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Research paper

The role of seasonality and photoperiod on the lethality of suicide attempts: A case-control study

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ABSTRACT

Background: The risk factors related to suicidal behaviors are complex and not yet fully known. Several studies underline how suicide results from the combination of psycho-social, biological, cultural, and environmental factors. The aim of this study was to investigate the potential role of seasonality and photoperiod on high-lethality suicide attempts (HLSA) compared with low-lethality suicide attempts (LLSA) in a sample of psychiatric inpatients.
Methods: After attempting suicide, subjects were admitted in the emergency/psychiatric ward of the IRCCS Ospedale Policlinico San Martino from 1st August 2013 to 31st July 2018. Socio-demographic and clinical characteristics were collected.
Results: The sample consisted of four hundred thirty-two individuals admitted for suicide attempt. One hundred thirty-three subjects (30.8%) of the sample committed a HLSA. The HLSA group peaked in the months with a higher sunlight exposure (June and July). Bivariate correlation analyses between seasonality/photoperiod in the whole sample and HLSA were positively associated with summer and highest solar intensity period.
Limitations: Data were limited to a single hospital, patients' seasonal environment, meteorological variables and psychological factors. In addition, the presence of acute life-events fostering the suicidal crisis has not been investigated.
Conclusions: The current study provides a novel perspective on the questions surrounding the impact of seasonality and daylight exposure on lethality of suicide attempts. further studies are needed to provide deeper understandings on the delicate molecular network that links suicide behaviors, seasonality and daylight in order to develop more effective prevention and treatment strategies in the future.

1. Introduction

Suicide and all related behaviors are a serious social and health problem worldwide. The World Health Organization (WHO) reported that approximately 800.000 people died by suicide worldwide in 2016, and that the number of people attempting suicide each year is even higher. Suicide was the second leading cause of death among 15–29 year old people in 2016 with an annual global age-standardized suicide rate of 10.5 per 100.000 population (World Health Statistics, 2017).

The etiology and risk factors related to suicidal behaviors are complex and not yet fully known. Several studies underline how suicide results from the combination of psycho-social, biological, cultural, and environmental factors (Christodoulou et al., 2012; Rumble et al., 2018). Psychosocial factors include life event stressors such as family violence, sexual or substances abuse, parental separation, loneliness and hopelessness, traumatic life events, social isolation or discrimination among specific at risk sub-populations (Bando et al., 2017; World Health Statistics, 2017; Ásgeirsdóttir et al., 2018; Lee et al., 2018; O'Neill et al., 2018; Veisani et al., 2018). Moreover, different biological risk factors for suicidal behaviors have been identified, such as mental illnesses (in particular bipolar disorder and borderline personality disorder), involuntary admissions, altered metabolic parameters, increased

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inflammatory markers, cyclothymic temperament, altered neurotransmission involving serotonin and dopamine dysfunctions (Hawton and van Heeringen, 2009; Costa et al., 2015; DeShong et al., 2015; Aguglia et al., 2016; Pompili et al., 2017; Serafini et al., 2017; Batty et al., 2018; Daray et al., 2018; Fond et al., 2018; Kuo et al., 2018; Peng et al., 2018).

However, suicidal behaviors are not completely explained by the complex network of these phenomena and epidemiological studies have been carried out in order to shed further light on these dynamics. For instance, the study of geographical variations in suicide rates suggested additional explanatory variables (Sun et al., 2011; Woo et al., 2012) and significant associations between seasonality and both completed and suicide attempts have been reported (Hakko et al., 1998; Ajdacic-Gross et al., 2010; Christodoulou et al., 2012; White et al., 2015; Aguglia et al., 2016; Canner et al., 2018; Akkaya-Kalayci et al., 2017; Sawa et al., 2017; Dixon and Kalkstein, 2018; Hofstra et al., 2018; Rumble et al., 2018). In particular, Coimbra et al., (2016) confirmed the significant role of seasonality on suicide attempts and Galvão et al. (2018) showed that completed suicides occurred more frequently in spring and early summer in their survey on 2.146.418 completed suicides. However, mechanisms underlying the link between seasonality of suicidal behaviors are still unclear and need further investigation.

Therefore, recent studies focused on the possible role of other environmental factors involved in suicidal behaviors such as air pollution, photoperiod, daylight exposure and meteorological variables, with controversial results (Donagay et al., 2003; Toro et al., 2009; White et al., 2015; Makris et al., 2016; Akkaya-Kalayci et al., 2017; Casas et al., 2017; Jee et al., 2017; Min and Min, 2018; Seregi et al., 2017; Dixon and Kalkstein, 2018; Gao et al., 2019). In a vast clinical study investigating the relationship between suicide rates and economic and climate variables carried out in twenty-nine European countries, the authors reported that the climatic effect (cold climate) predicted suicides more strongly than economic variables. Furthermore, the authors showed that in Europe suicidality followed the climate/temperature cline which was from south to north-east (Fountoulakis et al., 2016a). Furthermore, several clinical studies indicated that suicide rate is also correlated to increased ambient temperature (Doganay et al., 2003; Toro et al., 2009; Likhvar et al., 2011; Grjibovski et al., 2013; Helama et al., 2013; Holopainen et al., 2014; Qi et al., 2014; Akkaya-Kalayci et al., 2017; Bando et al., 2017; Carleton, 2017; Dixon and Kalkstein, 2018; Gao et al., 2019). In fact, studies on the association between temperature and suicide showed that 26.6% − 60% of variation in suicides could be explained by temperature variations (Helama et al., 2013; Ishii et al., 2013; Fountoulakis et al., 2016b), but not with sunlight exposure, especially for completed suicide (Gao et al., 2019).

Moreover, evidence showed significant associations between hours of sunshine and completed suicide carried out through violent methods (Linkowski et al., 1992; Maes et al., 1993; Preti and Miotto, 1998; Wu et al., 2009; Vyssoki et al., 2012; Vyssoki et al., 2014; Ludwig and Dwivedi, 2018). These studies confirmed the hypothesis of higher lethality of suicidal behaviors during spring/summer, higher daylight exposure or exposure associated with increased ambient temperature. However, few studies investigated the relationship between seasonality and lethality of the suicidal attempts. Lin et al. (2008) showed that violent suicides are more likely to be influenced by seasonal factors, with significant peaks in March–May (early to late spring), than non-violent suicides. These findings were not confirmed by Veisani et al. (2017) who reported seasonal trends in spring and autumn of suicides by violent methods and spring and summer for what concerns non-violent suicides.

However, to the best of our knowledge, the possible influence of photoperiod and seasonality on the lethality of suicide attempts has not been investigated yet. Therefore, in this study we investigated (a) the potential role of seasonality on the lethality of suicide attempts in psychiatric inpatients; (b) the potential role of the photoperiod on high-lethality suicide attempts (cases) compared with low-lethality suicide attempts (controls) in a sample of psychiatric inpatients.

