Relationship of Nocturnal Wakefulness to Suicide Risk Across Months and Methods of Suicide

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ABSTRACT

Objective: Insomnia is a risk factor for suicide, and the risk of suicide after accounting for population wakefulness is disproportionately highest at night. This study investigated whether this risk varied across months and/or methods of suicide.

Methods: Time, date, method (eg, firearm, poisoning), and demographic information for 35,338 suicides were collected from the National Violent Death Reporting System for the years 2003–2010. Time of fatal injury was grouped into 1-hour bins and compared to the estimated hourly proportion of the population awake from the American Time Use Survey for 2003–2010. Negative binomial modeling then generated hourly incidence risk ratios (IRRs) of suicide. Risks were then aggregated into 4 categories: morning (6:00 AM to 11:59 AM), afternoon (noon to 5:59 PM), evening (6:00 PM to 11:59 PM), and night (midnight to 5:59 AM).

Results: The risk of suicide was higher at night across all months ($P < .001$) and methods ($P < .001$). The mean nocturnal IRR across months was 3.18 (SD = 0.314), with the highest IRR in May (3.90) and the lowest in November (2.74). The mean (SD) nocturnal IRR across methods was 3.09 (0.472), with the highest IRR for fire (3.75) and the lowest for drowning (2.44). Additionally, nocturnal risk was elevated within all demographics (all $P < .001$). However, there were no month-by-time or method-by-time interactions across demographics (all $P > .05$).

Conclusions: Regardless of month or method, the incidence risk of suicide at night is higher than at any other time of day. Additionally, demographic subgroups did not differentially experience higher risks across months or mechanisms at night.

J Clin Psychiatry 2020;81(2):19m12964

To cite: Tubbs AS, Perlis ML, Basner M, et al. Relationship of nocturnal wakefulness to suicide risk across months and methods of suicide. *J Clin Psychiatry*. 2020;81(2):19m12964.

To share: https://doi.org/10.4088/JCP.19m12964

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Sleep and circadian rhythms play a significant role in suicidality. Pigeon and colleagues[1] reported that disturbed sleep increased the risk of suicidal ideation and suicide attempts and deaths by 2 to 3 times and that this effect was specifically related to insomnia and nightmares. Insomnia increases the risk of suicide attempts by 3.5 times in adults, with a 5.5-fold increase in the 25- to 44-year-old demographic.[2] Insomnia is strongly associated with current suicidality in undergraduates[3–5] and military personnel.[6,7] Insomnia also predicts future suicidality across adults.[6,8–12] Case-control studies[13,14] show that insomnia and sleep disturbance are more prevalent among those who died by suicide than among matched controls. From these studies, it is clear that difficulty with sleep contributes to suicidal behavior.

Three recent studies[15–17] highlight nocturnal wakefulness as a risk factor for suicide. Perlis and colleagues[15] extracted the time of fatal injury for over 35,000 suicides, combined this with estimations of the waking population size, and determined that the number of suicides at night vastly exceeded the number of expected suicides given the proportion of the population awake at that time. This equated to a 3.6-fold risk of suicide at night that was consistent across demographics. Additionally, Ballard and colleagues[16] experimentally investigated the role of nocturnal wakefulness in suicidality with a single-night polysomnography study. They found participants with suicidal ideation were more likely to be awake at 4:00 AM, that wakefulness between 4:00 and 5:00 AM was associated with suicidal thinking the next day, and that these effects were independent of depression severity and other covariates. Finally, there is a circadian pattern in suicides among individuals who are heavily intoxicated (blood alcohol levels of 80 mg/dL or more), with a peak in suicide counts at 9:00 PM.[17] Thus, nocturnal wakefulness is associated with a heightened risk of suicidal thinking and behavior, and this risk may be modifiable by alcohol or other substances.

Given the concordance between epidemiologic and experimental data, it is imperative to determine the mechanisms connecting suicidality to nocturnal wakefulness. The interpersonal-psychological theory of suicide suggests that suicidality is associated with isolation and thwarted belongingness, both of which can be exacerbated when individuals are awake and alone during the night.[18–20] From a neurobiological perspective, nocturnal wakefulness in the context of sleep deprivation is associated with reduced frontal cortical connectivity and impaired cognition,[21–23] both of which may increase suicidality through altered decision making, poor impulse control, and disrupted risk/reward evaluations. Unfortunately, the paucity of data and inconsistent methods limit inferences on these mechanisms.[24]

Clinical Points

- Increasing evidence supports nocturnal wakefulness as a risk factor for suicide.
- The suicide risk associated with nocturnal wakefulness does not appear dependent on the season in which or the method by which the suicide occurs.
- Sleep disturbances in patients with a history or risk of suicidality should be treated to reduce suicide risk.

