Risk for Suicide and Homicide Peaks at Night:

Findings From the National Violent Death Reporting System, 35 States, 2003–2017

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Abstract

Objective: The Mind after Midnight hypothesis proposes that nocturnal wakefulness increases the risk for dysregulated behaviors. Prior studies highlight a greater risk for suicide at night after adjusting for population wakefulness. How this risk varies hour to hour, differs across subgroups, or applies to other behaviors is unknown.

Methods: Data on 78,647 suicides and 50,526 homicides from the National Violent Death Reporting System were combined with population wakefulness data for 2003–2017 from the American Time Use Survey. Hourly incident risk ratios (IRRs) were estimated after adjusting for population wakefulness. Two-way analysis of variances identified significant time-by-subgroup interactions that were quantified in post hoc analyses.

Results: Suicide counts peaked at 12:00 PM, while homicide counts peaked at 10:00–11:00 PM. Adjusting for demographics and population wakefulness revealed a 5-fold greater risk for suicide at 3:00 AM (aIRR: 5.20 [4.74–5.70]) and an 8-fold greater risk for homicide at 2:00 AM (aIRR: 8.04 [6.35–10.2]). Hourly risk for suicide varied by age, ethnicity, blood alcohol level, and current partner conflict. Hourly risk for homicide varied by sex and blood alcohol level.

Conclusions: Risk for suicide and homicide is greater at night than expected based on the number of people awake at that time. Nighttime risk was greater among young adults and those intoxicated with alcohol, but not among those with a history of suicidal ideation or attempts. Further research should evaluate mechanisms of risk and confirm these findings at an individual level.

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Disrupted sleep may increase the risk for suicide[1,2] through chronically insufficient or poor-quality sleep. The Mind after Midnight hypothesis[3,4] proposes that disrupted sleep also creates acute risk for dysregulated behaviors through nocturnal wakefulness (ie, prolonged wakefulness during the habitual sleep period). Regardless of the cause, nocturnal wakefulness drives risk by combining circadian processes that promote sleep at night with sleep deprivation–induced cognitive deficits. Nocturnal wakefulness also occurs at times of psychosocial isolation—friends and family are asleep, and community services are shuttered. These factors may enable vulnerable individuals to progress from maladaptive thoughts to impulsive, dysregulated behaviors.

Evidence for the Mind after Midnight hypothesis partially derives from 24-hour patterns of suicide timing and population wakefulness. Although raw hourly suicide counts peak around noon (see Perlis et al[4] for a comprehensive review), adjusting raw counts for the number of people awake (and thus capable of attempting suicide) revealed a 3-fold peak in incident suicide risk between midnight and 6:00 AM. Subsequent work has replicated this nighttime suicide risk in Australia,[5] identified greater nighttime risk for military service members,[6] and measured increased nocturnal wakefulness among those with suicidal ideation.[7–9]

Nocturnal wakefulness may affect several cognitive domains. Positive mood is minimal and negative mood is maximal during this time,[10–13] risk/reward processing is altered due to changes in subcortical reward circuits,[14–17] and executive functions are compromised owing to circadian changes in cortical connectivity and

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.

Clinical Points

- Risk for death by suicide and homicide is elevated at night, particularly among younger age groups and individuals intoxicated with alcohol.
- Wakefulness at night may predispose individuals to dysregulated behaviors, and interventions to reduce or mitigate disrupted sleep may reduce risk.

mounting sleep pressure in the frontal cortex.[18–24] Such deficits are correlated with suicide risk: individuals with multiple suicide attempts (or at risk for suicide) have impaired executive function,[25–28] and the suicide crisis syndrome may emerge from disrupted neurocognition.[29,30] Individuals who cannot regulate their emotions, manage risk, or inhibit their impulses may also resort to violence[31,32] or inadvertently place themselves in danger. Few studies have examined time-of-day trends in violent crime. Although some analyses highlight a peak in homicides between 6:00 PM and 6:00 AM[33–35] and approximately 55% of all violent crimes occur between 7:00 PM and 7:00 AM,[36] hour-by-hour incidence data remain limited. If homicide and suicide share a nighttime peak in incidence, then these behaviors may share nocturnal wakefulness as a common risk factor.

