58’N
7	Perm	1 034 002	58°01,04’N
8	Saint Petersburg	5 283 371	59°93,90’N

The data on population size in Table 1 for 2021 has been collected on the 2020 All-Russian population census. This study analyzes the city of federal importance Moscow, which also includes the following cities: Zelenograd, Moscow, Moskovsky, Troitsk, Shcherbinka. Also, the city of federal importance Saint Petersburg includes the following cities: Zelenogorsk, Kolpino, Krasnoe Selo, Kronstadt, Lomonosov, Pavlovsk, Peterhof, Pushkin, St. Petersburg, Sestroretsk.

The data on daylight hours for the years from 2000 until 2021 has been gathered from the webpage http://voshod-solnca.ru.

In order to consider the seasonality of suicides in the chosen cities, the median deaths per month have been computed as well as the suicide seasonality indices according to the formula below:

$$I_s = \frac{\bar{y}_i}{\bar{y}}$$

Here $\bar{y}_i$ is the weighted average number of deaths in month $i \in \{1,2,\dots,12\}$, weighted by the number of days in it, and $\bar{y}$ is the weighted average number of deaths in each year, weighted by the number of days in it.

The indices of daylight hours were computed similarly for each city as the day weighted average for a given month. These seasonality indices of suicides and daylight hours were compared in order to determine their connection via the Pearson correlation coefficient.

In order to study the impact of daylight hours on the seasonality of suicides in Russian cities Granger causality test was performed. Prior to that, the linear trend had been removed from the number of deaths variable by applying the first difference operator.

A lot of Russian and foreign researchers study the phenomenon of seasonality in peoples' suicidal behaviour. Some works consider the psychopathological reasons for the seasonal fluctuations of suicides (Kim et al. 2004), others consider sociological, biological and ecological factors instead (Souêtre et al. 1987).

Experts in the field of medicine determined the link between seasonal levels of suicides and climate factors such as air temperature and daylight hours (Rozanov et al. 2018a). The authors of this research have analyzed 17 years of monthly data on suicides in the city of Odessa from 2001 util 2016 and concluded that daylight hours and air temperature are highly and positively correlated with the frequency of suicides (0.97 and 0.96 respectively). This way it was determined that the number of suicides in May exceeds that of in December by 58%. To justify the relationship between suicidal behaviour and climate factors the authors bring up the fact that the number of suicides is close to the average in September and March exactly, which correspond to the periods of autumn and spring solstice. For other months the following pattern can be seen: the shorter the daylight hours, the smaller the frequency of suicides in the city and vice versa. The authors speculate that this link between suicides and climate is due to the dynamics of serotonin and melatonin in the human body and due to neurohumoral mechanisms of thermal adaptation.

The authors of another study looked at the relation between suicides in south and north countries and daylight hours (Petridou et al. 2002). The researchers revealed a consistent seasonality in the prevalence of suicides, which peaks approximately in June in the northern hemisphere and in December in the southern hemisphere. They also found a positive relationship between the seasonal amplitude of suicides and the number of sunny days in the respective countries. These results point to a possible provoking effect of sunlight on suicides.

Researchers from Finland and Switzerland also propose that seasonal fluctuations of suicides frequency are connected with climate factors, in particular, with changes in air temperature (Holopainen et al. 2013). By having the vastest continuous demographical statistics available in the world, the authors were able to analyze the data on mortality from suicides in Switzerland and Finland since the 1750s. Thanks to these early records on demographic changes in these countries, the researchers had access to 260 years' worth of time series data. According to the authors, the increases and decreases in the mortality levels from suicides can be caused by sharp changes in temperature twice a year in May and October (it is exactly in these months that the number of suicides peaks in Switzerland and Finland). The authors explain this phenomenon with the relationship between

temperature fluctuations and the activity of brown adipose tissue in the human body, which aggravates depression, in turn, leading to suicidal behaviour. The authors think that there is evidence to suggest that the farther is the region from the equator, the later the level of suicides peaks in spring. However, they acknowledge that currently there is no data that confirms the correlation of underlying brown adipose tissue activity with the indicators of anxiety or depressive episodes in people.

The seasonality of suicides is outlined by researchers of many countries. For instance, the researchers from Poland also noted an increased rate of suicides during spring (Młodozeniec et al. 2010). Having analyzed 29,232 cases of suicide deaths registered in Poland from 1999 until 2003, they came to the conclusion that there was a clear seasonal component in suicidal behavior among Polish men, but not women.

Nevertheless, in the scientific community there are also studies that did not find the seasonality of suicidal behaviour in some particular regions. For example, no evidence for the seasonality of suicides was found in Tasmania (Lee, Pridmore 2014), Los Angeles and Sacramento (Tietjen & Kripke 1994), which may be due to the specific socio-economic factors of these regions or the lacking sample size.

It has been discovered that longer daylight hours associated with seasonal changes can shift the balance of melatonin and its production levels in the body (Danilenko et al. 2021). This, in turn, affects the regulation of sleep and mood, which increases the risk of depression in individuals. During long sunny days, the secretion of melatonin is reduced, which provokes the disruption of the body's circadian rhythms. This can lead to decreased sleep quality and changes in the psycho-emotional state, which increases the likelihood of developing depressive disorders.

Research suggests that melatonin levels may be associated with the risk of developing depression (Wang et al. 2021). Low levels of melatonin have been found in people suffering from depression, which may indicate problems with the regulation of circadian rhythms and sleep. Melatonin also has antioxidant effects and protects the brain from stress, which may alleviate symptoms of depression (Wu et al. 2013).

Additionally, melatonin can influence the production of neurotransmitters such as serotonin, which plays a key role in mood regulation (Jenkins et al. 2016). There is evidence that melatonin and serotonin levels are interrelated, and that changes in melatonin levels can affect a person's psychological state (Dollins et al. 1993).

Since melatonin is produced when there is less light radiation, higher levels of this hormone are observed in autumn and winter, when the nights are longer, and, conversely, lower levels are found in spring and summer (Danilenko et al. 2021).

As depression plays an important role in suicides (Angst et al. 1999) and daylight hours directly affect the biorhythms of the body, melatonin regulation and the risks of depression, understanding this relationship can be important for developing preventive measures for suicidal behaviour.

Results

Let us consider the distribution of suicide cases in Russian cities by months. For this purpose, suicide seasonality indices were constructed. The distribution of these indices is displayed in Table 2.

Table 2. Suicide seasonality indices in Russian cities.