However, when experimental data are lacking, population level data can provide insight. Suppose that the nocturnal risk of suicide varied across calendar months, specifically by increasing during the summer. This difference would lend support to current theories about temperature and light exposure as environmental factors driving suicidal behavior.[25–30] Alternatively, suppose the nocturnal risk of suicide was disproportionately elevated for a particular method of suicide. This finding would provide useful information for public health interventions regarding that specific method. Therefore, the present study explored whether the nocturnal risk of suicide varied across months or methods of suicide and whether this risk was influenced by demographic or geographic factors.

METHODS

Datasets

The datasets used for this analysis have been described previously.[15] Briefly, suicide data were collected from the United States National Violent Death Reporting System (NVDRS; see Paulozzi et al[31] and www.cdc.gov/violenceprevention/nvdrs/) for the years 2003 to 2010. The NVDRS collects data from participating states through medical examiner and police reports. These reports include the estimated time of death/fatal injury; the month in which the suicide occurred; the age (including minors), race, ethnicity, and sex of the victim; and the primary method used to commit suicide. Population wakefulness data were drawn from the American Time Use Survey (ATUS; see Basner et al[32] and www.bls.gov/tus/data.htm) for the same years. ATUS data are collected annually by telephone from individuals aged 15 years and older across the United States. The ATUS provides information on the percentage of the population awake at each clock hour, including subdivisions by demographic (race, ethnicity, age, and sex) and month.

Variable Definitions

Clock hours were grouped into 4 time categories: night (midnight to 5:59 AM), morning (6:00 AM to 11:59 AM), afternoon (noon to 5:59 PM), and evening (6:00 PM to 11:59 PM). Months and suicide methods (guns, asphyxia, poison, fall, vehicle, sharp weapons, drowning, and fire) were reported as part of the NVDRS dataset and assessed as categorical variables. Demographics included sex (male or female), age (15– 24, 25–34, 35–44, 45–54, 55–64, 65–74, and 75 years or older), race (white, black, Asian, and other), and ethnicity (Hispanic, non-Hispanic) based on these data available from the NVDRS and ATUS datasets. Geographic analyses were conducted in 2 ways. First, latitude effects were assessed by comparing states that were clearly at or above 40° N or clearly at or below 35° N. The goal of this analysis was to address variations in seasonal light exposure by taking the most extreme data available. Data for states in between these latitudes were not used. The second analysis divided states into 4 regions (West, Midwest, South, and Northeast) in accordance with the American Association of Suicidology[33] to determine regional effects on suicide risks.

Generating Incidence Risk Ratios

The statistical analysis used quasi-Poisson and negative binomial regression to generate incidence risk ratios (IRRs). The choice between quasi-Poisson and negative binomial regression depended on the number of suicides observed in each category, as smaller counts are more accurately modeled using quasi-Poisson regression. Suicide counts were modeled as functions of time of day, month, or method and their interaction. Empirically, at least 5 suicides at each time were required for adequate model fit, so any categories that did not have at least 5 suicides per time of day were eliminated. Population wakefulness was estimated based on ATUS survey responses. These proportions were adjusted for the relevant month and demographic subgroup (sex, age, race, and ethnicity) and entered as an offset/exposure variable in the model. Modeling counts in this way produces an IRR, which represents the increased risk of suicide at that level (eg, month, time) as compared to a reference level. Ordinarily, this reference would be another level within the same categorical variable (eg, comparing black to white individuals). Effect coding is an alternative approach that compares each level to the grand mean across levels (eg, comparing black individuals to the mean across all races). To avoid arbitrary assignment of a reference level, effect coding was used in both the by-months and by-methods analyses. For months, effect coding was used for time, month, and the interaction. For methods, effect coding was used only for time, as comparisons were made only within method. Effect coding was achieved using package "wec" in R.[34] Statistical tests of significance were conducted using 1- or 2-way analysis of variance (ANOVA) depending on the particular model used. All analyses were conducted using R (version 3.5.1; R Foundation) and graphs were generated using ggplot2.[35]