Subgroup variations in overnight suicide risk may suggest potential mechanisms. The prefrontal cortex does not fully mature until age 25,[37] so nocturnal wakefulness likely strains underdeveloped executive functions in adolescents and young adults. Circadian misalignment in youth also appears to dysregulate risk/reward processing, particularly as it relates to substance use.[14,38,39] Alcohol impairs executive functions[40] and may increase nighttime risk for suicide[41] or homicide. The interpersonal theory of suicide[42] and the suicide crisis syndrome[30] emphasize disrupted interpersonal relations as potential precipitants of suicidal behavior, so individuals experiencing interpersonal conflict may be at similar risk for dysregulated behaviors. Finally, greater negative mood during nocturnal wakefulness may place a particular burden on individuals with preexisting mood disorders.

To gain further insights into subgroup variations in overnight risk for suicide and homicide, the present study leveraged 15 years of US national archival data to (1) examine the population wakefulness–adjusted risk for suicide and homicide on an hour-by-hour basis and (2) explore these patterns in risk among multiple demographic and clinical subgroups. Based on prior publications and the above reasoning, it was hypothesized that hour-by-hour risk for suicide and homicide would peak during the night (11:00 PM to 5:00 AM), with risk further increased in individuals with underdeveloped or compromised executive function (eg, young adults and intoxicated adults), current depressed mood, or experiencing current partner conflict.

METHODS

Datasets

Case data were acquired from the National Violent Death Reporting System (NVDRS) on 78,647 suicides and 50,526 homicides between 2003 and 2017. Data are derived from law enforcement reports, death certificates, and medical examiner reports that are maintained by the Centers for Disease Control and Prevention. The NVDRS began with data from 6 states and by 2017 included 35 states plus the District of Columbia and Puerto Rico. Data can be accessed by application to the NVDRS Restricted Access Database (www.cdc.gov/violenceprevention/datasources/nvdrs/dataaccess.html). Suicides from 2003 to 2010 were previously analyzed,[43,44] but those reports did not specifically address hour-by-hour incident risks. These data were combined with new data to improve statistical power for detecting between-group differences.

Population estimates of sleep/wake timing were derived from the American Time Use Survey (ATUS, https://www.bls.gov/tus) for the same years. The ATUS is a weighted, nationally representative telephone-based survey conducted by the US Bureau of Labor and Statistics among 10,000 US adults annually. Respondents recorded their activities, including sleeping, in 30-minute epochs for 24 hours. Population estimates of epoch-by-epoch wakefulness were then calculated by age, sex, race, and ethnicity for 2003–2017 and averaged to obtain hour-by-hour estimates of population wakefulness (ie, minutes awake per hour).

The University of Arizona Institutional Review Board determined that this project involved de-identified human subject data and was thus exempt from further review.

Variables

NVDRS case variables included time and date of fatal injury, age, sex, race, ethnicity, military service, autopsy testing for alcohol and cannabis, current depressed mood, current partner conflict, and prior suicidal ideation or attempts. Not all data were available for all cases. Military service was defined as current or past military service and categorized as no or yes. Autopsy data on blood alcohol levels (BALs) were categorized as none, <80 mg/dL, or ≥80 mg/dL. Cannabis was categorized as absent or present. Current depressed mood was defined as "victim was perceived by self or others to be depressed at the time of injury" ("no or unknown" vs "yes"), and current partner conflict was defined as "problems with a current or former intimate partner appear to have contributed to the [suicide/homicide]"

("no or unknown" vs "yes"). Suicides were characterized by a history of suicidal ideation ("no or unknown" vs "yes") or a suicide attempt ("no or unknown" vs "yes").

Statistical Analyses

All analyses were conducted in R (version 4.2.1, R Foundation for Statistical Computing, Vienna, Austria); the code is available at https://github.com/atubbs-sleep. For descriptive analyses, the time was divided into 4 categories consistent with prior reports[8,9,43]: morning: 0500–1059, afternoon: 1100–1659, evening: 1700–2259, and night: 2300–0459. Inferential analyses were conducted in 2 steps for suicides and homicides: (1) hour-by-hour incident risk for the whole sample and (2) significant time-by-subgroup variations. Across analyses, effect coding was used so that clock hour estimates were compared to the grand mean across clock hours rather than a reference clock hour.

