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Research report

Seasonal spring peaks of suicide in victims with and without prior history of hospitalization for mood disorders

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ABSTRACT

Background: Seasonal spring peaks of suicide are highly replicated, but their origin is poorly understood. As the peak of suicide in spring could be a consequence of decompensation of mood disorders in spring, we hypothesized that prior history of mood disorders is predictively associated with suicide in spring.
Methods: We analyzed the monthly rates of suicide based upon all 37,987 suicide cases in the Danish Cause of Death Registry from 1970 to 2001. History of mood disorder was obtained from the Danish Psychiatric Central Register and socioeconomical data from the Integrated Database for Labour Market Research. The monthly rate ratio of suicide relative to December was estimated using a Poisson regression. Seasonality of suicide between individuals with versus without hospitalization for mood disorders was compared using conditional logistic regression analyses with adjustment for income, marital status, place of residence, and method of suicide.
Results: A statistically significant spring peak in suicide was observed in both groups. A history of mood disorders was associated with an increased risk of suicide in spring (for males: RR = 1.18, 95% CI 1.07–1.31; for females: RR = 1.20, 95% CI 1.10–1.32).
Limitations: History of axis II disorders was not analyzed. Danish socioeconomical realities have only limited generalizability.
Conclusions: The results support the need to further investigate if exacerbation of mood disorders in spring triggers seasonal peaks of suicide. Identifying triggers for seasonal spring peaks in suicide may lead to uncovering novel risk factors and therapeutic targets for suicide prevention.

APRIL is the cruelest month, breeding
Lilacs out of the dead land, mixing
Memory and desire, stirring
Dull roots with spring rain.

T.S Eliot The burial of the dead. The Wasteland 1922

1. Introduction

Suicide is a major public health problem throughout the world, taking approximately one million lives every year worldwide (WHO, 2009; Mann, 2003). An intriguing and highly-replicated epidemiological feature of suicide is its seasonal spring peak (Lester and Frank, 1990; Maes et al., 1993a; Chew and McCleary, 1995; Hakko et al., 1998; Lester, 2001; Petridou et al., 2002) with a temporal mirror image in the Southern Hemisphere (Cantor et al., 2000; Rock et al., 2003). At the same time, a peak in spring has also been reported for exacerbation of mood disorder, as manifested in hospital admissions, mood disorder severity, electroconvulsive therapy (ECT) use, and worsening of depression scores (Zung and Green, 1974; Eastwood and Peacocke,

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1976; Eastwood and Stiasny, 1978; Frangos et al., 1980; Fossey and Shapiro, 1992; Morken et al., 2002; Maes et al., 1993b; Goodwin and Jamison, 2007). The association between spring peaks in suicide and spring peaks in exacerbation of mood disorders is conducive to a hypothesis that the spring peak in suicide is driven by a seasonal decompensation of mood disorders in spring. If so, one would expect a greater suicide peak in spring among individuals with a history of hospitalization for mood disorders. To our knowledge, only one previous study on a limited sample of 115 suicides has explored the pattern of seasonality of suicide in victims with versus without history of hospitalization for mood disorders, finding a spring/summer peak only in individuals with hospitalization for mood disorders (Kim et al., 2004). In our study, using the data covering the entire national population in Denmark over a 32-year period, we plan to estimate seasonality of suicide in those with versus those without history of hospitalization for mood disorders. As we theorize that an environmental factor is responsible for precipitation or exacerbation of mood disorders in spring which trigger suicide in vulnerable individuals, we expected to find an increased relative risk of suicide in spring among those with history of hospitalization for mood disorders compared to those without such a history. Previous research on seasonality of suicide has found gender differences, specifically a higher seasonality of suicide in males than in females (Micciolo et al., 1989; Preti, 1997) and the existence of a secondary peak in the fall in females (Hakko et al., 1998; Micciolo et al., 1989; Meares et al., 1981; Lester and Frank, 1988). In addition, there are significant interactions between gender and deliberate self-harm methods (Hawton et al., 2008) and between seasons and deliberate self-harm (with a greater seasonality in parasuicides in females: Barker et al., 1994). Due to interactions between gender and seasonality of suicide and suicidality, we also aimed to analyze the interaction between prior history of mood disorder, gender, and the amplitude of the seasonal peaks of suicide.