RESULTS

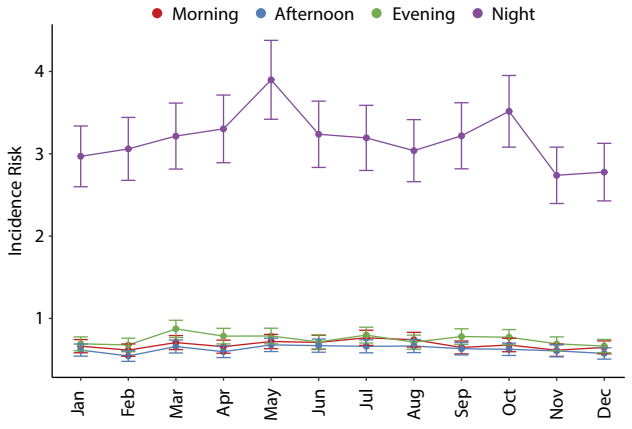
Summary of the Data

Data on a total of 35,338 suicides were extracted from the NVDRS dataset between 2003 and 2010. Some cases included missing data and were excluded as appropriate in analyses (eg, month of death was present, but not method). Table 1 shows the suicide counts by time of day, month, and

Table 1. Suicide Counts by Time of Day, Month, and Method Across Demographic Factors (N = 35,338)

Suicide Variable	Sex		Age, y							Race				Ethnicity		Latitude		Region			
	Female	Male	15–24	25–34	35–44	45–54	55–64	65–74	>75	White	Black	Asian	Other	Non-Hispanic	Hispanic	>40° N	≤35° N	Midwest	Northeast	South	West
Total	6,636	28,700	5,000	5,659	6,740	7,252	4,686	2,688	2,943	31,239	2,701	526	686	33,384	1,618	6,165	6,995	4,150	3,504	19,996	7,620
Time of Day																					
Morning	1,706	7,705	967	1,222	1,653	1,956	1,454	922	1,183	8,408	651	123	188	8,896	425	1,649	1,784	1,067	1,058	5,185	2,082
Afternoon	2,299	9,081	1,456	1,601	2,169	2,498	1,643	916	956	10,155	814	180	172	10,839	444	2,127	2,272	1,426	1,117	6,506	2,314
Evening	1,703	7,519	1,452	1,649	1,891	1,920	1,086	585	498	8,123	757	136	156	8,711	423	1,504	1,916	940	873	5,414	1,977
Night	928	4,395	1,125	1,187	1,027	878	503	265	306	4,553	479	87	170	4,938	326	885	1,023	717	456	2,891	1,247
Month																					
January	525	2,288	422	409	549	568	375	213	249	2,492	212	38	56	2,648	143	510	579	335	292	1,583	598
February	515	2,137	377	454	494	537	332	214	214	2,339	214	43	48	2,514	105	451	563	298	241	1,518	587
March	607	2,520	444	468	566	686	430	228	277	2,778	236	45	53	2,939	152	557	631	336	310	1,764	713
April	572	2,347	410	509	555	586	415	175	233	2,582	219	39	53	2,754	136	490	590	340	303	1,696	572
May	596	2,600	436	534	669	599	399	257	259	2,819	238	53	68	3,028	141	561	616	359	338	1,797	697
June	564	2,449	455	476	555	615	403	224	260	2,659	229	49	58	2,846	137	520	591	378	300	1,691	641
July	563	2,617	437	517	604	663	423	231	270	2,806	251	40	71	3,001	158	553	615	378	292	1,793	712
August	595	2,452	435	501	580	623	412	224	231	2,711	234	40	49	2,888	135	512	603	347	320	1,737	637
September	575	2,369	420	455	529	657	389	248	221	2,579	244	35	76	2,787	124	526	539	349	294	1,650	648
October	522	2,483	433	489	584	587	387	233	267	2,670	218	50	49	2,824	149	536	613	359	281	1,714	647
November	508	2,256	370	440	575	550	345	220	236	2,424	219	47	59	2,621	119	487	527	338	277	1,531	611
December	494	2,182	361	407	480	581	376	221	226	2,380	187	47	46	2,534	119	462	528	333	256	1,522	557
Method																					
Asphyxia	1,291	5,646	1,512	1,577	1,519	1,197	528	190	197	5,796	616	234	217	6,275	605	1,231	1,232	963	1,119	3,429	1,418
Drowning	134	286	40	71	77	99	62	42	27	313	79	21	3	404	14	120	68	49	102	209	58
Fall	273	670	165	156	206	202	102	50	59	780	97	48	4	885	50	263	102	95	244	419	182
Fire	75	165	29	39	50	70	38	9	5	177	42	15	5	226	11	61	34	29	59	114	37
Gun	2,794	18,603	2,760	3,070	3,636	4,146	3,113	2,144	2,405	19,261	1,587	132	352	20,482	681	3,390	4,636	2,265	1,138	13,212	4,759
Poison	1,764	2,113	265	488	929	1,173	666	172	171	3,593	175	36	62	3,687	165	750	761	544	489	1941	884
Sharp weapon	96	457	37	71	110	147	91	44	50	488	38	12	11	523	30	106	82	70	127	264	90
Vehicle	169	590	170	146	174	171	55	23	15	639	60	26	28	699	56	193	63	96	217	283	163