Analysis 1: hour-by-hour incident risk for the whole sample. Individual NVDRS cases were tabulated into hourly case counts by hour of fatal injury, age, sex, race, and ethnicity. Counts were then matched with estimated population wakefulness by age, sex, and race/ethnicity from the ATUS. Robust Poisson multivariable models estimated the incident risk ratio (IRR) with clock hour as the predictor/independent variable, case count as the outcome/dependent variable, and population wakefulness as an exposure/offset term. Model 1 was unadjusted, and Model 2 was adjusted for age, sex, race, ethnicity, military service, current depressed mood, current partner conflict, prior suicidal ideation, and prior suicide attempt. IRRs are reported as point estimates and 95% confidence intervals (eg, IRR [95% CI]).

Analysis 2: significant time-by-subgroup interactions. Two-way analysis of variances examined whether any covariates had significant interactions with time of day in predicting risk. All tests were adjusted for age, sex, race, and ethnicity, where appropriate, and *P* values were adjusted for multiple comparisons according to the familywise error rate. Marginal time-by-subgroup effects were examined for significant interactions.

RESULTS

The characteristics of individuals who died by suicide or homicide are presented in Tables 1 and 2, respectively. High missingness was noted for BAL (suicide: 50.5% and homicide: 37.5%) and cannabis (suicide: 68.5% and homicide: 62.4%). Suicide case counts were highest during the afternoon (N = 24,573, 1100–1659) and lowest at night (N = 14,833, 2300–0459). For homicide, case counts were highest at night (N = 17,997, 2300–0459) and lowest in the morning (N = 6,434, 0500–1059).

IRRs were elevated between 12:00 AM and 5:00 AM for both suicide (Figure 1A) and homicide (Figure 1B) compared to the 24-hour average risk. The peak unadjusted suicide risk (Model 1) was 526% greater at 2:00 AM (IRR: 5.26 [3.26–8.47]), and the peak adjusted suicide risk (Model 2) was 520% greater at 3:00 AM (aIRR: 5.20 [4.74–5.70]). For death by homicide, the peak unadjusted homicide risk was 980% greater at 2:00 AM (IRR: 9.80 [5.69–16.9]), and the peak adjusted homicide risk was 804% greater at 2:00 AM (aIRR: 8.04 [6.35–10.2]).

Time-of-day-by-subgroup interactions in suicide risk were observed for age ($P < .001$), ethnicity ($P = .014$), BAL ($P < .001$), and current partner conflict ($P < .001$) (Figure 2). Compared to individuals aged 45–54 years (the largest age group), risk peaked around 4:00 AM for individuals aged 15–24 (aIRR: 3.11 [2.39–4.05]) and 25–34 (aIRR: 2.15 [1.63–2.86]) years. Individuals aged 35–44 years showed modest peaks in risk at 2:00 AM (aIRR: 1.40 [1.03–1.91]) and 3:00 AM (aIRR: 1.49 [1.12–1.99]), but they, like those aged 55–64 years, were overall not substantially different from individuals aged 45–54 years. Finally, there was a peak in risk at 6:00 AM for individuals aged 65–74 (aIRR: 1.78 [1.40–2.25]) and 75+ (aIRR: 2.25 [1.69–3.00]) years. Hispanic individuals had elevated risk between 10:00 PM and 3:00 AM with a maximal 232% increase at 2:00 AM (aIRR: 2.32 [1.67–3.23]). Individuals with a positive BAL showed increased risk between 8:00 PM and 4:00 AM; those with a BAL less than 80 mg/dL had a peak risk of 168% (aIRR: 1.68 [1.40–2.01] at 12:00 AM), and those with a BAL of 80 mg/dL had a peak risk of 233% (aIRR: 2.33 [1.88–2.89] at 1:00 AM). Additionally, individuals with a positive BAL had reduced daytime risk (8:00 AM–4:00 PM). Individuals who had a current partner conflict had an elevated risk from 8:00 PM to 11:00 PM and from 1:00 AM to 3:00 AM with a peak risk at 11:00 PM (aIRR: 1.53 [1.24–1.89]).