2. Method

2.1. Data sources

Data for the present study were retrieved from four Danish national longitudinal registers. The first was the Cause of Death Register which has recorded causes and dates of all deaths in Denmark since 1970. The second register was the Danish Psychiatric Central Register. This register covers all psychiatric inpatient facilities in Denmark and cumulatively records all admission and discharge information, such as dates and main and auxiliary diagnoses. Diagnoses of illnesses and causes of death in these two medical registries were coded according to the 8th edition of the International Classification of Diseases (ICD-8) until the end of 1993 and, thereafter, according to the 10th edition (ICD-10). The third register was the Integrated Database for Labour Market Research (IDA database) which contains yearly socioeconomic information such as employment, income, marital status, place of residence, etc., for all national residents in Denmark since 1980. Personal data is completed for individuals residing in Denmark on the 31st of December of the calendar year. The last register was the Danish Civil Registration System (CRS) which contains a personal identifier, designated as the CPR-number, for all individuals residing in Denmark. The CPR-number is used in all nationwide registers and can be logically checked for errors. It was therefore the key for the retrieval and merging of individual data from the different register databases in this study.

2.2. Subjects, variables, and statistical methods

Our primary study cases were composed of all definite suicides (codes E950-959 in ICD-8 and X60-84 in ICD-10) recorded in the Cause of Death Register from the years 1970 through 2001. From this register and the CPR-number, we obtained the date of death and the method of suicide for all suicide victims. We categorized the date of suicide according to the 12 months of the year, and also into the time windows of the approximated four seasons, defined as winter (January–March), spring (April–June), summer (July–September), and fall (October–December). Method of suicide was also grouped into two categories delineated as nonviolent and violent methods.

We then obtained information about personal history of hospitalization for mood disorders from the Danish Psychiatric Central Register. We defined a positive history for a subject if the person had been admitted for hospital treatment because of a mood disorder since 1969 (when the first computerized data became available) until the time of suicide. Major mood disorder codes included manic-depressive illness (for ICD-8: 296.1, 296.2, 296.3, 298.1 and for ICD-10: F30, F31) and unipolar depression (for ICD-8: 300.4, 300.5, 296.0, 298.0 and for ICD-10: F32, F33).

For cases that occurred during 1981 to 1997, the only time during which complete data was available, we were able to obtain socioeconomic data from the IDA database for the year preceding the year in which the suicide took place. The examined variables included marital status (single or cohabitating versus married), annual gross income (by quartile according to the annual 5-year age-specific distribution in the general population), and place of residence (the capital, suburb of the capital, provincial city with more than 100,000 inhabitants, or provincial town with more than 10,000 inhabitants versus rural areas). We chose these variables for data adjustment because they are highly associated with suicide in Denmark (Qin et al., 2003).

We constructed contingency tables for the study variables and computed the rate ratio of suicide across months and seasons using procedures available in SAS version 8.

We first calculated rate ratio of suicide in each month based upon all 37,987 suicides over the 32-year period, according to history of hospitalization for mood disorders and by using the rate in December as the reference (see Fig. 1 and Table 1). The rate ratio and 95% confidence intervals were obtained with Poisson regression analysis, where the logarithm of the expected number of suicides in each month was regressed on the logarithm of actual days in each period assuming the national population over a calendar year remained constant. Using a similar statistical technique, we then estimated the rate ratio of suicide, separately for men and women, for the approximated seasons of spring, summer, and fall and compared each with the reference season of winter (see Table 1). To further examine the seasonal differences by history of mood disorder and to control for potentially confounding effects of personal socioeconomic factors and method of suicide, we used suicide victims with a history of hospitalization for mood disorders as cases and

victims without such a history as comparison controls and then computed the relative risk ratio of suicide in relation to seasonality (see Table 2). Study subjects were restricted to the 21,169 suicides who, from 1981 to 1997, were residing in Denmark on the 31st of December before the year of death. We analyzed the data with conditional logistic regression with a stratum by calendar year, first using crude analysis and later adjusting for income, marriage, place of residence, and method of suicide. Based on the adjusted model and cases of both men and women, we tested gender differences of seasonal variance of suicide by history of hospitalization for mood disorders using the likelihood ratio test.