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vladivostok	1.16	0.89	1.00	0.91	1.03	1.11	1.38	1.04	0.92	0.82	0.91	0.84
Krasnodar	0.90	1.07	1.10	1.03	1.16	1.15	1.23	0.91	0.98	0.74	0.84	0.88
Khabarovsk	0.95	0.96	1.03	1.13	1.17	1.00	1.04	1.12	1.03	0.98	0.80	0.80
Saratov	1.01	0.93	1.00	1.08	1.13	1.02	1.27	1.09	0.98	0.89	0.84	0.77
Tolyatti	1.20	0.94	1.06	1.09	1.12	0.97	1.02	0.87	1.07	0.87	0.83	0.96
Moscow	0.98	0.94	1.00	1.09	1.11	1.12	1.06	1.06	0.92	0.91	0.93	0.87
Perm	1.02	0.95	0.99	1.06	1.11	1.12	1.02	1.06	0.97	0.94	0.89	0.87
Saint Petersburg	1.06	0.97	1.00	1.12	1.08	1.03	1.10	1.03	0.93	0.94	0.86	0.88

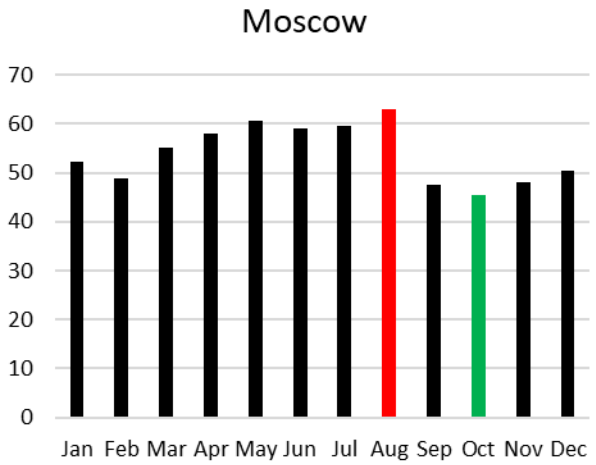
The months in which min and max suicides occur as well as some additional relevant characteristics of each Russian city in this study are presented in Table 3.

Table 3. Suicide seasonality profiles for Russian cities.

City	Latitude (degrees)	Average annual number of suicides	Month of max suicides	Month of min suicides
Vladivostok	43°11’N	49	July	October
Krasnodar	45°03’N	112	July	October
Khabarovsk	48°48’N	113	May	December
Saratov	51°53’N	134	July	December
Tolyatti	53°50’N	50	January	November
Moscow	55°75’N	705	June	December
Perm	58°01’N	230	June	December
Saint Petersburg	59°93’N	561	April	November

The overall trend is seen for all cities aside from Tolyatti: an increase in suicides in spring and summer and a decrease in autumn and winter periods. Thus, for most cities the peak of suicides is seen in June or July and the minimum occurs in the range from October to December. The one exception is the city of Tolyatti, in which the peak occurs in January. However, as with the other cities, Tolyatti also has a minimum occurring in the abovementioned period in November. This deviation for Tolyatti could be explained by the relatively low number of the average annual number of suicides, only 50 cases per annum, which leaves the index sensitive to outliers for each given month.

Since the average value, which was used to compute the seasonality indices, is sensitive to outliers, median monthly number of suicides has been computed for 22 years (Figure 1).


Moscow
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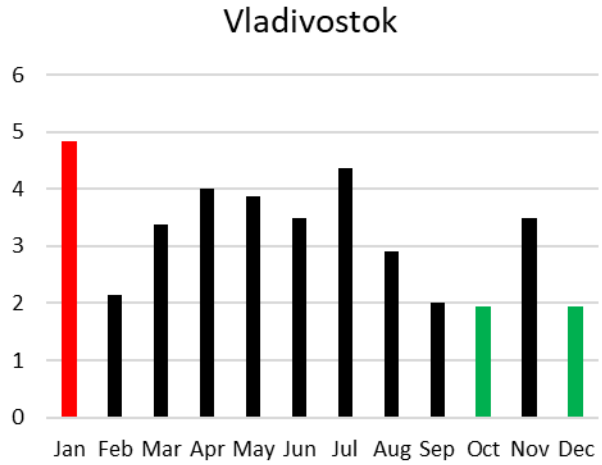
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Vladivostok
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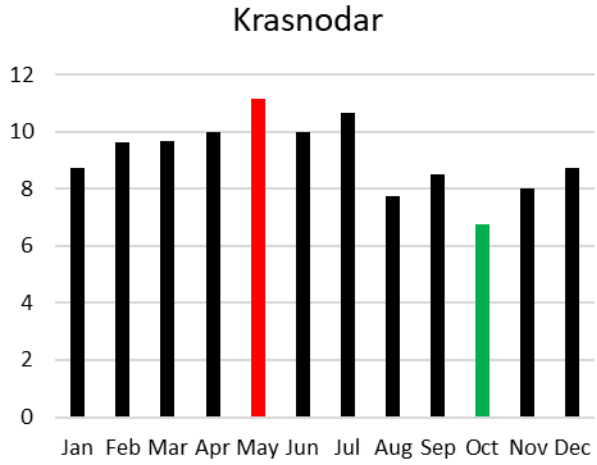
Krasnodar
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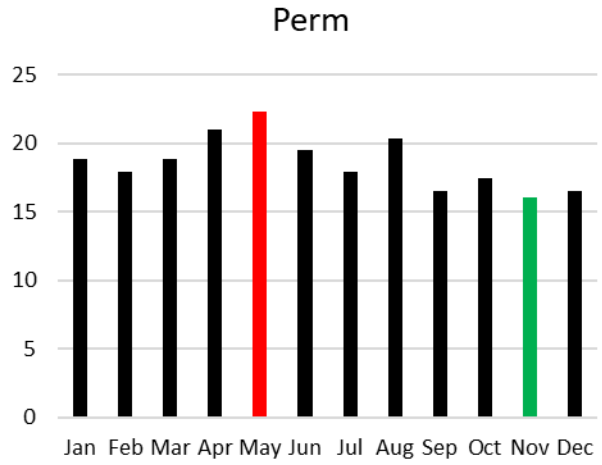
Perm
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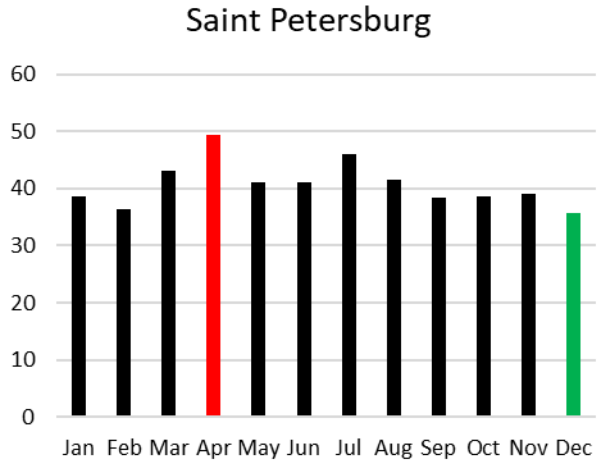
Saint Petersburg
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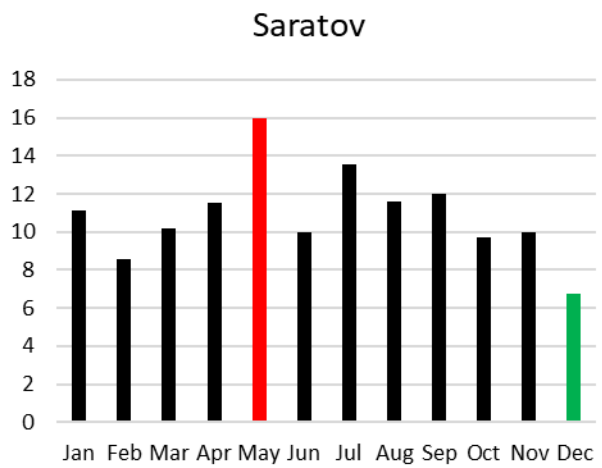
Saratov
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12
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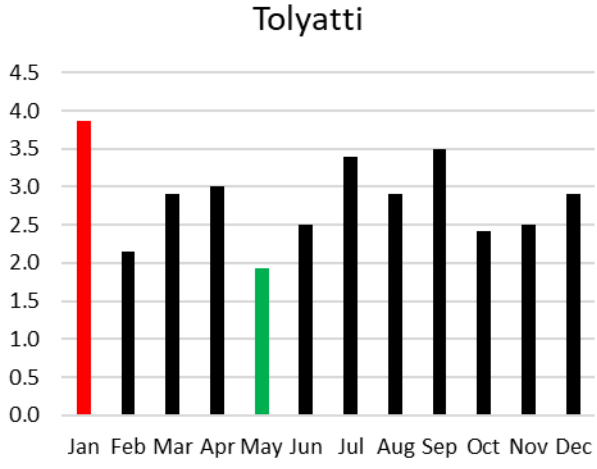
8
6
4
2
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Tolyatti
4.5
4.0
3.5
3.0
2.5
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1.5
1.0
0.5
0.0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