Time-of-day-by-subgroup interactions in risk for death by homicide were observed for sex ($P < .001$) and BAL ($P < .001$) (Figure 3). Female homicide victims were more likely to die between 5:00 AM and 9:00 AM (peak risk at 7:00 AM, IRR: 1.90 [1.42–2.53]) and less likely to die between 7:00 PM and 11:00 PM. Individuals with a positive BAL showed increased risk between 11:00 PM and 5:00 AM with a peak risk at 2:00 AM (<80 mg/dL, IRR: 2.17 [1.46–3.23]; ≥ 80 mg/dL, IRR: 2.96 [2.12–4.14]). No other subgroups showed significant differences in time-of-day risk.

DISCUSSION

Adjusting for population wakefulness yielded a 5-fold greater risk for suicide and an 8-fold greater risk for homicide from 2:00 AM to 3:00 AM when compared to the

Table 1.

Demographic and Clinical Characteristics of Suicide Victims in the NVDRS by Time of Day

Characteristic	Total	Morning[a]	Afternoon[a]	Evening[a]	Night[a]
N	78,647	18,062	24,573	21,179	14,833
Age, y					
15–24	11,114 (14.3%)	1,918 (10.7%)	3,080 (12.7%)	3,260 (15.7%)	2,856 (19.4%)
25–34	13,311 (17.1%)	2,628 (14.6%)	3,589 (14.8%)	3,743 (18.0%)	3,351 (22.8%)
35–44	13,725 (17.6%)	2,864 (16.0%)	4,118 (16.9%)	4,002 (19.2%)	2,741 (18.6%)
45–54	15,297 (19.7%)	3,514 (19.6%)	5,047 (20.8%)	4,250 (20.4%)	2,486 (16.9%)
55–64	11,253 (14.5%)	2,867 (16.0%)	3,824 (15.7%)	2,871 (13.8%)	1,691 (11.5%)
65–74	6,622 (8.5%)	1,940 (10.8%)	2,373 (9.8%)	1,509 (7.2%)	800 (5.4%)
75+	6,462 (8.3%)	2,210 (12.3%)	2,265 (9.3%)	1,191 (5.7%)	796 (5.4%)
Unknown	863	121	277	353	112
Sex					
Male	63,979 (81.4%)	14,871 (82.3%)	19,767 (80.4%)	17,146 (81.0%)	12,195 (82.2%)
Female	14,664 (18.6%)	3,190 (17.7%)	4,806 (19.6%)	4,030 (19.0%)	2,638 (17.8%)
Unknown	4	1	0	3	0
Race					
White	68,528 (87.3%)	15,823 (87.7%)	21,656 (88.3%)	18,452 (87.3%)	12,597 (85.3%)
Black	5,838 (7.4%)	1,342 (7.4%)	1,697 (6.9%)	1,582 (7.5%)	1,217 (8.2%)
Asian	1,133 (1.4%)	237 (1.3%)	356 (1.5%)	304 (1.4%)	236 (1.6%)
Other race	2,991 (3.8%)	637 (3.5%)	824 (3.4%)	807 (3.8%)	723 (4.9%)
Unknown	157	23	40	34	60
Ethnicity					
Non-Hispanic	74,028 (94.9%)	17,044 (95.2%)	23,291 (95.5%)	19,915 (94.8%)	13,778 (93.7%)
Hispanic	3,981 (5.1%)	861 (4.8%)	1,090 (4.5%)	1,100 (5.2%)	930 (6.3%)
Unknown	638	157	192	164	125
Military service					
No	59,188 (79.6%)	13,134 (76.8%)	18,306 (78.4%)	16,433 (81.6%)	11,315 (82.2%)
Yes	15,194 (20.4%)	3,971 (23.2%)	5,051 (21.6%)	3,716 (18.4%)	2,456 (17.8%)
Unknown	4,265	957	1,216	1,030	1,062
Blood alcohol level					
No alcohol	23,787 (61.1%)	5,943 (71.7%)	8,562 (71.7%)	5,997 (53.5%)	3,285 (43.7%)
< 80 mg/dL	3,560 (9.1%)	704 (8.5%)	994 (8.3%)	1,059 (9.5%)	803 (10.7%)
≥ 80 mg/dL	11,609 (29.8%)	1,639 (19.8%)	2,389 (20.0%)	4,144 (37.0%)	3,437 (45.7%)
Unknown	39,691	9,776	12,628	9,979	7,308
Cannabis					
Not present	20,835 (84.1%)	4,754 (85.3%)	6,562 (85.4%)	5,743 (84.6%)	3,776 (79.8%)
Present	3,942 (15.9%)	817 (14.7%)	1,126 (14.6%)	1,043 (15.4%)	956 (20.2%)
Unknown	53,870	12,491	16,885	14,393	10,101
Current depressed mood	26,403 (33.6%)	6,147 (34.0%)	8,670 (35.3%)	7,041 (33.2%)	4,545 (30.6%)
Current partner conflict	22,658 (28.8%)	4,347 (24.1%)	6,164 (25.1%)	6,936 (32.7%)	5,211 (35.1%)
Prior suicidal ideation	11,375 (14.5%)	2,457 (13.6%)	3,237 (13.2%)	3,256 (15.4%)	2,425 (16.3%)
Prior suicide attempt	12,125 (15.4%)	2,507 (13.9%)	3,860 (15.7%)	3,418 (16.1%)	2,340 (15.8%)