2. Materials and methods

2.1. Sample

Subjects were recruited at the Section of Psychiatry, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health (DINOGMI), IRCCS Ospedale Policlinico San Martino, University of Genoa (Italy). Participants were recruited in our inpatients service from 1st August 2013 to 31st July 2018. Subjects were considered for the study if their psychopathological conditions were deemed clinically stable as assessed by the two senior researchers, GS and MA.

Silverman's operative definition of “suicide attempt” has been used in this study, i.e. a kind of suicide—related behavior, classified as a suicidal act and characterized by self-inflicted, potentially injurious behavior with non-fatal outcome for which there is evidence—either explicit or implicit—of intent to die (Silverman et al., 2007). Moreover, our definition involves the presence of a lethal intent that can be of varying intensity but has to be present in the decision to carry out the suicidal act (Pompili et al., 2015).

Inclusion criteria were: (a) hospitalization in our emergency psychiatric ward for a suicide attempt; (b) aged more than 18 years old; (c) acceptance to participate in the study by signing a written informed consent after the aims of the study and study procedures were explained thoroughly. Exclusion criteria were: (a) pregnancy or having just given birth; (b) having a positive history of acute neurological injury, such as neurodegenerative illnesses, mental retardation, loss of consciousness related to the presence of severe neurological conditions; (c) the refusal or inability to provide a valid consent prior to participate in the study.

The study design was conducted in accordance with the guidelines provided in the current version of the Declaration of Helsinki. The study design was reviewed and approved by the local Ethical Review Board.

2.2. Assessments and procedures

Psychiatric diagnoses were formulated according to Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5) (American Psychiatric Association, 2013) and the subjects were divided into four diagnostic groups: schizophrenia-related disorders (referred to hereinafter as schizophrenia), bipolar and related disorders, depressive disorders and others (included personality disorders and substance-related disorders) according to previous studies (Aguglia et al., 2017, 2018). Clinical evaluations were carried out by expert clinicians and were carefully reviewed by a senior psychiatrist (with more than ten years of clinical experience in inpatients clinical setting). If patients had more than one diagnosis, the principal diagnosis was recorded.

Socio-demographic and clinical aspects of the subjects were investigated through the standardized clinical chart and lifetime computerized medical record used in our Psychiatric Unit. Age, gender, marital and occupational status, education level, previous suicide attempts, suicide method and pharmacological treatment at the moment of admission were recorded. All available information have been cross-referred. Furthermore, we considered month and season upon admittance in the psychiatric ward (i.e., Autumn from 21st September to 20th December, Winter from 21st December to 20th March, Spring from 21st March to 20th June, Summer from 21st June to 20th September). Hospitalization period was divided according to the sunlight exposure in spring–summer (s–s) (highest solar intensity period) and autumn–winter (a–w) (lowest solar intensity period), according to existing literature (Aguglia et al., 2017, 2018), defining “photoperiod” as the number of hours of day light and considering it as able to influence the individual's physiology and metabolic cycles.

In the wake of Schrijvers et al. (2012)'s conceptualization, we considered suicide as the final step of a multilayered process starting with suicidal ideation that progresses into planning and continues with the enacting of suicidal thoughts and plans by attempting suicide that may end up in completed suicides.

In the present study, we used Shneidman's (1996) and Joiner's (2007) definitions of lethality and divided our sample of suicide attempts into two groups according to the level of lethality:

(a) "high-lethality suicide attempt" (HLSA) for attempts that needed hospitalization for at least 24 h and either treatment in a specialized unit (including intensive care unit, hyperbaric unit, or burn unit), surgery under general anesthesia, or extensive medical treatment (beyond gastric lavage, activated charcoal, or routine neurological observations), including antidotes for drug overdoses, telemetry, or repeated tests or investigations;
(b) "low-lethality suicide attempts" (LLSA) that were attempts that did not meet these criteria (Beautrais, 2001; Miller et al., 2004; Chen et al., 2009; Horesh et al., 2012; Huang et al., 2014; Lee et al., 2014; Trakhtenbrot et al., 2016; Gvion and Levi-Belz, 2018).

HLSA (cases) were compared with LLSA (controls) in the second part of our analysis in order to better evaluate the differences between these groups.

2.3. Statistical analysis

Socio-demographic and clinical data were considered as mean and standard deviation (SD) for continuous variables and frequency and percentage regarding categorical variables. Kolmogorov-Smirnov test was used to confirm that the investigated variables had a normal distribution.

In order to analyze differences between cases and controls (HLSA vs LLSA), we used the Pearson χ^2 test with Yates correction for the comparison of categorical variables, and the *t*-test for independent samples for continuous variables. Comparative analyses on number of admissions were adjusted for age and gender. Furthermore, bivariate analyses were conducted.

All statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA) with statistical significance set at $p < .05$.

3. Results

Four hundred forty-seven ($N = 447$) subjects meeting our inclusion criteria were hospitalized after a suicide attempt in the study timeframe. Eleven subjects refused to take part in the survey and four subjects were not admitted to the psychiatric unit because of major physical comorbidities, e.g. cancers and advanced sarcoidosis. A final sample of 432 subjects was represented by formed, with a mean age of 49.1 (± 20.2). 77.1% of the sample was represented by females, 45.2% were single (of which 32% divorced and 68% never married), and 28% were employed at the time of enrollment. 32.9% of the sample had bipolar disorder, 8.6% schizophrenia and 33.8% major depressive disorder. Most of the subjects were taking poly-pharmacological treatments ($N = 377$, 87.3%) (Table 1).

One hundred thirty-three subjects ($N = 133$, 30.8%) of the sample committed a HLSA and two hundred ninety nine ($N = 299$, 69.2%) were in the LLSA group. The HLSA group peaked in the months with a higher sunlight exposure [Fig. 1]. Major differences between HLSA and LLSA were reported in June (18.0% vs 6.0%, respectively) and July (14.3% vs 5.7%, respectively) [Table 2].

Bivariate correlation analyses between seasonality/photoperiod in the whole sample and HLSA were positively associated with summer ($r = 0.143$; $p = .003$) and highest solar intensity period ($r = 0.204$; $p < .001$). Moreover, HLSA was negatively associated with autumn ($r = -0.096$; $p = .046$) and winter ($r = -0.151$; $p = .002$) [Table 3].

Table 1
Socio-demographic and clinical characteristics of the sample included.