In addition, we also performed analyses examining seasonal differences by method of suicide; however, we did not observe statistically significant differences between violent suicides and nonviolent suicides.

3. Results

Between 1970 and 2001, 24,470 males and 13,517 females committed suicide in Denmark. Among these, 17.1% of the suicides occurred in individuals previously hospitalized for mood disorders, with 2938 males and 3554 females accounting for the total.

A spring peak of suicide is apparent for both individuals with hospitalization for mood disorders and without hospitalization for mood disorders, but is more prominent in those with history of hospitalization for mood disorders (Fig. 1). The distinction of the interpolated curves is most discernable during April and May. The spring peak, although small, was significant for both genders (see Table 1) in both the positive history of hospitalization for mood disorders group (males — relative risk [RR]: 1.18, 95% confidence interval [CI]: 1.07, 1.31; females — RR: 1.20, 95% CI: 1.10, 1.32) and also in the no history of hospitalization for mood disorders group (males — RR: 1.07, 95% CI: 1.03, 1.11; females — RR: 1.11, 95% CI: 1.05, 1.18). No significant gender difference was detected ($\chi^2 = 6.12$, $P = 0.11$).

Meanwhile, we observed a marginal increase in spring for violent suicides (27% versus 25% expected) versus nonviolent suicides (25.5% versus 25% expected). However, the differences were not statistically significant ($\chi^2 = 9.84$, $P = 0.02$).

A conditional logistic regression analysis on the somewhat smaller sample of the 1981 to 1997 interval, which allowed for adjustment of socioeconomic factors (see Table 2), showed that the presence of history of hospitalization for mood disorders is associated with a greater risk of suicide during spring in men (adjusted RR: 1.25, 95% CI: 1.08, 1.44) and women (adjusted RR: 1.20, 95% CI: 1.04, 1.38).

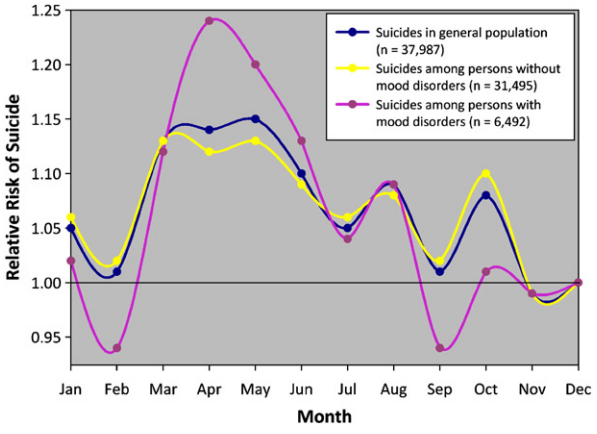

Fig. 1. Relative risk of suicide by month and mood disorder status.