[a]Morning: 0500–1059; afternoon: 1100–1659; evening: 1700–2259; night: 2300–0459.
Abbreviation: NVDRS = National Violent Death Reporting System.

24-hour average risk. Nighttime risk was greater among adolescents/young adults, those intoxicated with alcohol, and those experiencing current partner conflict, but not among those who used cannabis or were currently depressed. This study supports the Mind after Midnight hypothesis in 3 ways. First, it augments prior work by estimating the hour-by-hour change in overnight suicide risk. Second, it expands the scope of risk to include death by homicide, a distinct behavior from suicide. Third, the subgroup analyses yield circumstantial evidence for potential neurobiological mechanisms of risk.

Suicide and homicide share little in common, but their highly concordant overnight risk patterns suggest a common feature: nocturnal wakefulness. Insomnia, nightmares, substance use, shift work, and medical disease may all cause nocturnal wakefulness, but being awake when reason sleeps[4,44] likely carries a distinct risk for dysregulated behaviors. The Mind after Midnight[3] hypothesis highlights executive dysfunction, reward processing, and mood dysregulation as possible neurocognitive mechanisms of risk, and subgroup findings offer some insights into which mechanisms may be at work.

Table 2.

Demographic and Clinical Characteristics of Homicide Victims in the NVDRS by Time of Day