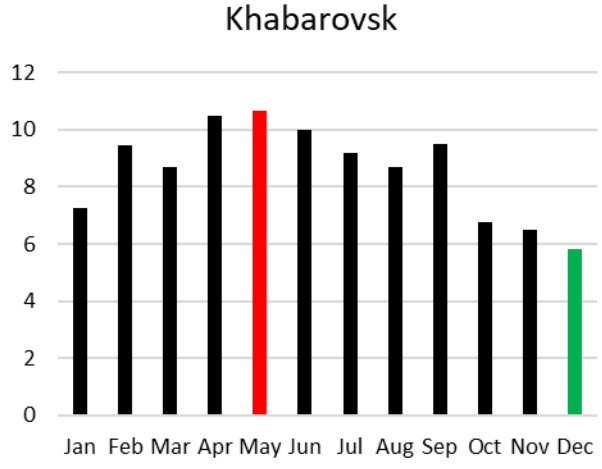
Khabarovsk
12
10
8
6
4
2
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Figure 1. Median monthly number of suicides by city.

The red color in Figure 1 indicates the month with the highest number of median monthly suicides, whereas the green color indicates the month in which the minimum occurs.

When using the median instead of the average the trend has slightly changed. In most cities the peaks now occur in May, while the min months stay within the October-December range. That being said, once again it is Tolyatti that is different within the group with the maximum occurring in January and minimum in May. Another deviation is the city of Vladivostok with a peak occurring in January. This situation could again be connected with the low average annual number of suicides with less than 50 cases per annum. Another reason could lie in the underreporting of suicides (Figure 2).

According to mortality researchers, excessive classification of external causes as undetermined intent could indicate questionable data quality (Andreev et al. 2015). Some experts state that the frequent use of this cause suggests the presence of data manipulation (Yumaguzin 2017).

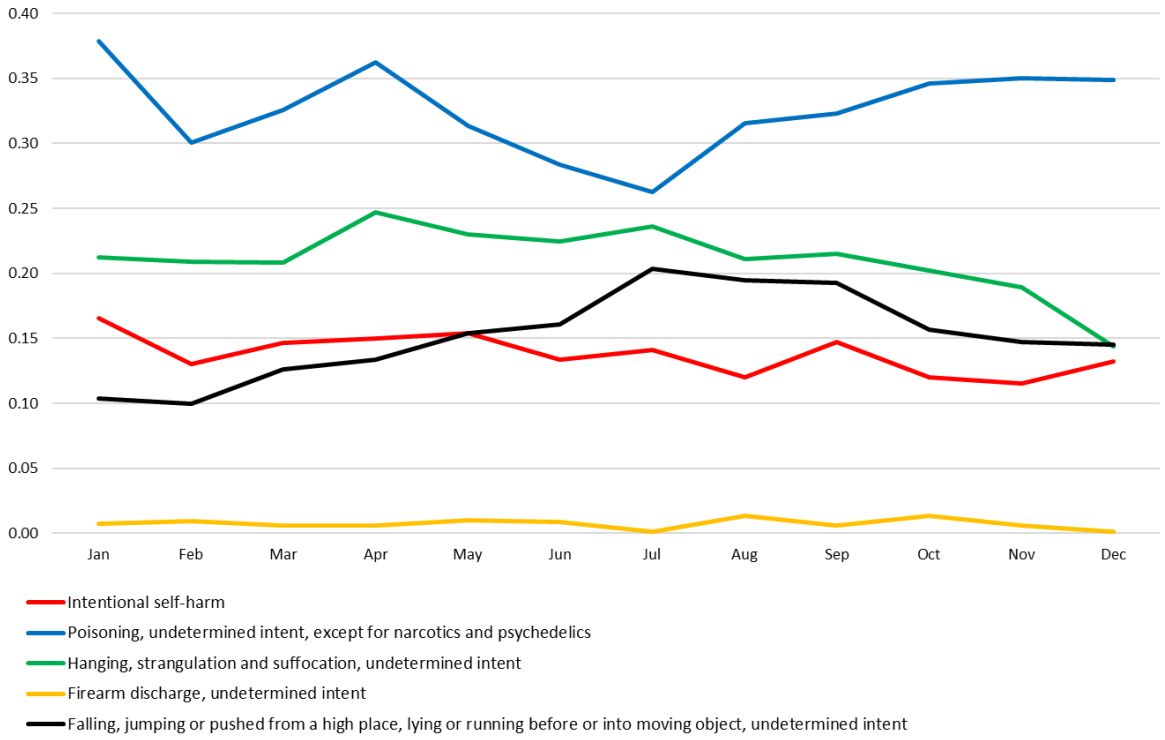

Figure 2. Monthly weighted average number of suicides and other causes of death in Tolyatti for 22 years, weighted by the number of days in each month.

Figure 2 displays that the suicide levels in Tolyatti are lower than those of even such causes as poisoning, undetermined intent, except for narcotics and psychedelics; hanging, strangulation and suffocation, undetermined intent; falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent. Thus, we can assume the presence of latent suicides among these causes of death.