	Suicide attempts ($N = 432$)
Gender (female), *N* (%)	333 (77.1)
Age (years), *mean ± SD*	49.1 ± 20.2
Education level, *mean ± SD*	11.2 ± 3.3
Marital status, *N* (%)	
Single	195 (45.2)
Married	93 (21.5)
Divorced	98 (22.7)
Widowed	46 (10.6)
Working status, *N* (%) Yes	121 (28.0)
Diagnosis, *N* (%)	
Bipolar and related disorders	142 (32.9)
Schizophrenia and related disorders	37 (8.6)
Depressive disorders	146 (33.8)
Others	107 (24.8)
Pharmacological treatment, *N* (%)	
Antipsychotics	252 (58.3)
Mood stabilizers	303 (70.1)
Antidepressants	165 (38.2)
Others	108 (25.0)
None	55 (12.7)
Type of suicide attempt, *N* (%)	
Drug intoxication	284 (65.7)
Defenestration	40 (9.3)
Drowning	1 (0.2)
Weapon	2 (0.3)
Stabbing	9 (2.1)
Burn/Gas/Caustic	26 (6.0)
Strangling	11 (2.5)
Cuts	59 (13.7)
Lethality of suicide attempts	
High lethality	133 (30.8)
Low lethality	299 (69.2)
Lifetime suicide attempts, *mean* ± SD	1.2 ± 1.1
Month of admissions, *N* (%)	
January	26 (6.0)
February	30 (6.9)
March	37 (8.6)
April	38 (8.8)
May	49 (11.3)
June	42 (9.7)
July	36 (8.3)
August	40 (9.3)
September	29 (6.7)
October	29 (6.7)
November	40 (9.3)
December	36 (8.3)
Seasonality, *N* (%)	
Autumn	101 (23.4)
Winter	88 (20.4)
Spring	131 (30.3)
Summer	112 (25.9)
Photoperiod, *N* (%)	
Spring–Summer	243 (56.2)
Autumn–Winter	189 (43.8)

4. Discussion

Our study shows that suicide attempts carried out in summer, when there is the highest solar intensity, were more likely to be highly lethal compared with those carried out in other periods of the year. June and July were the months in which highly lethal suicide attempts peaked when compared with low-lethality suicide attempts. Moreover, suicide attempts carried out in autumn were less likely to be highly lethal than in other photoperiods and seasons. Our sample showed a prevalence of major affective disorders and this may partly explain the particular trend in the lethality of suicide attempts that we reported because of the complex influence of daylight, circadian rhythms and seasons on affective disorders and suicide attempts. This is consistent with previous studies reporting more season- and circadian- related fluctuations of suicide rates among patients with mood disorders, in comparison to

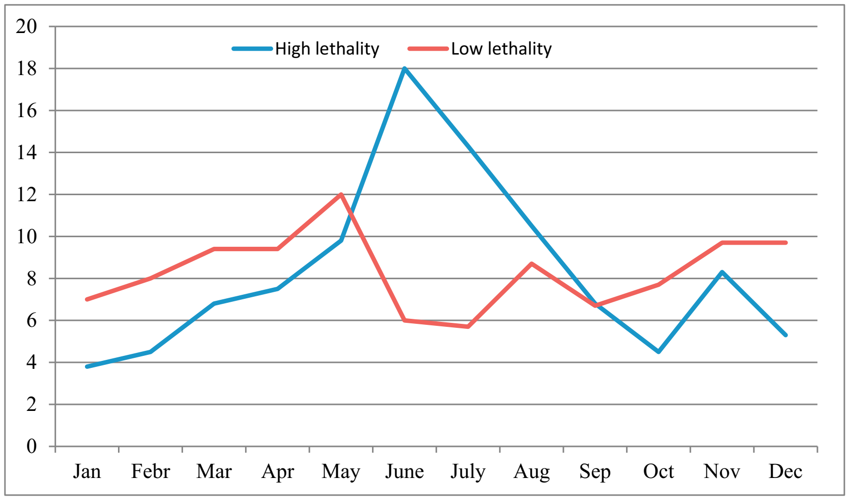

Fig. 1. Differences in terms of month admissions between high vs low lethality suicide attempts.

Table 2
Seasonality and photoperiod differences between high vs low lethality suicide attempts.

	High lethality (*N* = 133)	Low lethality (*N* = 299)	*t*/$\chi 2$	*df*	*p*
Seasonality, *N* (%)			19.516	3	< **0.001**
Spring	48 (36.1)	83 (27.8)			
Summer	47 (35.3)	65 (21.7)			
Autumn	23 (17.3)	78 (26.1)			
Winter	15 (11.3)	73 (24.4)			
Autumn, *N* (%)	23 (17.3)	78 (26.1)	3.974	1	**.046**
Winter, *N* (%)	15 (11.3)	73 (24.4)	9.793	1	**.002**
Spring, *N* (%)	48 (36.1)	83 (27.8)	3.024	1	.082
Summer, *N* (%)	47 (35.3)	65 (21.7)	8.865	1	**.003**
Photoperiod, *N* (%)			17.990	1	< **0.001**
Spring–Summer	95 (71.4)	148 (49.5)			
Autumn–Winter	38 (28.6)	151 (50.5)			

Table 3
Correlations between high lethality suicide attempts and environmental variables.

	Lethality of suicide attempt
Autumn	−0.096 (p = .046)
Winter	−151 (p = .002)
Spring	0.084 (p = .082)
Summer	0.143 (p = .003)
Longer photoperiod	0.204 (p < .001)

those with schizophrenia (Valtonen et al., 2006). Our findings confirm previous evidence showing that suicidal behaviors exhibit both circadian (van Houwelingen and Beersma, 2001; van Houwelingen et al., 2010) and seasonal rhythms (Germain and Kupfer, 2008). Both in attempted (Valtonen et al., 2006) and completed suicides (van Houwelingen and Beersma, 2001) time patterns were detected. In particular, our findings are consistent with previous evidence that reported the highest rate of completed suicides between May and July, when the period of daylight is always shorter for the a.m. hours than it is for the p.m. hours and this influences mechanisms that decode the duration of the melatonin signal in the melatonin-target tissues. Thus, increased sunlight exposure causes alterations in the metabolism of melatonin and serotonin (Brewerton et al., 2018; Maruani et al., 2018).

The reaction of the organism both to the stimulation of a longer period of light (as in spring and summer), and to the exposure of higher temperatures, may be implicated in the destabilization of the psychopathological framework, potentially favoring the increased rate of high lethality suicides detected. Regarding light effects, prolonged light exposure could dysregulate circadian rhythm causing sleep disruption. It is known that light exposure is the primary signal for the central clock in the suprachiasmatic nuclei (SCN) of the hypothalamus and suppresses melatonin synthesis by the pineal gland. The SCN influences the circadian rhythm of body temperature, as a key synchronizer of clocks in peripheral tissues (Potter et al., 2016; Maruani et al., 2018). The hypothalamus is anatomically connected with the thalamus and the limbic cortex, constituting a functional framework that links bodily sensations to emotional responses. In humans, the limbic cortex is in turn associated with the anterior portion of the insular cortex, processing convergent sensory information to produce an emotive correlation. Besides, areas of the insular cortex that are activated during recall of feelings are also activated during the conscious sensation of pain and temperature (Kandel et al., 2013). It is possible to hypothesize, therefore, a link between the perception of significant heat (from high temperatures) and an emotional correlation of discomfort, which can translate into behavioral anomalies in subjects at risk. Furthermore, patients with mood disorders are especially vulnerable to circadian dysregulation and sleep disruption, with an increased risk to the onset of mixed states (Muneer, 2017) and consequently to present dyscontrol of impulses and suicidal behaviors.