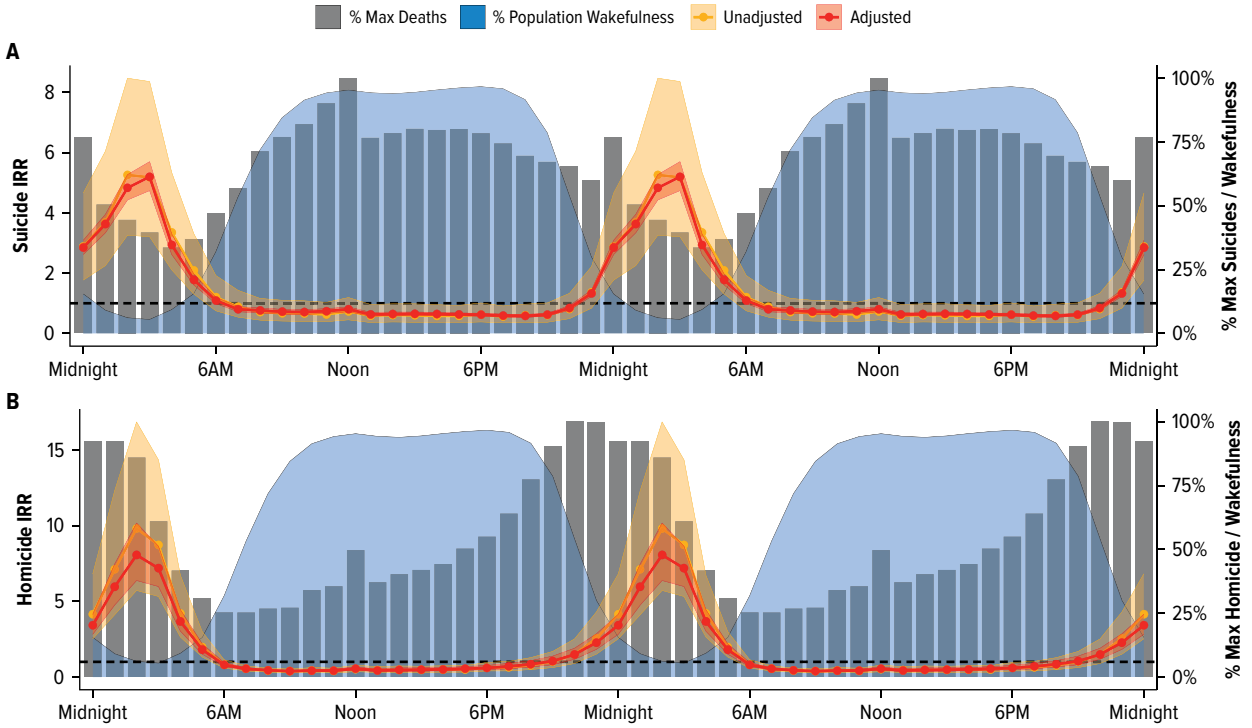
Characteristic	Total	Morning[a]	Afternoon[a]	Evening[a]	Night[a]
N	50,526	6,434	9,465	16,630	17,997
Age, y					
15–24	15,250 (31.5%)	1,385 (23.0%)	2,714 (30.5%)	5,297 (33.0%)	5,854 (33.4%)
25–34	14,355 (29.6%)	1,659 (27.5%)	2,388 (26.8%)	4,550 (28.4%)	5,758 (32.9%)
35–44	8,514 (17.6%)	1,198 (19.9%)	1,483 (16.7%)	2,819 (17.6%)	3,014 (17.2%)
45–54	5,591 (11.5%)	863 (14.3%)	1,117 (12.6%)	1,899 (11.8%)	1,712 (9.8%)
55–64	2,831 (5.8%)	491 (8.1%)	667 (7.5%)	917 (5.7%)	756 (4.3%)
65–74	1,190 (2.5%)	240 (4.0%)	316 (3.6%)	347 (2.2%)	287 (1.6%)
75+	755 (1.6%)	198 (3.3%)	213 (2.4%)	209 (1.3%)	135 (0.8%)
Unknown	2,040	400	567	592	481
Sex					
Male	41,597 (82.3%)	4,741 (73.7%)	7,507 (79.3%)	14,036 (84.4%)	15,313 (85.1%)
Female	8,928 (17.7%)	1,693 (26.3%)	1,958 (20.7%)	2,594 (15.6%)	2,683 (14.9%)
Unknown	1	0	0	0	1
Race					
White	18,079 (36.0%)	2,829 (44.2%)	3,630 (38.5%)	5,768 (34.8%)	5,852 (32.7%)
Black	28,779 (57.2%)	3,114 (48.6%)	5,197 (55.1%)	9,667 (58.4%)	10,801 (60.4%)
Asian	586 (1.2%)	99 (1.5%)	102 (1.1%)	207 (1.3%)	178 (1.0%)
Other race	2,830 (5.6%)	362 (5.7%)	496 (5.3%)	912 (5.5%)	1,060 (5.9%)
Unknown	252	30	40	76	106
Ethnicity					
Non-Hispanic	43,882 (87.9%)	5,550 (87.5%)	8,298 (88.9%)	14,468 (88.1%)	15,566 (87.4%)
Hispanic	6,020 (12.1%)	790 (12.5%)	1,033 (11.1%)	1,961 (11.9%)	2,236 (12.6%)
Unknown	624	94	134	201	195
Military service					
No	44,519 (93.8%)	5,562 (92.2%)	8,361 (93.6%)	14,768 (94.0%)	15,828 (94.3%)
Yes	2,947 (6.2%)	470 (7.8%)	572 (6.4%)	949 (6.0%)	956 (5.7%)
Unknown	3,060	402	532	913	1,213
Blood alcohol level					
No alcohol	19,518 (61.8%)	2,588 (71.3%)	4,346 (77.8%)	7,018 (66.7%)	5,566 (46.9%)
< 80 mg/dL	4,046 (12.8%)	363 (10.0%)	506 (9.1%)	1,250 (11.9%)	1,927 (16.2%)
≥ 80 mg/dL	8,040 (25.4%)	681 (18.8%)	734 (13.1%)	2,251 (21.4%)	4,374 (36.9%)
Unknown	18,922	2,802	3,879	6,111	6,130
Cannabis					
Not present	11,287 (59.4%)	1,534 (64.2%)	2,153 (58.6%)	3,603 (57.9%)	3,997 (59.5%)
Present	7,718 (40.6%)	857 (35.8%)	1,523 (41.4%)	2,620 (42.1%)	2,718 (40.5%)
Unknown	31,521	4,043	5,789	10,407	11,282
Current depressed mood	151 (0.3%)	34 (0.5%)	39 (0.4%)	45 (0.3%)	33 (0.2%)
Current partner conflict	869 (1.7%)	157 (2.4%)	201 (2.1%)	266 (1.6%)	245 (1.4%)
Prior suicidal ideation	10 (0.0%)	1 (0.0%)	1 (0.0%)	2 (0.0%)	6 (0.0%)
Prior suicide attempt	27 (0.1%)	7 (0.1%)	6 (0.1%)	7 (0.0%)	7 (0.0%)