It is also important to note that hanging, strangulation and suffocation, undetermined intent exhibit the same seasonal pattern as that of Russia as a whole: the number of deaths increases in spring and decreases in autumn-spring.

Since the 1990s the level of mortality from events of undetermined intent has drastically increased. In 2018 the losses from events of undetermined intent were 2.1 times higher than from suicide for

male population and 3 times higher for female population (Semyonova et al. 2020). According to Yumaguzin and Vinnik, events of undetermined intent are a reservoir for latent assaults and suicides. Besides, since 2014 the volume of events of undetermined intent in Russia exceeded the mortality levels from assaults and suicides combined (Yumaguzin & Vinnik 2019). In their paper the authors attempt to estimate the real level of suicides in Russia by redistributing the events of undetermined intent among assaults, suicides and accidents. According to their estimates the suicide levels in Russia are underestimated by 30%.

In the article by Andreev, Shkolnikov, Pridemore and Nikitina an estimate of suicide levels and other causes is also constructed by using the method of reclassifying the events of undetermined intent. The results of this research indicated an underestimation of 24% in the official data sources for the natural movement of the population in 2011 (Andreev et al. 2015).

Other estimates for 2011–2018 in Russia suggest that the real mortality from suicides exceeds that stated in the official data sources by 58.3% for males and by 85.7% for females (Semyonova et al. 2020).

Krenev and Vasin have outlined multiple causes among the events of undetermined events which are mechanically similar to suicides (Krenev & Vasin 2012). The following potential suicides have been selected from the ICD-10:

1) Poisoning by and exposure to nonopioid analgesics, antipyretics and antirheumatics, undetermined intent (Y10)
2) Hanging, strangulation and suffocation, undetermined intent (Y20)
3) Drowning and submersion, undetermined intent (Y21)
4) Injuries from firearms and explosives, undetermined intent (Y22 - Y25)
5) Exposure to smoke, fire and flames, undetermined intent (Y26)
6) Contact with steam, hot vapours and hot objects, undetermined intent (Y27)
7) Contact with sharp object, undetermined intent (Y28)
8) Contact with blunt object, undetermined intent (Y29)
9) Falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent (Y30 – Y31)
10) Crashing of motor vehicle, undetermined intent (Y32)
11) Other specified events, undetermined intent (Y33)
12) Unspecified event, undetermined intent (Y34)

The practice of underreporting suicides due to the overuse of the events of undetermined intent is present not only in Russia, but also in other countries. For instance, in Estonia the fraction of the events of undetermined intent is higher than in Russia (Vasin 2015). The researchers attribute this to negligent investigations in the country.

In most developed countries the data on mortality causes is more detailed and is available for scientific research (Vasin 2015). However, concealment of violent causes of death occurs in developed countries as well. In the USA there have been systematic classifications of suicides as poisoning, undetermined intent (Fingerhut & Cox 1998). Similar underreporting was also present in Australia (Snowdon & Choi 2020). Also, in the research conducted in Sweden, it was found that about two thirds of all causes of death, which were classified as events of undetermined intent, were in fact cases of suicide. It was discovered by interviewing relatives, friends and medics as well as by analyzing the death certificates (Tollefsen et al. 2012).

The monthly weighted average number of deaths from suicides and some events of undetermined intent, weighted by the number of days in each month is shown in Figure 3.

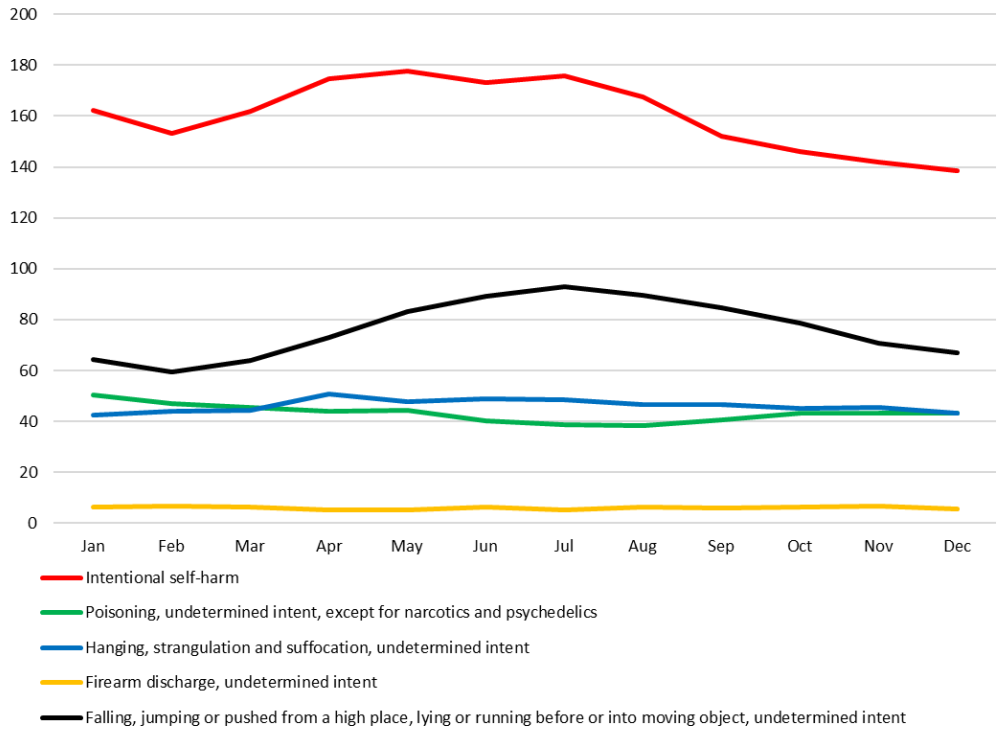

Figure 3. The monthly weighted average number of deaths from suicides and some events of undetermined intent, weighted by the number of days in each month, for all studied Russian cities.

Seasonality indices have also been computed for each city for all 5 causes. The average distributions of these indices for all 8 cities as a whole are presented in Figures 4, 5, 6 and 7.