The photoperiod spring-summer, in which we reported the highest lethality in suicide attempts, is a particular period of the year from the circadian-clock point of view because of the challenge to alignment of the circadian rhythms with the sleep-wake cycle.

Interestingly, in-depth findings about the brain activity during this photoperiod are provided by studies on animals that showed how the very long day might challenge the network within the circadian pacemaker that is comprised of the evening and morning active cells, and that takes part in the seasonal adaptation in diurnal animals such as sheep and horses (Lincoln et al., 2003; Hazlerigg et al., 2004). When day lengths become shorter in fall and winter, the morning active cells dominate the circadian output, e.g. the sleep-wake behavior. However, this dominance is gradually transferred to the evening active cells as the days get longer in spring and the coincidence effect of the morning and evening active cells disappears when the melatonin signal duration becomes insufficient to sensitize adenylate cyclase and support a peak expression of the morning-active cells (Nagoshi et al., 2010). The speeding up of the evening active cells (e.g. by sunshine) makes the morning active cells higher firing rate in spring-summer photoperiod but not in fall-winter and this determines important melatonin-dependent effects on clock- gene expression in spring and autumn (CRY2 and PER2 genetic variants have been reported). The expression of CRY2 and

PER2 variants is regulated by the circadian pacemaker system also in human and has been associated with vulnerability for unipolar and bipolar depression (Lavebratt et al., 2010). Different clock genes have been associated with higher suicide risk in bipolar patients such as CLOCK gene that is associated with violent suicide attempts, thus possibly involving the lethality of the attempts but also TIMELESS, PER3 and ARNTL genes that are involved in the modulation of the course of bipolar illness, e.g. the recurrence and frequency of episodes which have a predictive value for suicide attempts (Pawlak et al., 2017).

Moreover, lower melatonin levels have been significantly associated with completed suicides in post- mortem studies (Kurtulus Dereli et al., 2018) and this may further support our findings of more lethal suicide attempts and lower levels of melatonin in spring – summer, when there are less hours of darkness during which melatonin is produced in pinealocytes. Interestingly, melatonin results from the n- acetylatylation of 5-HT via the catalyzation of enzymes aralkylamine n-acetyltransferase (AANAT) and acetylserotonin O-methyltransferase (ASMT) that are regulated by clock- genes. Therefore, both a decrease in 5-HT and increase in daylight impair melatonin synthesis (Tosini et al., 2012; Meng et al., 2018).

However, different hypotheses have been developed to shed light on the relationship between suicides and spring-summer photoperiod and one of these explains how the increase in temperatures experienced by the human body in spring and early summer would contribute to cerebral hyperactivity associated with symptoms such as anxiety potentially enhancing the risk of suicide (Vaughan et al., 2011; Helama et al., 2013; Holopainen et al., 2014; Gao et al., 2019). Moreover, further theories about the association between 5-HT dysfunctions and suicidal behaviors have been developed to explain the seasonal pattern of suicides worldwide. In particular, the disruption in the functioning of the 5-HT system links affective disorders, anxiety, seasonal admissions with mania and violence and/or impulsive behaviors like sexual abuse, aggression, homicide and obviously suicide (Marazziti et al., 2013; White et al., 2015; Brewerton et al., 2018).

Recently, the use of blue light hotspots in railway platforms to decrease the incidence of railway suicides has been investigated and contrasting evidence have been reported (Matsubayashi et al., 2013; Ichikawa et al., 2014; Matsubayashi et al., 2014). For instance, Matsubayashi et al. (2013) indicated that suicide deaths decreased significantly by 84% across the eleven Japanese stations where blue lights were installed. On the other hand Ichikawa et al. (2014) argued that blue lights may have much more limited potential as a suicide prevention strategy than previously suggested, as suicide attempts occurring where platform lights are installed and turned on only comprise a small number of the total rail-related attempts. However, current understandings of this existing, albeit small, effect of blue light hotspots on impulsivity and suicidal behaviors suggest that the stimulation of melanopsin retinal ganglion cells by blue light activates the retino-hypothalamic tract to the suprachiasmatic nuclei (SCN) that acts melatonin pathways (Matsubayashi et al., 2013; Matsubayashi et al., 2014). In particular, evidence showed that blue light in the range of 460–480 nm is more effective compared to monochromatic light of 555 nm in phase-shifting the human circadian clock, thus leading to decrease in heartbeat rates and promoting relaxation (Tosini et al., 2016).

Future research should focus on effective prevention strategies targeting the use of light dependent neuronal pathways to decrease suicide attempts and suicide rates. In particular, the use of blue light hotspots and melatonin oral supplementation programs in subjects with mood disorders during photoperiods at higher suicide risk should be further investigated.

4.1. Limitations

The present study should be considered in the light of the following limitations. First, patients' seasonal environment and psychological factors as well as the presence of acute life-events fostering the suicidal crisis have not been investigated. Second, our findings result only from one city and we could not evaluate the possible confounding effect of weather, humidity and other geographical variables co-existing with the photoperiod. Diagnoses were formulated by expert clinicians according to the DSM-5 but no structured interviews have been performed. Another limitation that should be taken into account is the lack of specific rating scales assessing the lethality of side effects. Since none of these is validated in Italian language, we preferred to rely upon Shneidman's and Joiner's definitions of lethality, although we acknowledge that the use of a specific instrument may provide with adjunctive relevant data. No data concerning the photoperiod, in which previous suicide attempts were carried out, have been collected. Moreover, data concerning the pharmacological treatment in spring-summer of patients with mood disorders were not collected. Therefore, we cannot evaluate the possible effect of autonomous treatment interruption in spring-summer on suicide attempts.

5. Conclusions

Despite the large body of evidence, further studies are needed to provide deeper understandings on the delicate molecular network that links suicide behaviors, seasonality and daylight in order to develop more effective prevention and treatment strategies in the future. Future research may lead to the development of specific medications targeting these molecular systems that may help both suicide prevention and recurrence of acute affective episodes.

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Conflict of interest

No conflict declared.

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Authors' contributions

Dr. Aguglia designed the study and wrote the first revision of paper, prof. Serafini and Dr. Salvi reviewed and edited the original draft, Dr. Solano and Dr. Giacomini managed the database and undertook the statistical analyses, Dr. Conigliaro and Dr. Romano collected the data, managed the literature searches, Dr. Mencacci significantly participated to the first revision of original article and revised the English language, Prof. Aguglia and Prof. Amore supervised the study design and search strategy. All authors contributed to and approved the final version of the manuscript.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jad.2018.12.094.