Figure 1. Risk of Suicide by Time of Day Across Months[a]



[a]The incidence risk ratios (plotted as mean ± SE) were much higher at night as compared to the mean across all times of day. Risk peaked in May and October, although these increases were not statistically significant. Times of day are defined as follows: night = midnight to 5:59 AM; morning = 6:00 AM to 11:59 AM; afternoon = noon to 5:59 PM; evening = 6:00 PM to 11:59 PM.

method of suicide across demographic variables. By raw counts, most suicides occurred in the afternoon (n = 11,381), in May (n = 3,196), and by firearms (n = 21,397). More males committed suicide than females (n = 28,700 males vs n = 6,636 females), and suicide counts were highest among 45- to 54-year-olds (n = 7,252), white individuals (n = 31,239), and non-Hispanic individuals (n = 33,384). The number of suicides was roughly equivalent between states categorized as above 40° N (n = 6,165) and at or below 35° N (n = 6,995). By region, most suicides were in the South (n = 19,996), with fewer suicides in the West (n = 7,620), Midwest (n = 4,150), and Northeast (n = 3,504).

Suicide Month Analysis

The first question was whether, after accounting for population wakefulness, the hourly IRR of suicide varied across months. The results are shown in Figure 1. May showed the highest IRR (mean ± SE = 3.9 ± 0.48), while November had the lowest IRR (2.7 ± 0.34). However, a 2-way ANOVA for month, time of day, and an interaction showed that the IRR varied significantly across time of day ($P < .001$), but not across months ($P = .33$) or by the interaction ($P = 1.00$). A post hoc Wald test showed that incidence risk at night was significantly higher than at any other time of day ($P < .001$). The mean (SD) IRR at night across months was 3.18 (0.314).

In subgroup analyses, each demographic was evaluated separately for an effect of time of day by month. These results are presented in Figure 2; women tended to have slightly higher nighttime risks than men, nighttime risk appeared to decrease with age, and Hispanic individuals tended to have higher nocturnal risks than non-Hispanic individuals. However, a 2-way ANOVA found that, while IRRs varied significantly across time for men and women, all ages, all races, Hispanic and non-Hispanic individuals, all latitudes, and all regions (all $P < .001$), they were not significantly different across months, nor was there a significant month-by–time of day interaction (all $P > .05$).

Suicide Method Analysis

The second question was whether the IRR of suicide varied by time across suicide methods. An initial 2-way ANOVA evaluating time by method showed that risk varied significantly by time of day and by method (both $P < .001$) but that the interaction was not significant ($P = .3026$). Thus, no method had a significantly higher risk at a specific time than any other method at that same time. Post hoc Wald tests found that the risk was highest at night and for guns (both $P < .001$). The mean (SD) IRR at night across methods was 3.09 (0.472). However, suicide counts were heavily skewed across methods, with more than half of the suicides involving firearms. Therefore, the risk of each method at each time of day was evaluated independently, as opposed to comparing risks across methods. Effect coding was used to compare the risk at each time to the grand mean across the day within each method. Figure 3 shows the IRRs for each method at each time.

As in the by-months analysis, IRRs were evaluated across sex, age, race, ethnicity, latitude, and region. These results are presented in Figure 4. Nocturnal risk for each method did not vary by sex, age, race, ethnicity, or geography. A 2-way ANOVA showed that IRRs varied significantly by time of day and method for all demographic groups (all $P < .001$), reiterating that the risk of suicide is not equivalent across all times or every method. However, the interaction between time of day and method was not significant for any subgroup (all $P > .05$). Thus, there was no method of suicide that was systematically more common in any particular demographic or geographic group.