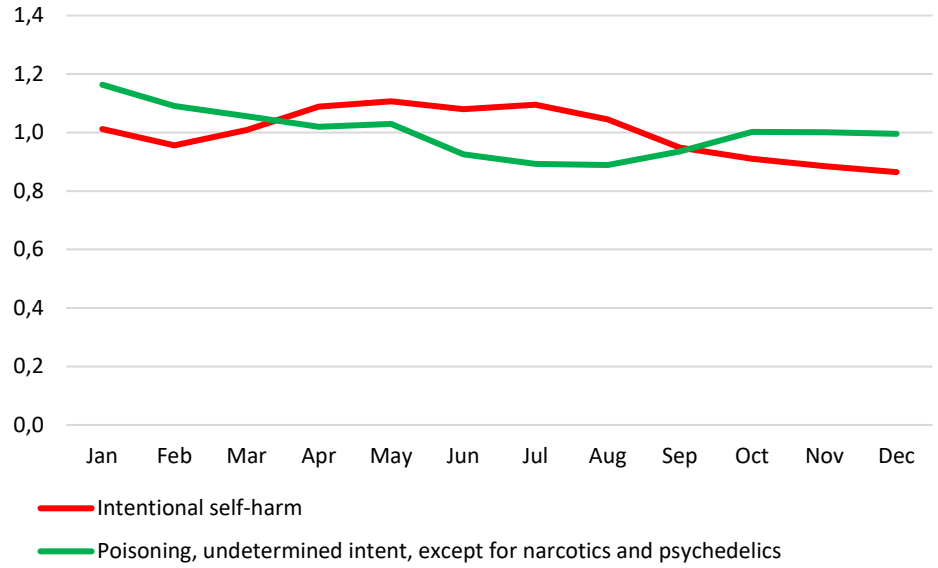

Figure 4. Seasonality indices for suicides and poisoning, undetermined intent, except for narcotics and psychedelics.

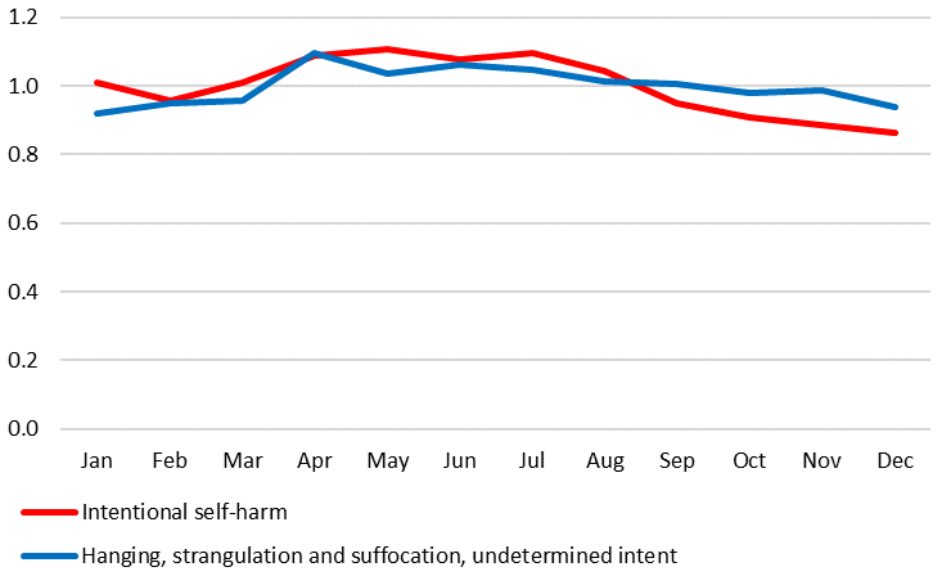

Figure 5. Seasonality indices for suicides and hanging, strangulation and suffocation, undetermined intent.

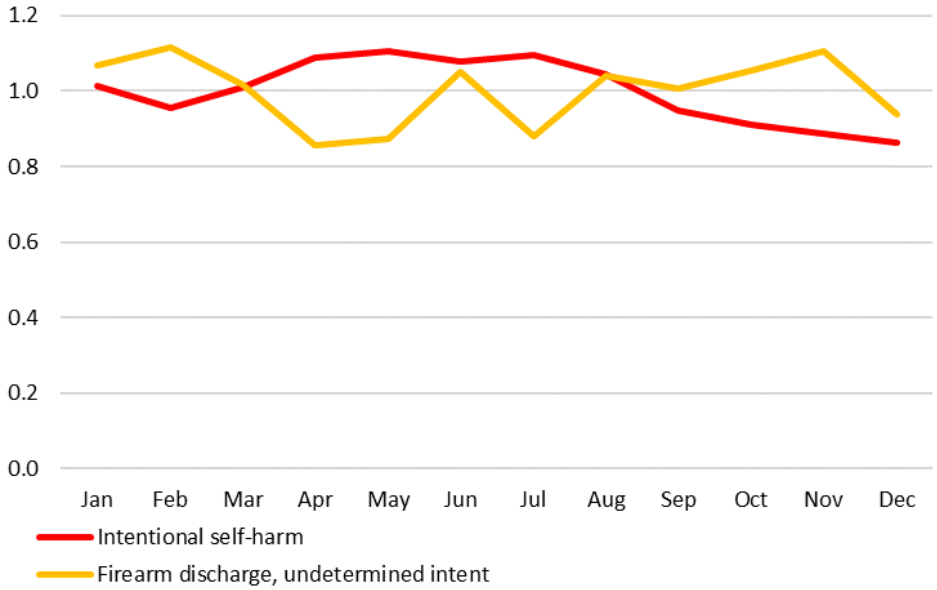

Figure 6. Seasonality indices for suicides and firearm discharge, undetermined intent.

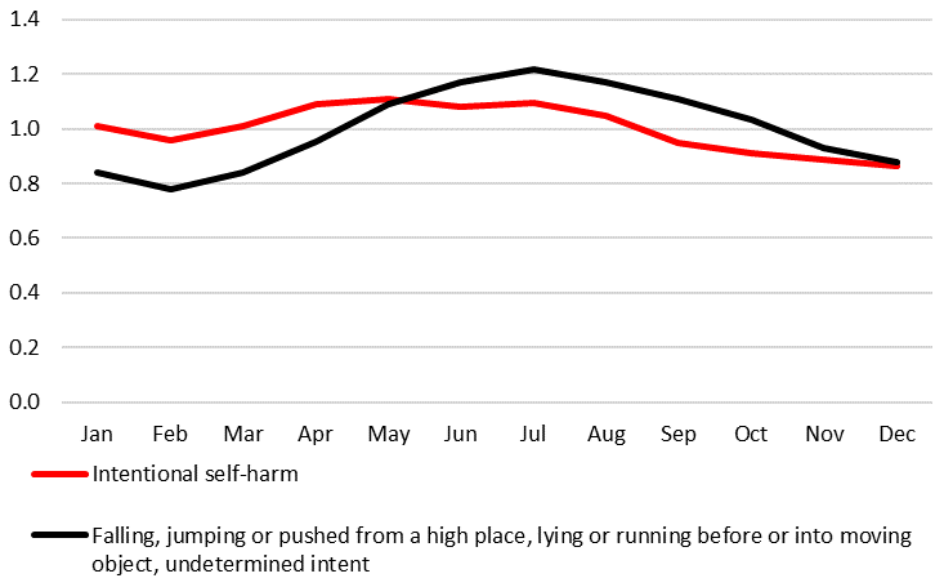

Figure 7. Seasonality indices for suicides and falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent.