[a]Morning: 0500–1059; afternoon: 1100–1659; evening: 1700–2259; night: 2300–0459.
Abbreviation: NVDRS = National Violent Death Reporting System.

Nighttime suicide risk varied by age and alcohol intoxication, 2 groups with reduced executive function. Individuals aged 15–24 years experienced a 3-fold greater nighttime risk for suicide, possibly because nocturnal wakefulness may test and overwhelm the limited executive functions of an immature prefrontal cortex.[37] As the prefrontal cortex matures, executive functions should strengthen and risk should diminish, as was seen in the smaller increase in risk among those aged 25–34 years. Risk for homicide did not vary by age, but young adults accounted for more than half of all homicide victims, so there may have been insufficient age-related variance to detect a pattern. The fact that homicide deaths were so highly concentrated among young adults, including overnight deaths, suggests that young adults may place themselves in positions of danger (possibly due to impaired risk/reward assessment) that older adults would avoid. Indeed, circadian misalignment appears to increase sensitivity to reward anticipation and reduce sensitivity to reward loss, particularly in young adults.[14–17,45] There was also an unexpected finding of increased suicide risk among older adults at 6:00 AM. This peak is outside the hypothesized window of risk and may stem from sleep inertia, a period

Figure 1.

Population Wakefulness–Adjusted Risks for Death by Suicide and Homicide[a]



[a]Raw case counts for suicide (A) and homicide (B) from the NVDRS were binned by clock hour and scaled to the percent of the maximum bin count (grey bars). Percent population wakefulness for each clock hour was then estimated from the ATUS (light blue shaded area). Robust Poisson regression models then estimated the IRR of suicide and homicide by clock hour. Models are unadjusted (yellow) and adjusted for age, sex, race, ethnicity, military service, currently depressed, current partner conflict, prior suicidal ideation, and prior suicide attempts (red). The shaded bands around the IRRs represent 95% CIs. The black dotted horizontal line represents an IRR of 1, meaning neither increased nor decreased risk compared to the 24-hour average. Data are double-plotted for clarity.

Abbreviations: ATUS = American Time Use Survey, IRR = incidence risk ratio, NVDRS = National Violent Death Reporting System.