References

Aguglia, A., Moncalvo, M., Solia, F., Maina, G., 2016. Involuntary admissions in Italy: the impact of seasonality. Int. J. Psychiatry Clin. Pract. 20 (4), 232–238. http://doi:10.1080/13651501.2016.1214736.

Aguglia, A., Borsotti, A., Cuniberti, F., Serafini, G., Amore, M., Maina, G., 2017. The influence of sunlight exposure on hospitalization in emergency psychiatry. Chronobiol. Int. 34 (10), 1413–1422. http://doi:10.1080/07420528.2017.1374286.

Aguglia, A., Borsotti, A., Maina, G., 2018. Bipolar disorders: is there an influence of seasonality or photoperiod? Braz. J. Psychiatry. 40, 6–11. http://doi:10.1590/1516-4446-2016-2144.

Ajdacic-Gross, V., Bopp, M., Ring, M., Gutzwiller, F., Rossler, W., 2010. Seasonality in suicide – a review and search of new concepts for explaining the heterogeneous phenomena. Soc. Sci. Med. 71, 657–666. http://doi:10.1016/j.socscimed.2010.05.030.

Akkaya-Kalayci, T., Vyssoki, B., Winkler, D., Willeit, W., Kapusta, N.D., Dorffner, G., Özlü-Erkilic, Z., 2017. The effect of seasonal changes and climatic factors on suicide attempts of young people. BMC Psychiatry 17, 365. http://doi:10.1186/s12888-017-1532-7.

American Psychiatric Association, 2013. Diagnostic and Statistical Manual of Mental Disorders, fifth ed. American Psychiatric Publishing, Arlington (VA).

Ásgeirsdóttir, H.G., Valdimarsdóttir, U.A., Þorsteinsdóttir, P.K., Lund, S.H., Tomasson, G., Nyberg, U., Ásgeirsdóttir, T.L., Hauksdóttir, A., 2018. The association between different traumatic life events and suicidality. Eur. J. Psychotraumatol. 9 (1), 1510279. http://doi:10.1080/20008198.2018.1510279.

Bando, D.H., Teng, C.T., Volpe, F.M., de Masi, E., Pereira, L.A., Braga, A.L., 2017. Suicide and meteorological factors in Sao Paulo, Brazil, 1996-2011: a time series analysis. Braz. J. Psychiatry. 39, 220–227. http://doi:10.1590/1516-4446-2016-2057.

Batty, G.D., Gale, C.R., Tanji, F., Gunnell, D., Klvimaki, M., Tsuji, I., Jokela, M., 2018. Personality traits and risk of suicide mortality: findings from a multi-cohort study in the general population. World Psychiatry 17 (3), 371–372. http://doi:10.1002/wps.20575.

Beautrais, A.L., 2001. Suicides and serious suicide attempts: two populations or one? Psychol. Med 31 (5), 837–845.

Brewerton, T.D., Putnam, K.T., Lewine, R.R.J., Risch, S.C., 2018. Seasonality of cerebrospinal fluid monoamine metabolite concentrations and their associations with meteorological variables in humans. J. Psychiatr. Res. 99, 76–82. http://doi:10.1016/j.jpsychires.2018.01.004.

Canner, J.K., Giuliano, K., Selvarajah, S., Hammond, E.R., Schneider, E.B., 2018. Emergency department visits for attempted suicide and self-harm in the USA: 2006–2013. Epidemiol. Psychiatr. Sci. 27 (1), 94–102. http://doi:10.1017/S2045796016000871.

Carleton, T.A., 2017. Crop-damaging temperatures increase suicide rates in India. Proc. Natl. Acad. Sci. USA. 114 (33), 8746–8751. http://doi/10.1073/pnas.1701354114.

Casas, L., Cox, B., Bauwelinck, M., Nemery, B., Deboosere, P., Nawrot, T.S., 2017. Does air pollution trigger suicide? A case-crossover analysis of suicide deaths over the life span. Eur. J. Epidemiol. 32 (11), 973–981. 232. http://doi:10.1007/s10654-017-0273-8.

Chen, V.C., Cheng, A.T., Tan, H.K., Chen, C.Y., Chen, T.H., Stewart, R., et al., 2009. A community-based study of case fatality proportion among those who carry out suicide acts. Soc. Psychiatry Psychiatr. Epidemiol. 44, 1005–1011. http://doi:10.1007/s00127-009-0021-9.

Christodoulou, C., Douzenis, A., Papadopoulos, F.C., Papadopoulou, A., Bouras, G., Gournellis, R., Lykouras, L., 2012. Suicide and seasonality. Acta. Psychiatr. Scand. 125, 127–146. http://doi:10.1111/j.1600-0447.2011.01750.x.

Coimbra, D.G., Pereira, E, Silva, A.C., de Sousa-Rodrigues, C.F., Barbosa, F.T., de Siqueira Figueredo, D., Araùjo Santos, J.L., Barbosa, M.R., de Medeiros Alves, M., Nardi, A.E., de Andrade, T.G., 2016. Do suicide attempts occur more frequently in the spring too? A systematic review and rhythmic analysis. J. Affect. Disord. 196, 125–137. http://doi:10.1016/j.jad.2016.02.036.

Costa Lda, S., Alencar, A.P., Nascimento Neto, P.J., dos Santos Mdo, S., da Silva, C.G., Pinheiro Sde, F., Silveira, R.T., Bianco, B.A., Pinheiro Jr., R.F., de Lima, M.A., Reis, A.O., Rolim Neto, M.L., 2015. Risk factors for suicide in bipolar disorder: a systematic review. J. Affect. Disord. 170, 237–254. http://doi:10.1016/j.jad.2014.09.003.

Daray, F.M., Mann, J.J., Sublette, M.E., 2018. How lipids may affect risk for suicidal behavior. J. Psychiatr. Res. 104, 16–23. http://doi:10.1016/j.jpsychires.2018.06.007.

DeShong, H.L., Tucker, R.P., O'Keefe, V.M., Mullins-Sweatt, S.N., Wingate, L.R., 2015. Five factor model traits as a predictor of suicide ideation and interpersonal suicide risk in a college sample. Psychiatry Res. 226 (1), 217–223. http://doi:10.1016/j.psychres.2015.01.002.

Dixon, P.G., Kalkstein, A.J., 2018. Where are weather-suicide associations valid? An examination of nine US counties with varying seasonality. Int. J. Biometeorol. 62 (5), 685–697. 232. http://doi:10.1007/s00484-016-1265-1.

Doganay, Z., Sunter, A.T., Guz, H., Ozkan, A., Altintop, L., Kati, C., Colak, E., Aygun, D., Guven, H., 2003. Climatic and diurnal variation in suicide attempts in the ED. Am. J. Emerg. Med. 21, 271–275.