We can see that the seasonal fluctuations of suicides, hanging, strangulation and suffocation, undetermined intent as well as falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent have a similar profile with an increase in the number of deaths during the spring-summer period and a decrease during autumn and winter. In order to check the hypothesis of whether there is a relationship between the distributions of those causes and the distribution of suicides, Pearson correlation coefficient has been computed. The results of the calculations are presented in Table 4.

Table 4. Pearson correlation coefficients between the death causes.

Causes	Pearson correlation coefficient	P-value	Significance at α = 0.05
1 and 2	0.329	0.296	not significant
1 and 3	0.597	0.04	significant
1 and 4	0.298	0.347	not significant
1 and 5	0.592	0.042	significant

In Table 4 the causes are numbered according to the scheme below:
1) Intentional self-harm
2) Poisoning, undetermined intent, except for narcotics and psychedelics
3) Hanging, strangulation and suffocation, undetermined intent
4) Firearm discharge, undetermined intent
5) Falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent

The correlation between suicides and hanging, strangulation and suffocation, undetermined intent as well as falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent ended up being significant at the confidence level of $\alpha = 0.05$. The linear relationship between the variables is positive. This can point to the presence of latent suicides among these two causes.

Based on this assumption, the seasonality indices have been recomputed again by including two causes of death: hanging, strangulation and suffocation, undetermined intent; falling, jumping or

pushed from a high place, lying or running before or into moving object, undetermined intent. Here and thereafter the three causes of death combined will be called the suicides estimate.

The distribution of seasonality indices for the suicides estimate by month for each city are displayed in Table 5.

Table 5. Seasonality indices for the suicides estimate in Russian cities.

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vladivostok	0.93	0.89	1.06	1.09	1.06	1.12	1.21	1.03	0.98	0.92	0.91	0.80
Krasnodar	0.90	1.05	1.05	1.00	1.13	1.15	1.16	1.00	1.05	0.79	0.85	0.87
Khabarovsk	0.99	0.90	0.94	1.07	1.13	0.98	1.09	1.13	1.05	0.98	0.92	0.82
Saratov	1.01	0.94	0.88	1.03	1.09	1.05	1.21	1.15	1.03	0.97	0.86	0.79
Tolyatti	0.96	0.88	0.96	1.06	1.08	1.04	1.16	1.05	1.11	0.96	0.90	0.84
Moscow	0.90	0.88	0.95	1.05	1.09	1.13	1.11	1.08	0.99	0.97	0.95	0.92
Perm	0.99	0.94	0.97	1.05	1.13	1.14	1.03	1.08	0.99	0.95	0.88	0.86
Saint Petersburg	1.00	0.93	0.94	1.07	1.08	1.07	1.13	1.07	0.99	0.95	0.89	0.88

The months in which min and max suicides estimate occurs as well as some additional relevant characteristics of each Russian city in this study are presented in Table 6.

Table 6. Suicides estimate seasonality profiles for Russian cities.

City	Latitude (degrees)	Average annual number of the suicides estimate	Month of max suicides	Month of min suicides
Vladivostok	43°11’N	135	July	December
Krasnodar	45°03’N	146	July	October
Khabarovsk	48°48’N	162	May, August	December
Saratov	51°53’N	198	July	December
Tolyatti	53°50’N	183	July	December
Moscow	55°75’N	1470	July	February
Perm	58°01’N	245	July	December
Saint Petersburg	59°93’N	909	July	December

After estimating the number of suicides by including additional causes of death, the number of suicides in the cities has drastically increased. For example, in Tolyatti the average annual number of deaths has increased by 266%, in Vladivostok by 176% and in Moscow by 109%. At the same time in Perm this increase constituted only 7%, which could indicate that the suicides in this city are recorded fairly.

Seasonality indices for daylight hours have been computed analogously to the seasonality indices for suicides. The average distribution of daylight hours by month in all the Russian cities is presented in Figure 8.

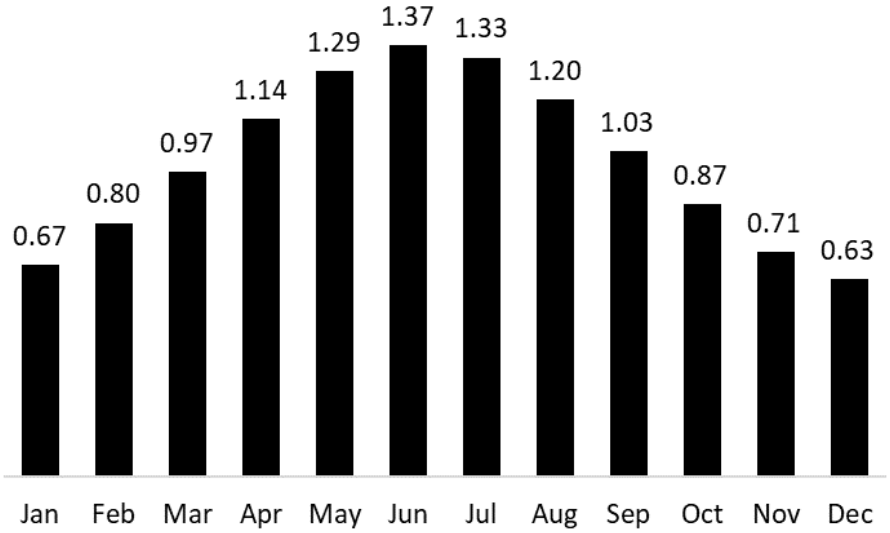

Figure 8. Daylight hours distribution by month for all Russian cities.

The longest daylight hours occur in summer months, in particular, June is the month with the longest daylight hours. In September and March the daylight hours are equal approximately to the annual average. The month with the smallest value of the daylight hours is December.

In order to check the relationship between the seasonality indices for daylight hours and suicides for all 8 Russian cities, Pearson correlation coefficient has been computed. The results of the calculations are presented in Table 7.

Table 7. Pearson correlation coefficients between the seasonality indices for daylight hours and suicides in Russian cities.

City	Pearson correlation coefficient	P-value	Significance at α = 0.05
Before accounting for hanging, strangulation and suffocation, undetermined intent; falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent			
Vladivostok	0.59	0.044	significant
Krasnodar	0.7	0.012	significant
Khabarovsk	0.78	0.003	significant
Saratov	0.8	0.002	significant
Tolyatti	0.02	0.95	not significant
Moscow	0.86	0	significant
Perm	0.83	0.001	significant
Saint Petersburg	0.67	0.018	significant
After accounting for hanging, strangulation and suffocation, undetermined intent; falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent			
Vladivostok	0.898	0	significant
Krasnodar	0.831	0.001	significant
Khabarovsk	0.735	0.006	significant
Saratov	0.791	0.002	significant
Tolyatti	0.816	0.001	significant
Moscow	0.934	0	significant
Perm	0.894	0	significant

Saint Petersburg	0.901	0	significant

In all cities a strong positive and significant linear relationship was found between suicides and daylight hours. The coefficients demonstrate a high, positive and significant correlation between the seasonality indices for suicides and daylight hours. This may indicate that an increase in daylight hours is related to an increase in suicides in these cities.