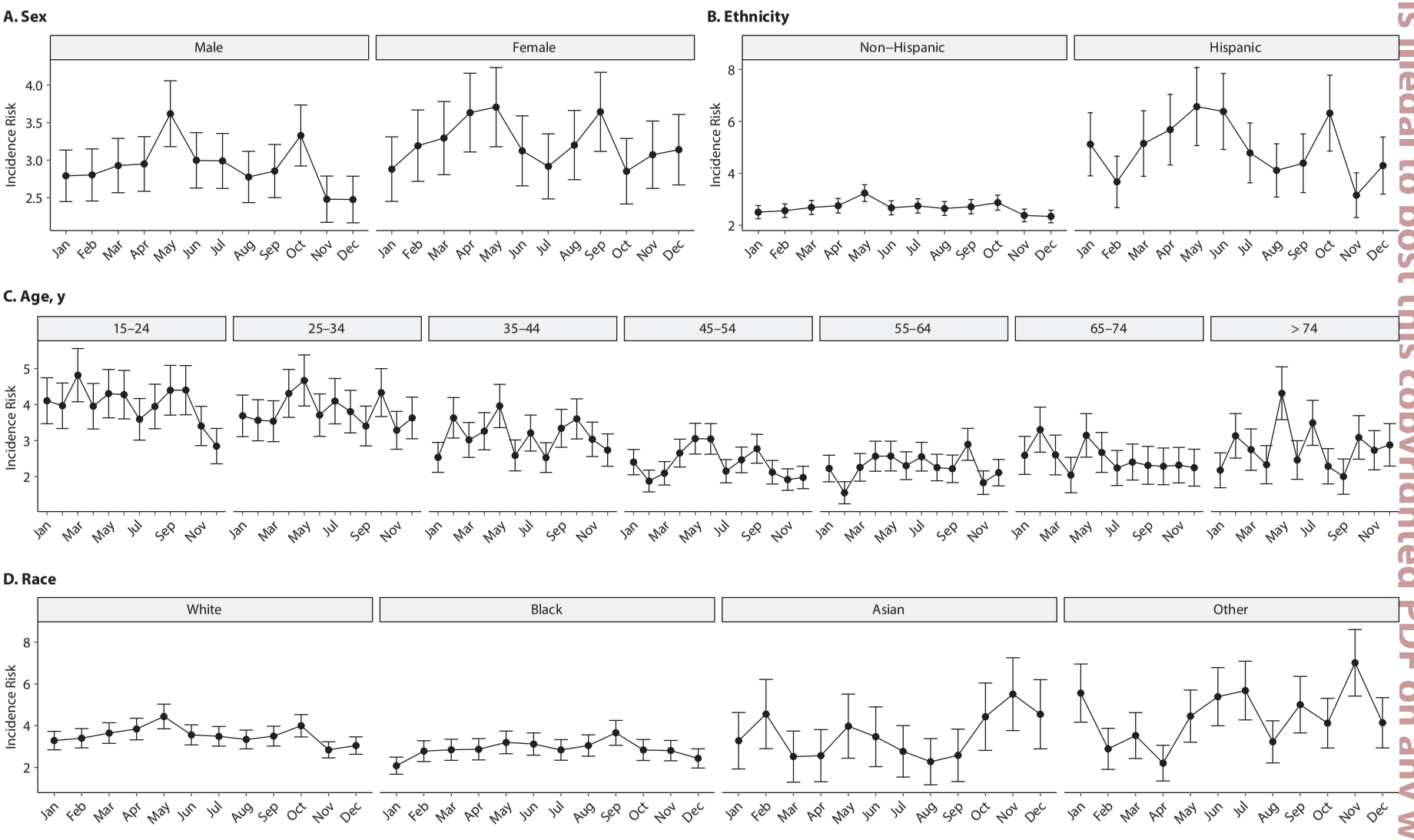
DISCUSSION

This study found that the nocturnal risk of suicide is approximately 3 times that of the across-day average after accounting for population wakefulness. Additionally, the increased risk at night remained constant regardless of month or method of suicide. While differences may exist across demographics and methods, these differences are not dependent on time of day. These findings reinforce previous results in suggesting that nocturnal wakefulness is a significant risk factor for suicide.

Suicide Month Analysis

Seasonal effects on suicide have been described in both the northern and southern hemispheres. Holopainen and colleagues[30] found that suicide peaks occurred in May and October, which they hypothesized was due to dramatic changes in temperature. This result reinforced an earlier finding that Finnish suicides were highest in spring, when solar radiation was highest.[36] A study of young people in the more equatorial country of Turkey[37] found a peak in suicide attempts in the summer. In Brazil, Bando and Volpe[38] found that male suicide peaked in late spring and reached

Figure 2. Nocturnal Risk of Suicide Across Months by Demographic Characteristics[a]