Fond, G., Faugere, M., Faget-Agius, C., Cermolacce, M., Richieri, R., Boyer, L., Lancon, C., 2018. Hypovitaminosis D is associated with negative symptoms, suicide risk, agoraphobia, impaired functional remission, and antidepressant consumption in schizophrenia. Eur. Arch. Psychiatry Clin. Neurosci [Epub ahead of print]. http://doi:10.1007/s00406-018-0932-0.

Fountoulakis, K.N., Chatzikosta, I., Pastiadis, K., Zanis, P., Kawohl, W., Kerkhof, A.J., et al., 2016a. Relationship of suicide rates with climate and economic variables in Europe during 2000–2012. Ann. Gen. Psychiatry 15 (1), 19. http://doi:10.1186/s12991-016-0106-2.

Fountoulakis, K.N., Savopoulos, C., Zannis, P., Apostolopoulou, M., Fountoukidis, I., Kakaletsis, N., Kanellos, I., Dimellis, D., Hyphantis, T., Tsikerdekis, A., Pompili, M., Hatzitolios, A.L., 2016b. Climate change but not unemployment explains the changing suicidality in Thessaloniki Greece (2000–2012). J. Affect. Disord. 193, 331–338. http://doi:10.1016/j.jad.2016.01.008.

Galvão, P.V.M., Silva, H.R.S.E., Silva, C.M.F.P.D., 2018. Temporal distribution of suicide mortality: a systematic review. J. Affect. Disord. 228, 132–142. http://doi:10.1016/j.jad.2017.12.008.

Gao, J., Cheng, Q., Duan, J., Xu, Z., Bai, L., Zhang, Y., Zhang, H., Wang, S., Zhang, Z., Su, H., 2019. Ambient temperature, sunlight duration, and suicide: a systematic review and meta-analysis. Sci. Total. Environ. 646, 1021–1029. http://doi:10.1016/j.scitotenv.2018.07.098.

Germain, A., Kupfer, D.J., 2008. Circadian rhythm disturbances in depression. Hum. Psychopharmacol. 23, 571–585. http://doi:10.1002/hup.964.

Grjibovski, A.M., Kozhakhmetova, G., Kosbayeva, A., Menne, B., 2013. Associations between air temperature and daily suicide counts in Astana, Kazakhstan. Medicina (Kaunas) 49 (8), 379–385.

Gvion, Y., Levi-Belz, Y., 2018. Serious suicide attempts: systematic review of psychological risk factors. Front. Psychiatry 9, 56. http://doi:10.3389/fpsyt.2018.00056.

Hakko, H., Rasanen, P., Tiihonen, J., 1998. Seasonal variation in suicide occurrence in Finland. Acta. Psychiatr. Scand. 98 (2), 92–97.

Hawton, K., van Heeringen, K., 2009. Suicide. Lancet 373, 1372–1381. http://doi:10.1016/S0140-6736(09)60372-X.

Hazlerigg, D.G., Andersson, H., Johnston, J.D., Lincoln, G., 2004. Molecular characterization of the long-day response in the Soay sheep, a seasonal mammal. Curr. Biol. 14 (4), 334–339.

Helama, S., Holopainen, J., Partonen, T., 2013. Temperature-associated suicide mortality: contrasting roles of climatic warming and the suicide prevention program in Finland. Environ. Health. Prev. Med. 18 (5), 349–355. http://doi.org/10.1007/s12199-013-0329-7.

Hofstra, E., Elfeddali, I., Bakker, M., de Jong, J.J., van Nieuwenhuizen, C., van der Feltz-Cornelis, C.M., 2018. Springtime peaks and christmas troughs: a national longitudinal population-based study into suicide incidence time trends in the Netherlands. Front. Psychiatry 9, 45. http://doi:10.3389/fpsyt.2018.00045.

Holopainen, J., Helama, S., Partonen, T., 2014. Does diurnal temperature range influence seasonal suicide mortality? Assessment of daily data of the Helsinki metropolitan area from 1973 to 2010. Int. J. Biometeorol. 58 (6), 1039–1045. http://doi:10.1007/s00484-013-0689-0.

Horesh, N., Levi-Belz, Y., Apter, A., 2012. Medically serious versus non-serious suicide attempts: relationships of lethality and intent to clinical and interpersonal characteristics. J. Affect. Disord. 136, 286–293. http://doi:10.1016/j.jad.2011.11.035.

Huang, Y.C., Wu, Y.W., Chen, C.K., Wang, L.J., 2014. Methods of suicide predict the risks and method switching of subsequent suicide attempts: a community cohort study in Taiwan. Neuropsychiatr. Dis. Treat. 10, 711–718. http://doi:10.2147/NDT.S61965.

Ichikawa, M., Inada, H., Kumeji, M., 2014. Reconsidering the effects of blue-light installation for prevention of railway suicides. J. Affect. Disord. 152–154, 183–185. http://doi:10.1016/j.jad.2013.09.006.

Ishii, N., Terao, T., Araki, Y., Kohno, K., Mizokami, Y., Arasaki, M., Iwata, N., 2013. Risk factors for suicide in Japan: a model of predicting suicide in 2008 by risk factors of 2007. J. Affect. Disord. 147 (1-3), 352–354. http://doi:10.1016/jad.2012.11.038.

Jee, H.J., Cho, C.H., Lee, Y.J., Choi, N., An, H., Lee, H.J., 2017. Solar radiation increases suicide rate after adjusting for other climate factors in South Korea. Acta. Psychiatr. Scand. 135 (3), 219–227. http://doi:10.1111/acps.12676.

Joiner, T., 2007. Why People Die By Suicide. Harvard University Press, Cambridge, MA, pp. 37.

Kandel, E.R., Schwartz, J.H., Jessell, T.M., Siegelbaum, S.A., Hudspeth, A.J., 2013. Principles of Neural Science, fifth ed. Mc Graw Hill Medical.

Kuo, C.J., Chen, W.Y., Tsai, S.Y., Chen, P.H., Ko, K.T., Chen, C.C., 2018. Excessive mortality and causes of death among patients with personality disorder with comorbid psychiatric disorders. Soc. Psychiatry Psychiatr. Epidemiol [Epub ahead of print]. http://doi:10.1007/s00127-018-1587-x.

Kurtulus Dereli, A., Demırci, G.N., Dodurga, Y., Özbal, S., Cankurt, U., Boz, B., Adiguzel, E., Acar, K., 2018. Evaluation of human pineal gland acetylserotonin O-methyltransferase immunoreactivity in suicide: a preliminary study. Med. Sci. Law. 58(4), 233–238. http://doi:10.1177/0025802418797178.

Lavebratt, C., Sjoholm, L.K., Partonen, T., Schalling, M., Forsell, Y., 2010. PER2 variation is associated with depression vulnerability. Am. J. Med. Genet. B Neuropsychiatr. Genet. 153B (2), 570–581. http://doi:10.1002/ajmg.b.31021.