4. Discussion

4.1. Findings and possible explanations

The connection between the spring peak of suicide with seasonal decompensation of depression was first noticed and suggested more than 30 years ago (Zung and Green, 1974). Yet, what drives this peak remains unknown. Considering the very high association between suicide and mood disorders, an obvious hypothesis is that decompensation of mood disorders occurs during or slightly preceding the peak of suicide in spring. We now confirm that hospitalization for mood disorders are associated with a greater seasonality of suicide with peaks in spring. The Danish registers allowed the analysis of multiple years, covered the entire population of Denmark, provided the capability to link cause of death with psychiatric history, and substantially permitted an adjustment for socioeconomic factors which otherwise may have masked or spuriously created an erroneous temporal pattern. Previously, Kim et al. (2004), in a relatively small all male sample ($N = 115$), reported that suicide victims with history of hospitalization for mood disorders showed a spring/summer seasonal pattern in contrast to suicide victims with personality disorders who did not show a seasonal distribution of suicide; those with psychotic disorders tended to commit suicide more often in fall/winter. Two other previous large scale analyses of seasonality of suicide in Denmark (Yip et al., 2006) and Italy (Rocchi et al., 2007) related the suicide peak to mental illness in general, but did not specifically analyze data for the contribution of mood disorders. Valtonen et al. (2006), studying suicide attempts in psychiatric patients living in Helsinki, reported greater temporal fluctuation in rates of attempts in patients with mood disorders than in those with schizophrenia; while the troughs were found in the winter, the peaks of attempts were identified in the fall rather than, as in the abundant literature on completed suicide, in the spring. In contrast, a study of more serious suicide attempts (requiring hospital treatment) in the entire population of Finland over a 7 year period identified troughs in December and peaks in April, consistent with the majority of reports on seasonality of completed suicide (Haukka et al., 2008).

There are generally two theories about the driving forces involved in the seasonal peaks in suicide. The first theory is bioclimatic: seasonal variation in bright light, photoperiod, and other meteorological variables, such as environmental temperature, may induce adverse changes in neurotransmitter systems. Of potential relevance, the neurotransmitters implicated by the monoamine-deficiency theory of mood regulation/dysregulation, such as dopamine, norepinephrine, and serotonin, are also neurotransmitters of thermoregulation. Seasonal changes in neurotransmitter systems have been previously reported. For instance, Maes et al. (1995) reported that plasma L-tryptophan, the precursor of serotonin, a neurotransmitter broadly implicated in depression and suicide, has a trough in spring.

Table 1
Seasonal rate ratios of completed suicide compared with the reference season of winter, in men and women, with and without history of hospitalization for mood disorders.

Season	Suicide cases with mood disorders [a]	Suicide cases without mood disorders	Suicide cases with mood disorders [a]		Suicide cases without mood disorders	
	Number cases	Number cases	Rate ratio	95% CI	Rate ratio	95% CI
Men	**2938**	**21,532**				
Jan–Mar	700	5400	1.01	0.91, 1.12	1.05	1.01, 1.09 *
Apr–Jun	825	5533	1.18	1.07, 1.31 *	1.07	1.03, 1.11 *
Jul–Sep	707	5355	1.00	0.90, 1.11	1.02	0.98, 1.06
Oct–Dec	706	5244	1		1	
Women	**3554**	**9963**				
Jan–Mar	856	2419	1.05	0.95, 1.15	1.02	0.97, 1.08
Apr–Jun	994	2653	1.20	1.10, 1.32 *	1.11	1.05, 1.18 *
Jul–Sep	869	2482	1.04	0.95, 1.14	1.03	0.97, 1.09
Oct–Dec	835	2409	1		1	

[a] Case classified as a history of hospital admission for mood disorders.
* $P<0.01$.

Despite limited evidence to the contrary (Silverstone et al., 1995; Simkin et al., 2003), the majority of research findings suggest that the peak of suicide is greater in rural areas than in urban areas (Maes et al., 1993a,b; Chew and McCleary, 1995; Meares et al., 1981; Micciolo et al., 1991; Flisher et al., 1997) and in outdoor workers compared to indoor workers (Koskinen et al., 2002), making it plausible that an outdoors-related environmental factor could contribute to suicide peaks in spring. If so, this factor could be physical, chemical, biological, socioeconomic, or some combination of these variables.

Although many factors have been proposed to correlate with suicide peaks, no single factor has consistent support from the literature and/or withstands scrutiny. For instance, the environmental factor most often suggested to trigger the suicide peak is light. Photoperiod (day length from sunrise to sunset), changes in photoperiod, and light intensity have been proposed as possible driving forces for peaks of suicide and depression (Goodwin and Jamison, 2007). However, upon careful scrutiny, the peak times of suicide occurrence (April and May) do not match the peak of photoperiod (centered on the summer solstice in late June) or the time when photoperiodic changes are at their greatest (centered on the spring equinox in March) (Souetre et al., 1990; Linkowski et al., 1992; Terao et al., 2002).