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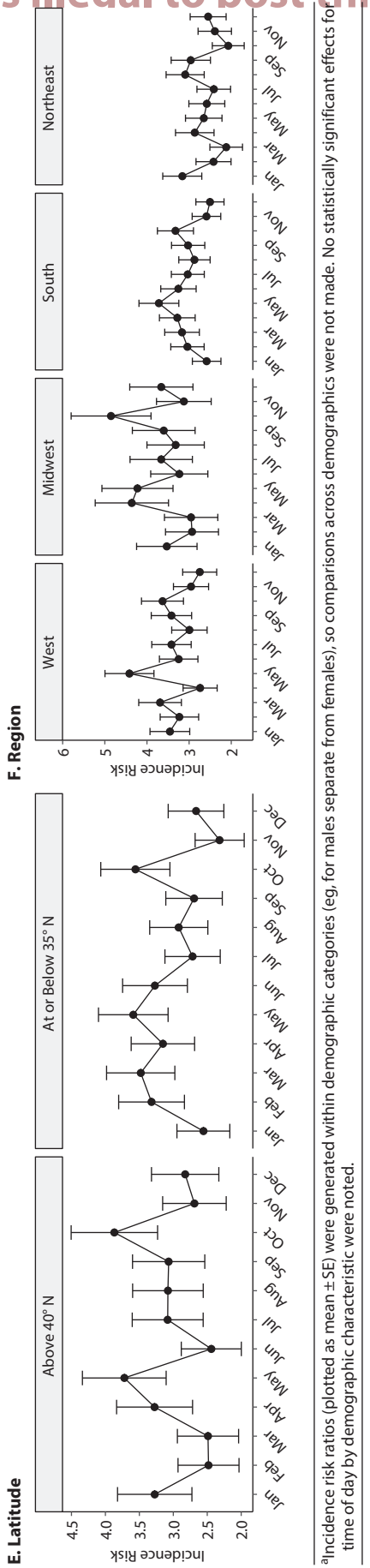
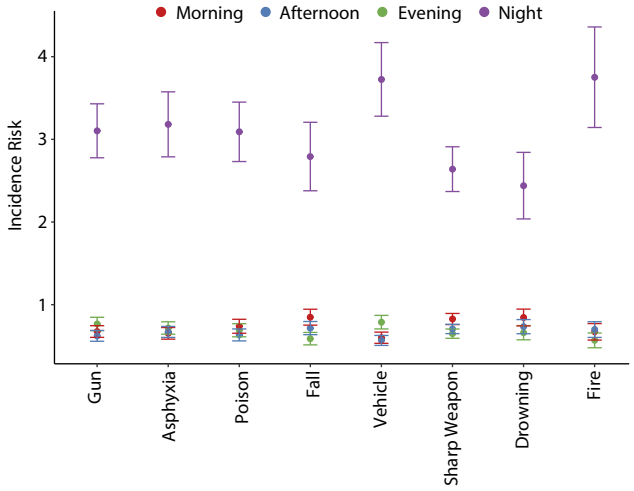


Figure 2 (continued).

[a]Incidence risk ratios (plotted as mean ± SE) were generated within demographic categories (eg, for males separate from females), so comparisons across demographics were not made. No statistically significant effects for time of day by demographic characteristic were noted.

Figure 3. Risk of Suicide by Time of Day Across Methods of Suicide[a]



[a]The incidence risk ratios (plotted as mean ± SE) were higher at night as compared to the mean risk across all times of day. While vehicles and fires showed an elevated risk, this increase was not statistically significant. Times of day are defined as follows: night = midnight to 5:59 AM; morning = 6:00 AM to 11:59 AM; afternoon = noon to 5:59 PM; evening = 6:00 PM to 11:59 PM.