Lee, C.Y., Wu, Y.W., Chen, C.K., Wang, L.J., 2014. The rate of fatality and demographic characteristics associated with various suicide methods: a community-based study in Northern Taiwan. Crisis 35, 245–252. http://doi:10.1027/0227-5910/a000266.

Lee, H., Myung, W., Lee, C., Choi, J., Kim, H., Carroll, B.J., Kim, D.K., 2018. Clinical epidemiology of long-term suicide risk in a nationwide population-based cohort study in South Korea. J. Psychiatr. Res. 100, 47–55. http://doi:10.1016/j.jpsychires.2018.01.018.

Likhvar, V., Honda, Y., Ono, M., 2011. Relation between temperature and suicide mortality in Japan in the presence of other confounding factors using time-series analysis with a semiparametric approach. Environ. Health. Prev. Med. 16 (1), 36–43. http://doi:10.1007/s12199-010-0163-0.

Lin, H.C., Chen, C.S., Xirasagar, S., Lee, H.C., 2008. Seasonality and climatic associations with violent and nonviolent suicide: a population-based study. Neuropsychobiology 57, 32–37. http://doi:10.1159/000129664.

Lincoln, G.A., Andersson, H., Hazlerigg, D., 2003. Clock genes and the long-term regulation of prolactin secretion: evidence for a photoperiod/circannual timer in the pars tuberalis. J. Neuroendocrinol. 15 (4), 390–397.

Linkowski, P., Martin, F., De Maertelaer, V., 1992. Effect of some climatic factors on violent and non-violent suicides in Belgium. J. Affect. Disord. 25, 161–166.

Ludwig, B., Dwivedi, Y., 2018. The concept of violent suicide, its underlying trait and neurobiology: a critical perspective. Eur. Neuropsychopharmacol. 28 (2), 243–251. http://doi:10.1016/j.euroneuro.2017.12.001.

Maes, M., Cosyns, P., Meltzer, H.Y., De Meyer, F., Peeters, D., 1993. Seasonality in violent suicide but not in nonviolent suicide or homicide. Am. J. Psychiatry 150 (9), 1380–1385.

Makris, G.D., Reutfors, J., Larsson, R., Isacsson, G., Ösby, U., Ekbom, A., Ekselius, L.,