After accounting for two additional causes of death, the correlation coefficients have increased for all analyzed cities. On top of that, the correlation for the city of Tolyatti became significant at 5%.

Granger causality

In order to establish the relationship (or lack thereof) between the daylight hours and the suicides in Russia, Granger causality test has been performed.

Granger causality test is used to determine a weak form of causality between two time series variables and consists of a statistical test, which establishes the predictive power of some variable. This test compares the forecast accuracy in the case where one time series is explained only by its lagged values and the case where additional lagged terms from the second time series are added. If the additional terms improve the forecast accuracy, it is said that the second time series Granger causes the first time series. Despite the fact that this test does not give a definitive answer as to whether the actual causality is present, it serves as a good benchmark for further investigations.

Since this test is only applicable to stationary time series and the time series of suicide mortality coefficients are not stationary, difference operators were applied on the time series to make them stationary. In order to check if the differenced series are indeed stationary, the augmented Dickey-Fuller (ADF) test has been performed. Indeed, it showed that all time series were stationary at all sane significance levels. The results of the Granger causality test for differenced time series can be found in Table 8. Note that the series of differenced suicide coefficients was used as the dependent variable.

Table 8. The results of the Granger causality test.

City	P-value	Significance at $\alpha = 0.05$	Is Granger causality present?
Lags included = 1			
Vladivostok	0.0073	significant	Yes
Krasnodar	0.2621	not significant	No
Khabarovsk	0.5613	not significant	No
Saratov	0.2714	not significant	No
Tolyatti	0.3972	not significant	No
Moscow	0.5352	not significant	No
Perm	0.6723	not significant	No
Saint Petersburg	0.8939	not significant	No
Lags included = 2			
Vladivostok	0.0002	significant	Yes
Krasnodar	0	significant	Yes
Khabarovsk	0.0203	significant	Yes
Saratov	0	significant	Yes
Tolyatti	0.0002	significant	Yes
Moscow	0	significant	Yes
Perm	0.0001	significant	Yes
Saint Petersburg	0	significant	Yes
Lags included = 3			

Vladivostok	0.0001	significant	Yes
Krasnodar	0	significant	Yes
Khabarovsk	0.0015	significant	Yes
Saratov	0	significant	Yes
Tolyatti	0	significant	Yes
Moscow	0	significant	Yes
Perm	0	significant	Yes
Saint Petersburg	0	significant	Yes

When using only one lag no Granger causality was found, aside from the case of Vladivostok. This means that the first lag of the dependent variable is sufficient in forecasting its future values and there is no improvement when adding the lag of the second time series. However, when using 2 and 3 lags the past values of daylight hours improve the predictive power of the model compared to not adding them.

Thus, the test results allow us to conclude that forecasting the number of suicides by using its lags as well as the lags of daylight hours improves the accuracy compared to only using the lags of the number of suicides when using 2 and 3 lags for each variable. This may indicate that there is a weak causal relationship between suicides and daylight hours.

Discussion

This research is, to the best of our knowledge, the first to attempt to estimate the relationship between daylight hours and suicidal behaviour in Russia. The link between suicides and climate factors is an active field of research in other countries, while lacking its deserved attention in the Russian scientific community. We have only found one Russian paper in which climate and ecological factors are mentioned with regards to being connected with the fluctuations of suicidal behaviour seasonality in Russia, although not statistically analyzed (Rozanov & Grigoriev 2018b).

Despite analyzing 8 cities in Russia, which are located on different latitudes with the maximal difference between any given two cities being 16 degrees, the suicides seasonality profile after accounting for possible latent cases turned out to be quite similar among them: the maximum occurring most commonly in June and minimum in December. This phenomenon could be connected with the predominantly northern locations of Russian cities, thus, more data on some of the more south countries of the world is needed to more accurately analyze the difference between the seasonal fluctuations of suicides.

Studying causality in time series data is an extremely difficult task. The variables in question may be influenced by hidden variables, the correlation could end up being spurious and mislead the researchers into false discoveries. Currently there is no method to guarantee the presence or lack of causal relationship between two time series. There is also a problem of the third variable, which can influence the two series, making it seem like the relationship is there, while in reality it is not. The Granger causality test does not control for that, making it an unreliable, yet, perhaps, the only viable option to try and at least attempt to find a causal relationship.

Conclusion

This scientific research provides an analysis of suicides seasonality in various Russian countries. The overall trend is an increase of the number of suicides in the spring-summer period and a decrease in autumn-winter, with Tolyatti not following the pattern and having its suicide peaks in January. This

could be connected with the underreporting of suicides and classifying them as other causes with events of undetermined intent, in particular, hanging, strangulation and suffocation, undetermined intent; falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent. Havning taken these causes into account changed the distribution of suicides by month in the researched cities. This seasonal profile in Russian cities may arise due to the varying daylight hours in each month. For instance, high, positive and significant correlation was found between suicides and daylight hours.

The results of the Granger causality test showed that forecasting the number of suicides by using its lagged values as well as the lags of daylight hours improves the accuracy when compared with just using the lags of the number of suicides for the case of 2 and 3 lags being used in the model. This could indicate that daylight hours Granger cause the number of suicides. However, when using ony 1 lag no Granger causality has been found between the variables.

Research limitations

In order to conduct the Granger causality test, each time series for all countries had to be differenced to make them stationary. This could have tampered with the behaviour of the time series, skewing the testing results.

This research analyzes the suicides which were officially documented, thus, some suicides may have been missing entirely or classified as events of undetermined intent. The authors have attempted to incorporate latent suicides into the analysis by including two other causes of death: hanging, strangulation and suffocation, undetermined intent; falling, jumping or pushed from a high place, lying or running before or into moving object, undetermined intent. However, not all such cases are necessarily latent suicides, it might only be some fraction. Also, not all latent suicides are located in these two causes in particular, other causes may contain some latent suicides as well. For instance, some researchers find latent suicides in relatively high quantities among medicinal poisonings (Semyonova et al. 2020).

Since this work only analyzes actual suicides and does not consider attempted ones, it is not possible to see whether the same seasonal patterns are present in attempted suicides.

Despite all the limitations, this paper contributes to existing knowledge on suicides seasonality and its possible causes.