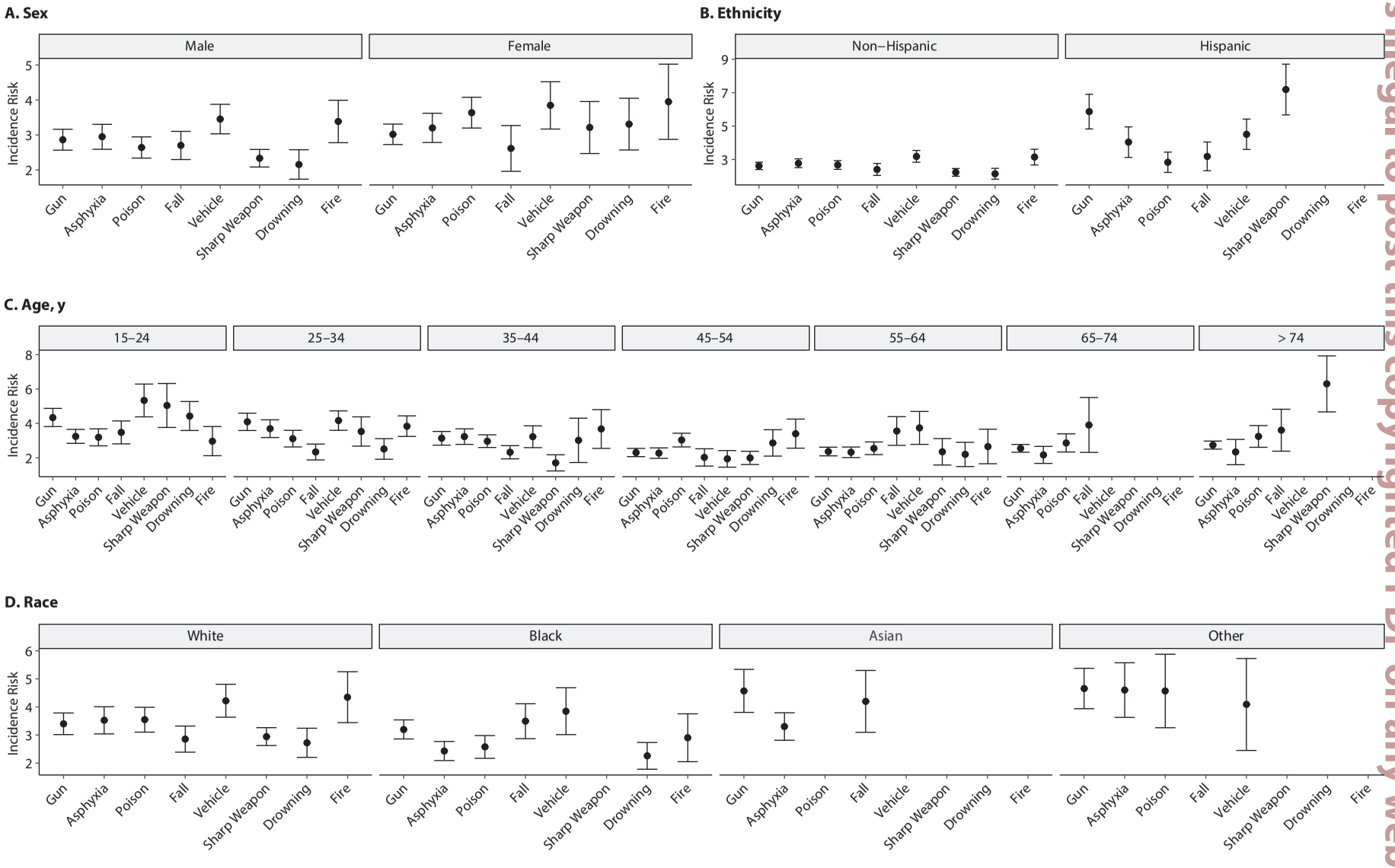
a minimum in late fall, whereas female suicide peaked in summer and reached its minimum in winter. The increased risk for suicide in spring was also present in Danish suicide completers with a history of mood disorders.[39] The springtime increase in suicides has been correlated with increased light exposure, possibly through modulation of serotonergic activity.[25–29] Whatever the mechanism, season appears to play a role in suicide risk.

Contrary to this literature, the present study found that the risk of suicide was highest at night across all months and that no month showed a risk significantly different from that of any other. While Figure 1 appears to show an increase in nocturnal suicide risk in May and October, this finding was not statistically significant and cannot be interpreted further. If a seasonal effect does exist for suicide risk, it is likely insignificant compared to the time of day, and future research on seasons and suicide should account for time of day.

Suicide Methods Analysis

It is interesting that the nocturnal risk of suicide did not vary across methods of suicide. From a practical standpoint, some methods might be less accessible at night than others (eg, there are fewer cars/trains active at night to be hit by). Nevertheless, in accordance with the hypofrontality theory advanced by Perlis and colleagues,[23] this finding suggests that nocturnal wakefulness may be more associated with the initial decision to commit suicide than the choice of method. The finding also accords with other evidence of disinhibited behaviors at night, such as those around food choices. Individuals who go to bed later are more likely to consume hedonistic and energy-rich foods, such as fast foods and sodas.[40,41] Similarly, a survey of Australian children and adolescents found that those who were awake later at night had a higher intake of "extra foods" and a lower diet quality.[42] In the case of suicide and food choice, nocturnal wakefulness may be driving impulsive decision making through impaired cortical activity. However, experimental studies are needed to explore this hypothesis.