Papadopou, F.C., 2016. Serotonergic medication enhances the association between suicide and sunshine. J. Affect. Disord. 189, 276–281. http://doi:10.1016/j.jad.2015.09.056.
Marazziti, D., Baroni, S., Pirone, A., Giannaccini, G., Betti, L., Testa, G., Schmid, L., Palego, L., Borsini, F., Bordi, F., Piano, I., Gargini, C., Castagna, M., Catena-Dell'Osso, M., Lucacchini, A., 2013. Serotonin receptor of type 6 (5-HT_6) in human prefrontal cortex and hippocampus post-mortem: an immunohistochemical and immunofluorescence study. Neurochem. Int. 62 (2), 182–188. http://doi:10.1016/j.neuint.2012.11.013.
Maruani, J., Anderson, G., Lejoyeux, B.E.M., Bellivier, F., Geoffroy, P.A., 2018. The neurobiology of adaptation to seasons: relevance and correlations in bipolar disorders. Chronobiol. Int. 35 (10), 1335–1353. http://doi:10.1080/07420528.2018.1487975.
Matsubayashi, T., Sawada, Y., Ueda, M., 2013. Does the installation of blue lights on train platforms prevent suicide? A before-and-after observational study from Japan. J. Affect. Disord. 147 (1–3), 385–388. http://doi:10.1016/j.jad.2012.08.018.
Matsubayashi, T., Sawada, Y., Ueda, M., 2014. Does the installation of blue lights on train platforms shift suicide to another station?: Evidence from Japan. J. Affect. Disord. 169, 57–60. https://doi:10.1016/j.jad.2014.07.036.
Meng, D., Li, H.Q., Deisseroth, K., Leutgeb, S., Spitzer, N.C., 2018. Neuronal activity regulates neurotransmitter switching in the adult brain following light-induced stress. Proc. Natl. Acad. Sci. USA 115 (20), 5064–5071. http://doi:10.1073/pnas.1801598115.
Miller, M., Azrael, D., Hemenway, D., 2004. The epidemiology of case fatality rates for suicide in the north-east. Ann. Emerg. Med. 43, 723–730.
Min, J.Y., Min, K.B., 2018. Outdoor light at night and the prevalence of depressive symptoms and suicidal behaviors: a cross- sectional study in a nationally representative sample of Korean adults. J. Affect. Disord. 227, 199–205. http://doi.10.1016/j.jad.2017.10.039.
Muneer, A., 2017. Mixed states in bipolar disorder: etiology, pathogenesis and treatment. Chonnam. Med. J. 53, 1–13. http://doi:10.4068/cmj.2017.53.1.1.
Nagoshi, E., Sugino, K., Kula, E., Okazaki, E., Tachibana, T., Nelson, S., Rosbash, M., 2010. Dissecting differential gene expression within the circadian neuronal circuit of Drosophila. Nat. Neurosci. 13 (1), 60–68. http://doi:10.1038/nn.2451.
O'Neill, S., McLafferty, M., Ennis, E., Lapsley, C., Bjourson, T., Armour, C., Murphy, S., Bunting, B., Murray, E., 2018,. Socio-demographic, mental health and childhood adversity risk factors for self-harm and suicidal behaviour in College students in Northern Ireland. J. Affect. Disord. 239, 58–65. http://doi:10.1016/j.jad.2018.06.006.
Pawlak, J., Szczepankiewicz, A., Kapelski, P., Rajewska-Rager, A., Slopien, A., Skibinska, M., Czerski, P., Hauser, J., Dmitrzak-Weglarz, M., 2017. Suicidal behavior in the context of disrupted rhythmicity in bipolar disorder-complementary research of clock genes with suicide risks factors and course of disease. Psychiatry Res. 257, 446–449. http://doi:10.1016/j.psychres.2017.07.057.
Peng, R., Dai, W., Li, Y., 2018. Low serum free thyroxine level is correlated with lipid profile in depressive patients with suicide attempt. Psychiatry Res. 266, 111–115. http://doi:10.1016/j.psychres.2018.05.059.
Pompili, M., Goracci, A., Giordano, G., Erbuto, D., Girardi, P., Klonsky, E.D., Baldessarini, R.J., 2015. Relationship of non-suicidal self-injury and suicide attempt: a psychopathological perspective. J. Psychopathol. 21, 348–353.
Pompili, M., Longo, L., Dominici, G., Serafini, G., Lamis, D.A., Sarris, J., Amore, M., Girardi, P., 2017. Polyunsaturated fatty acids and suicide risk in mood disorders: a systematic review. Prog. Neuropsychopharmacol. Biol. Psychiatry 74, 43–56. http://doi:10.1016/j.pnpbp.2016.11.007.
Potter, D.M., Skene, D.J., Arendt, J., Cade, J.E., Grant, P.J., Hardie, L.J., 2016. Circadian rhythm and sleep disruption: causes, metabolic consequences, and countermeasures. Endocr. Rev. 37 (6), 584–608.
Preti, A., Miotto, P., 1998. Seasonality in suicides: the influence of suicide method, gender and age on suicide distribution in Italy. Psychiatry Res. 81, 219–231.
Qi, X., Hu, W., Mengersen, K., Tong, S., 2014. Socio-environmental drivers and suicide in Australia: Bayesian spatial analysis. BMC Public Health. 14, 681. http://doi:10.1186/1471-2458-14-681.
Rumble, M.E., Dickson, D., McCall, W.V., Krystal, A.D.K., Case, D., Rosenquist, P.B., Benca, R.M., 2018. The relationship of person-specific eveningness chronotype, greater seasonality, and less rhythmicity to suicidal behavior: a literature review. J. Affect. Disord. 227, 721–730. https://doi:10.1016/j.jad.2017.11.078.
Sawa, M., Koishikawa, H., Osaki, Y., 2017. Risk factors of a suicide reattempt by seasonality and the method of a previous suicide attempt: a cohort study in a Japanese Primary Care Hospital. Suicide Life Threat. Behav. 47 (6), 688–695. http://doi:10.1111/sltb.12326.
Schrijvers, D.L., Bollen, J., Sabbe, B.G., 2012. The gender paradox in suicidal behavior and its impact on the suicidal process. J. Affect. Disord. 138, 19–26. https://doi:10.1016/j.jad.2011.03.050.
Serafini, G., Adavastro, G., Canepa, G., Capobianco, L., Conigliaro, C., Pittaluga, F., Murri, M.B., Valchera, A., De Berardis, D., Pompili, M., Lindqvist, D., Brundin, L., Amore, M., 2017. Abnormalities in Kynurenine pathway metabolism in treatment-resistant depression and suicidality: a systematic review. CNS Neurol. Disord. Drug Targets 16 (4), 440–453. http://doi:10.2174/1871527316666170413110605.
Seregi, B., Kapitány, B., Maróti-Agóts, Á., Rihmer, Z., Gonda, X., Döme, P., 2017. Weak associations between the daily number of suicide cases and amount of daily sunlight. Prog. Neuropsychopharmacol. Biol. Psychiatry 73, 41–48. http://doi:10.1016/j.pnpbp.2016.10.003.
Shneidman, E.S., 1996. The Suicidal Mind. Oxford University Press, NewYork, NY, pp. 133.
Silverman, M.M., Berman, A.L., Sanddal, N.D., O'Carroll, P.W., Joiner, T.E., 2007. Rebuilding the tower of Babel: a revised nomenclature for the study of suicide and suicidal behaviors. Part 1: background, rationale, and methodology. Suicide Life Threat. Behav. 37 (3), 248–263.
Sun, J., Guo, X., Ma, J., Zhang, J., Jia, C., Xu, A., 2011. Seasonality of suicide in Shandong China, 1991–2009: associations with gender, age, area and methods of suicide. J. Affect. Disord. 135 (1–3), 258–266. http://doi:10.1016/j.jad.2011.08.008.
Tosini, G., Ye, K., Iuvone, P.M., 2012. N-acetylserotonin: neuroprotection, neurogenesis, and the sleepy brain. Neuroscientist 18 (6), 645–653. http://doi:10.1177/1073858412446634.
Tosini, G., Ferguson, I., Tsubota, K., 2016. Effects of blue light on the circadian system and eye physiology. Mol. Vis. 22, 61–72.
Toro, K., Dunay, G., Bartholy, J., Pongracz, R., Kis, Z., Keller, E., 2009. Relationship between suicidal cases and meteorological conditions. J. Forensic Leg. Med. 16 (5), 277–279. http://doi:10.1016/j.jflm.2008.12.015.
Trakhtenbrot, R., Gvion, Y., Levi-Belz, Y., Horesh, N., Fischel, T., Weiser, M., et al., 2016. Predictive value of psychological characteristics and suicide history on medical lethality of suicide attempts: a follow-up study of hospitalized patients. J. Affect. Disord. 199, 73–80. http://doi:10.1016/j.jad.2016.03.054.
Valtonen, H., Suominen, K., Partonen, T., Ostamo, A., Lönnqvist, J., 2006. Time patterns of attempted suicide. J. Affect. Disord. 90, 201–207.
Van Houwelingen, C.A., Beersma, D.G., 2001. Seasonal changes in 24-h patterns of suicide rates: a study on train suicides in the Netherlands. J. Affect. Disord. 66, 215–223.
Van Houwelingen, C.A., Kerkhof, A.J., Beersma, D.G., 2010. Train suicides in the Netherlands. J. Affect. Disord. 127, 281–286. http://doi:10.1016/j.jad.2010.06.005.
Vaughan, C.H., Shrestha, Y.B., Bartness, T.J., 2011. Characterization of a novel melanocortin receptor-containing node in the SNS outflow circuitry to brown adipose tissue involved in thermogenesis. Brain Res. 1411, 17–27. http://doi:10.1016/j.brainres.2011.07.003.
Veisani, Y., Delpisheh, A., Sayehmiri, K., Moradi, G., Hassanzadeh, J., 2017. Seasonality in violent and nonviolent methods of suicide attempts: a cross-sectional study on systematic registry data. Acta Med. Iran 55 (8), 507–513.
Veisani, Y., Delpisheh, A., Sayehmiri, K., Moradi, G., Hassanzadeh, J., 2018. Trends of suicide attempts and completed suicide in Ilam Province of Iran; a demographic analysis study. Bull. Emerg. Trauma 6 (3), 245–248. http://doi:10.29252/beat-0603010.
Vyssoki, B., Praschak-Rieder, N., Sonneck, G., Blüml, V., Willeit, M., Kasper, S., Kapusta, N.D., 2012. Effects of sunshine on suicide rates. Compr. Psychiatry 53 (5), 535–539. http://doi:10.1016/j.comppsych.2011.06.003.
Vyssoki, B., Kapusta, N.D., Praschak-Rieder, N., Dorffner, G., Willeit, M., 2014. Direct effect of sunshine on suicide. JAMA Psychiatry 71, 1231–1237. http://doi:10.1001/jamapsychiatry.2014.1198.
World Health Statistics, 2017. Monitoring health for the SDGs. http://apps.who.int/gho/data/node.sdg.3-4-viz-2?lang=en.
White, R.A., Azrael, D., Papadopoulos, F.C., Lambert, G.W., Miller, M., 2015. Does suicide have a stronger association with seasonality than sunlight? BMJ Open 5, e007403. http://doi:10.1136/bmjopen-2014-007403.
Woo, J.M., Okusaga, O., Postolache, T.T., 2012. Seasonality of suicidal behavior. Int. J. Environ. Res. Public. Health 9 (2), 531–547. http://doi:10.3390/ijerph9020531.