References

1. Andreev, E, Shkolnikov VM, Pridemore WA, Nikitina SY (2015) A method for reclassifying cause of death in cases categorized as “event of undetermined intent”. Population Health Metrics 13(23): 1–25. https://doi.org/10.1186/s12963-015-0048-y
2. Angst J, Angst F, Stassen HH (1999) Suicide risk in patients with major depressive disorder. J Clin Psychiatry 60(2): 57–62. https://pubmed.ncbi.nlm.nih.gov/10073389/
3. Danilenko KV, Kobelev E, Zhanaeva SY, Aftanas LI (2021) Winter-summer difference in post-awakening salivary α-amylase and sleepiness depending on sleep and melatonin. Physiol Behav. https://doi.org/10.1016/j.physbeh.2021.113549
4. Dollins AB, Lynch HJ, Wurtman RJ, Deng MH, Kischka KU, Gleason RE, Lieberman HR (1993) Effect of pharmacological daytime doses of melatonin on human mood and performance. Psychopharmacology (Berl). 112(4): 490–496. https://doi.org/10.1007/BF02244899
5. Fingerhut LA, Cox CS (1998) Poisoning mortality, 1985–1995. Public Health Rep 113(3): 218–233. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1308672/

6. Holopainen J, Helama S, Björkenstam C, Partonen T (2013) Variation and seasonal patterns of suicide mortality in Finland and Sweden since the 1750s // Environ Health Prev Med 18(6): 494–501. https://doi.org/10.1007/s12199-013-0348-4
7. Jenkins TA, Nguyen JC, Polglaze KE, Bertrand PP (2016) Influence of Tryptophan and Serotonin on Mood and Cognition with a Possible Role of the Gut-Brain Axis. Nutrients 8(1): 56. https://doi.org/10.3390/nu8010056
8. Kim CD, Lesage AD, Seguin M, Chawky N, Vanier C, Lipp O, Turecki G (2004) Seasonal differences in psychopathology of male suicide completers. Compr Psychiatry 45(5): 333–339. https://doi.org/10.1016/j.comppsych.2004.06.007
9. Krenev A. A., Vasin S. A. (2012) «Rod smerti ne ustanovlen» - vedushchaya prichina nasilstvennoj smertnosti v Rossii ['The manner of death has not been established' is the leading cause of violent deaths in Russia]. Demoskop [Demoscope] Weekly 535. https://publications.hse.ru/articles/77703821 (in Russian)
10. Lee AY, Pridmore S (2014) Absence of seasonality of suicide in Tasmania (Australia). Australas Psychiatry 22(2): 204–206. https://doi.org/10.1177/1039856214526287
11. Młodozeniec A, Brodniak WA, Polewka A, Bembenek A. (2010) Sezonowość samobójstw w Polsce. Analiza danych Głównego Urzedu Statystycznego z lat 1999-2003 [Seasonality of suicide in Poland. Analysis of the Main Statistical Office data for the years 1999-2003]. Psychiatr Pol 44(1): 61–69. https://pubmed.ncbi.nlm.nih.gov/20449981/
12. Petridou E, Papadopoulos FC, Frangakis CE, Skalkidou A, Trichopoulos D (2002) A role of sunshine in the triggering of suicide. Epidemiology 13(1): 106–109. https://doi.org/10.1097/00001648-200201000-00017
13. Rozanov V.A., Grigoriev P.E. (2018) Environmental factors and suicide behavior in human being. Suicidology 9 (2): 30-49. https://cyberleninka.ru/article/n/ekologicheskie-faktory-i-suitsidalnoe-povedenie-cheloveka (in Russian)
14. Rozanov V.A., Grigoriev P.E., Zakharov S.E., Kryvda G.F. (2018) Analysis of completed suicides seasonality in relation to such external factors as length of the day and ambient temperature. Suicidology. 9 (3): 71-79. doi: https://doi.org/10.32878/suiciderus.18-09-03(32)-71-79 (in Russian)
15. Semyonova V.G., Ivanova A.E., Sabgaida T.P., Zubko A.V., Mikhailov A.Yu., Evdokushkina G.N., Zaporozhchenko V.G. (2020) Social and economic determinants of the age structure of mortality from suicide in Russia. Health care of the Russian Federation. 64(5): 243-252. https://doi.org/10.46563/0044-197X-2020-64-5-243-252 (in Russian)
16. Snowdon, J, Choi NG (2020) Undercounting of suicides: Where suicide data lie hidden. Global Public Health 15(12): 1894–1901. https://doi.org/10.1080/17441692.2020.1801789
17. 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(3): 215–225. https://doi.org/10.1016/0165-0327(87)90040-1
18. Tietjen GH, Kripke DF (1994) Suicides in California (1968–1977): absence of seasonality in Los Angeles and Sacramento counties. Psychiatry Res 53(2): 161–172. https://doi.org/10.1016/0165-1781(94)90107-4
19. Tollefsen I.M., Hem E., Ekeberg O. (2012). The reliability of suicide statistics: a systematic review. BMC Psychiatry 12(9). https://doi.org/10.1186/1471-244X-12-9
20. Vasin S. A. (2015). Mortality from undetermined causes of death in Russia and in a selected set of countries. Demographic Review 2(1): 89-124. https://doi.org/10.17323/demreview.v2i1.1790
21. Vishnevsky A. G. (2017) Smertnost ot vneshnih prichin v Rossii s serediny XX veka [Mortality from external causes in Russia since the mid-20th century]. Izdatelskij dom Vysshej shkoly ekonomiki [HSE Publishing House], Moscow 448 p. https://doi.org/10.17323/978-5-7598-1397-2 (in Russian)
22. Wang Y, Jiang Y, Zou M, Liu J (2021) Antidepressant actions of melatonin and melatonin receptor agonist: Focus on pathophysiology and treatment. Behav Brain Res 420(9): 113724. https://doi.org/10.1016/j.bbr.2021.113724

23. Wu YH, Ursinus J, Zhou JN, Scheer FA, Ai-Min B, Jockers R, van Heerikhuize J, Swaab DF (2013) Alterations of melatonin receptors MT1 and MT2 in the hypothalamic suprachiasmatic nucleus during depression. J Affect Disord 148(2–3): 357–367. https://doi.org/10.1016/j.jad.2012.12.025
24. Yumaguzin V. V. (2017) Smertnost ot povrezhdenij s neopredelennymi namereniyami kak pokazatel kachestva statistiki smertnosti ot vneshnih prichin [Mortality from events of undetermined intent as an indicator of the data quality on mortality from external causes]. Aist na kryshe. Demograficheskij zhurnal [Stork on the roof. Demographic magazine] 5: 40-47. https://publications.hse.ru/articles/211645194 (in Russian)
25. Yumaguzin V., Vinnik M. (2019). Assessment of the Real Rates of Homicides and Suicides in the Regions of Russia. Sotsiologicheskie issledovaniya 1: 116–126 DOI: https://doi.org/10.31857/S013216250003753-1 (in Russian)

Other information sources

NoNews: Ranking of countries by suicide rate. https://nonews.co/directory/lists/countries/suicide-rate

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WHO: Suicide. https://www.who.int/news-room/fact-sheets/detail/suicide