Figure 4. Nocturnal Risk of Suicide Across Suicide Methods by Demographic Characteristics[a]



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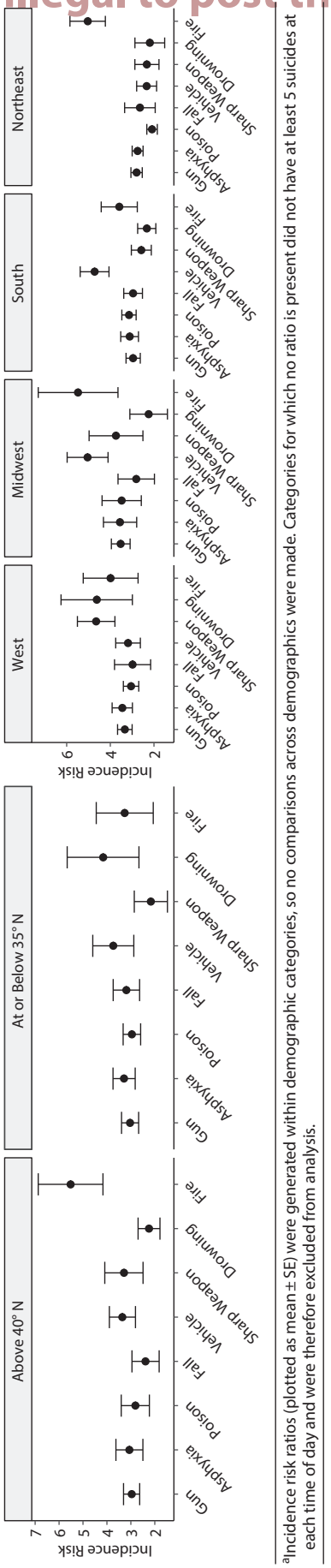

Figure 4 (continued).

[a]Incidence risk ratios (plotted as mean ± SE) were generated within demographic categories, so no comparisons across demographics were made. Categories for which no ratio is present did not have at least 5 suicides at each time of day and were therefore excluded from analysis.

Strengths and Limitations

This study has several strengths. Despite the use of a different statistical approach, the average nocturnal risk of suicide was in line with the risk reported by Perlis and colleagues.[15] Additionally, the analysis was based on a large sample size (over 35,000 suicides), with estimated population wakefulness adjusted for time of day and relevant demographics. However, this study has several limitations. First, it is unclear whether individuals who committed suicide at night were continuously awake until their suicide or had recently woken up. This distinction is important, as it might separate sleep deprivation from circadian effects. Second, the adjustment for wakefulness was not based on individuals who specifically had suicidal ideation, plans, or attempts. Thus, if suicide attempters systematically differ from the general population in the timing of wakefulness, this approach would not account for this difference. Additionally, we were unable to separate minors out from the age–15-to-24 demographic as we did not have separate ATUS wakefulness estimates for minors and adults in this category. Finally, the small number of minority suicides reported prevented the calculation of some IRRs.

Future Directions

It is critical to understand what biological and psychological mechanisms are at work in individuals who commit suicide at night. If middle insomnia leads to increased catastrophic thinking, hopelessness, and thwarted belonging, then treatment of insomnia may help vulnerable individuals to avoid times of dangerous thinking. Alternatively, if nocturnal hypofrontality contributes to suicidal decision making, then separating the role that sleep and circadian rhythms have on this hypofrontality may inform future interventions. Finally, these results need to be replicated in other suicidal behaviors, including attempts, planning, and ideation. Such replication would help to determine whether nocturnal wakefulness serves as an acute trigger for suicide attempts or else accumulation of nocturnal wakefulness promotes all forms of suicidal behavior.

CONCLUSIONS

Suicide is a growing crisis, and a greater understanding of precipitating factors is needed. In accordance with previous work, this report shows that suicide risk is higher at night than at any other time of day and that this risk does not vary significantly by month, method, or demographic characteristics. The implication that nocturnal wakefulness is a universal factor for suicide risk suggests that biological or psychological mechanisms may play a role outside of social and environmental factors. Future work is needed to fully assess sleep and nocturnal wakefulness as acute risk factors for suicidal behavior.

Submitted: June 20, 2019; accepted September 11, 2019.

Published online: February 25, 2020.

Potential conflicts of interest: None.

Funding/support: Partial grant support for this study was provided by the following grants from the National Institutes of Health and the Veterans Administration: K24 AG055602 and R01 AG054521 (Dr Perlis), R01 MD011600 (Dr Grandner), and IK2 CX000855 (Dr Chakravorty).

Role of the sponsors: The funding providers had no role in the conduct of the study or the publication of the results.

Previous presentation: Previously presented at the Associated Professional Sleep Societies SLEEP Conference; June 2–6, 2018; Baltimore, Maryland.

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Editor's Note: We encourage authors to submit papers for consideration as a part of our Focus on Suicide section. Please contact Philippe Courtet, MD, PhD, at pcourtet@psychiatrist.com.