The literature on the possible relationship between meteorological variables (including sunshine and temperature) and suicide is characterized by a large variability in the strength and direction of the reported associations (Deisenhammer, 2003). For instance, a very recent work (Ruuhela et al., 2009) concluded that winters with low global solar radiation are associated with an increase in the risk of suicide in Finland, while Papadopoulos et al. (2005) report a positive association between solar radiation and suicide in Greece. It is possible that the latitude and bioclimatic differences between the two countries could explain the contradictory results. Alternative biological factors have been proposed as triggers of suicide in spring, such as the marked tree pollen peaks in spring (Postolache et al., 2005), which could result in seasonally increased cytokine production in upper airways resulting in increased exacerbation of mood disturbance in spring (Guzman et al., 2007). Consistent with these hypotheses, intranasal tree pollen administration in previously sensitized rodents results in increased cytokine expression in the brain and behavioral alterations consisting of increased anxiety and disturbed social interaction (Tonelli et al., 2009). Moreover, rodents sensitized and exposed to tree pollen and subjected to acute stress manifest aggressive behaviors in the resident intruder test (Tonelli et al., 2008a), being previously

Table 2
Seasonal rate ratios for suicide, crude and adjusted for socioeconomical factors, in victims of suicide with vs without mood disorders, by gender.

Season	Cases [a] (suicide cases with mood disorders)	Controls [a] (suicide cases without mood disorders)	Crude analysis [b]		Adjusted analysis [c]	
	Number suicides	Number suicides	Rate ratio	95% CI	Rate ratio	95% CI
Men	**1710**	**11,971**				
Jan–Mar	395	3074	0.95	0.82, 1.11	1.01	0.87, 1.18
Apr–Jun	512	3083	1.23	1.07, 1.42 *	1.25	1.08, 1.44 *
Jul–Sep	418	2959	1.05	0.91, 1.22	1.05	0.91, 1.21
Oct–Dec	385	2855	1		1	
Women	**2239**	**5249**				
Jan–Mar	561	1268	1.12	0.97, 1.29	1.18	1.02, 1.37 **
Apr–Jun	632	1364	1.17	1.02, 1.35 **	1.20	1.04, 1.38 *
Jul–Sep	533	1322	1.01	0.88, 1.17	1.02	0.88, 1.18
Oct–Dec	513	1295	1		1	

Note: Test of gender differences of suicide seasonality, based on adjusted model: $\chi^2 = 6.12$, $P = 0.106$.
[a] Cases were suicide victims who had a history of hospital admission for mood disorders, while controls were suicide victims who did not had such a history.
[b] Crude rate ratios were adjusted for calendar year.
[c] Adjusted rate ratios were further adjusted for personal marital status, income, place of residence and method used for suicide.
* $P<0.01$.
** $P<0.05$.

described that aggression is an important component of completed suicide (Mann, 2003). Finally, victims of suicide have an increased level of gene expression of allergy related cytokines in the orbitofrontal cortex (Tonelli et al., 2008b), a region of the brain manifesting histopathological abnormalities in suicide victims (Mann, 2003).

Some studies have shown a pattern of seasonality of distinct methods of suicides. For instance, both Rasanen et al. (2002) and Ajdacic-Gross et al. (2003), using large sample sizes spread across long intervals, reported that various methods of suicide have a distinct seasonality component, supporting the claim that seasonality may result from seasonality of opportunity/availability of methods. If seasonality is distinct for each method, this would argue against a biological factor, which may be conducive to suicide in general and would point towards sociological considerations of opportunity, availability of means, and aborting factors. However, in our data, the spring peak was present for both violent and nonviolent means, although, consistent with the literature, it was marginally stronger for violent suicides.

Although the relative risk of suicide was elevated in spring and the differences between those with versus those without hospitalization for mood disorders were significant, the findings had relatively small magnitudes. It is important to mention that seasonality of suicide in Denmark is decreasing (Yip et al., 2006), which is consistent with the trends seen in Sweden (Rihmer et al., 1998), England and Wales (Yip et al., 2000) and Hong Kong (Yip and Yang, 2004). However, in other countries, such as Findland (Hakko et al., 1998; Rasanen et al., 2002; Partonen et al., 2004), and the United States (Bridges and Yip, 2005), the seasonal suicidal peaks do not show any abatement.

4.2. Strengths and limitations

Although exacerbation of mood disorders contributing to a seasonal peak of suicide in spring is a plausible explanation of the increased peak of suicide in spring among those with a history of hospitalization for mood disorders (Kim et al., 2004), current limitations of this paper do not allow ruling out other explanations. Individuals with hospitalization for mood disorders could have a different distribution of socioeconomic risk factors, and the seasonal variation in unemployment, income, and marriage/divorce could theoretically contribute to the greater seasonality of suicide in individuals with a prior history of hospitalization for mood disorders. Although we did adjust for many socioeconomic factors, we did not adjust for the seasonality in those factors.

Another important consideration is the undercoverage of mood disorders, as only cases of mood disorders which required medical attention and hospitalization were analyzed. Most individuals with mood disorders are never admitted to the hospital or visit an emergency room. Thus, the study is seriously limited by undercoverage of mood disorders. Even under the best circumstances, we know that not all cases are diagnosed and treated. Moreover, considering that the majority of suicide victims have a history of mood disorders (Mann, 2003), it is likely that the impact of those with history of mood disorders on total suicidality is much stronger than suggested by the current results. It is possible, however, that the seasonality in the patients without mood disorders is driven by individuals who have mood disorders but were never hospitalized for it, as it was previously postulated by Rihmer et al. (1998).

Another limitation is that we did not have antidepressant prescription data available for analysis. In addition, it would have been useful to have information on comorbidity with axis II disorders for analysis. Kim et al. (2004) reported that those with pure mood disorders showed a peak of suicide in spring, while those with mood disorders comorbid with axis II conditions showed no seasonality of suicide attempts. The authors suggested that axis II conditions flattened the seasonal distribution of suicide. Thus, axis II comorbidity might be an important effect modifier in our model. Similarly, other comorbid diagnoses may have been differentially distributed between groups and spuriously augment or diminish the effects.

Finally, it is difficult to generalize the socioeconomic environment in Denmark to other countries. Denmark is a small country, with small distances from countryside to cities, a comprehensive insurance system, relatively homogenous population and customs, and relatively narrow socioeconomic differences. However, seasonality of suicide in Denmark is not different from other countries, and approaches to suicide prevention are similar to those in Western Europe and the United States. Furthermore, there is a distinct advantage to test our hypothesis in a setting where socioeconomic differences, especially their impact on the individuals' access to mental health treatment, are not as prominent as elsewhere. Specifically, mental psychiatric treatment, inpatient or outpatient, is covered by the Danish National Health Service. Moreover, the Danish registers were critical to our findings, the first in a large total population sample, with the capability for detailed adjustments for demographic, diagnostic, social, and economic factors.

In summary, while peaks in depression and suicide during spring have been consistently reported, the cause of these seasonal peaks is still poorly understood. The key finding of this study suggests that the history of hospitalization for mood disorder increases the spring peak of suicide. If future research demonstrates that exacerbation of mood disorders directly contributes to seasonal peaks of suicide in spring, then the next logical step is to postulate that any seasonal environmental factors triggering seasonal decompensation of mood disorders in spring are likely to contribute to seasonal peaks of suicide in spring. Extrapolating from this, a flattening of the spring peak of suicide may well be achieved by successfully treating and preventing exacerbations of mood disorders in spring by reducing exposure to or the effects of precipitating or exacerbating environmental factors. Characterizing the mechanisms underlying the seasonal spring peak of suicide may ultimately enrich our relatively stagnant arsenal of interventions for suicide prevention.

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Conflict of interest

The authors declare that there is no conflict of interest.

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