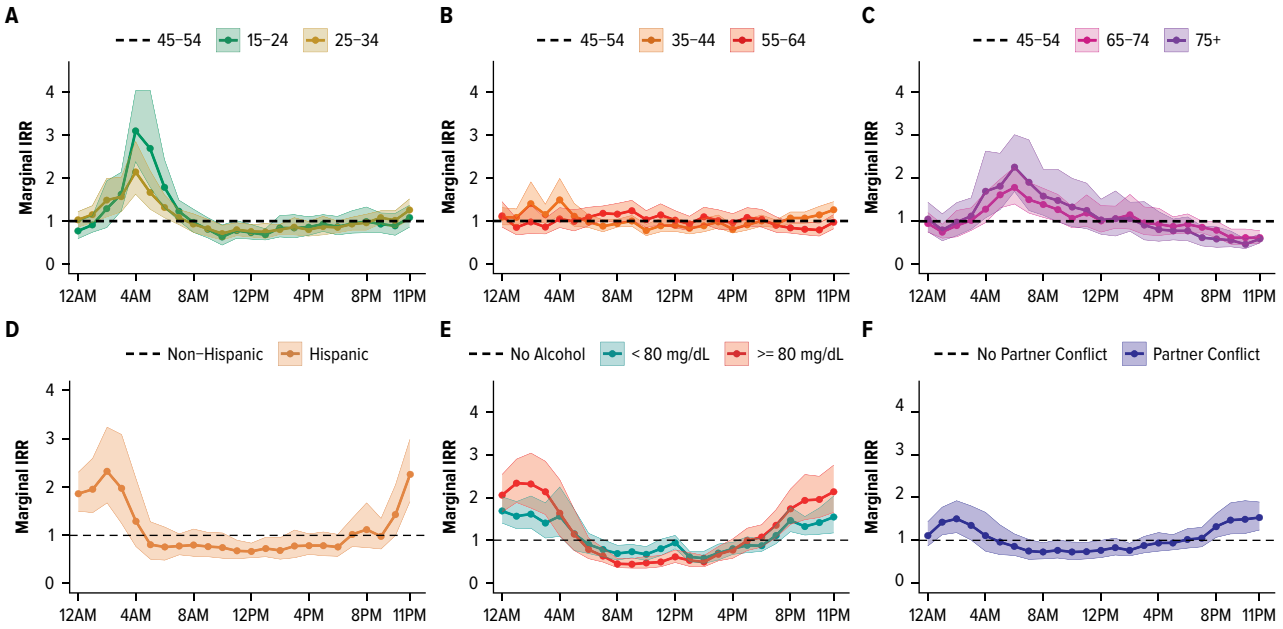
of impaired alertness and cognition following arousal. Older adults are more vulnerable to sleep inertia[46] and may experience greater deficits in executive function upon awakening that contribute to heightened suicide risk.

Alcohol intoxication correlated with greater nighttime risk for suicide and homicide. Less than half of suicides involve alcohol intoxication,[47] but alcohol acutely increases suicide risk[48,49] and represents a potent risk factor for some individuals. Alcohol also disrupts executive functions,[40] and individuals may use alcohol to enhance positive affect and/or combat negative affect,[50–53] which decline and rise at night, respectively.[10–13] Under the Mind after Midnight hypothesis, an individual experiencing nocturnal wakefulness may experience greater-than-normal negative mood (emotional dysregulation), overestimate the relief that consuming alcohol might provide (impaired risk/reward processing), and fail to control their impulses to drink (executive dysfunction). Although drinking may provide short-term relief, these benefits dissolve into greater mood dysregulation and behavioral disinhibition, thus increasing the risk for suicide or homicide. Indeed, Chakravorty and colleagues[41] found that most alcohol-related suicides occur at night, and the 2.3-fold greater rise in nighttime risk for suicide among those with an elevated BAL may represent the synergistic effects of nocturnal wakefulness and acute intoxication. Similar mechanisms may affect homicide victims by impairing their ability to perceive or mitigate the risk of imminent bodily harm. Lack of BAL data for homicide perpetrators, however, limits further interpretation.

Two groups demonstrated disproportionate overnight risk that is not clearly related to neurocognition. Hispanic individuals showed a roughly 2-fold greater risk for suicide from 11:00 PM to 3:00 AM than non-Hispanic individuals. Hispanic individuals may experience greater risk from nocturnal wakefulness due to more prevalent sleep disturbances, sleep apnea, and insufficient sleep,[54–56] as well as differences in rates of shift work or neighborhood environmental conditions (eg, noise). Women experienced an elevated risk for death by homicide between 4:00 AM and 9:00 AM. This finding is

Figure 2.

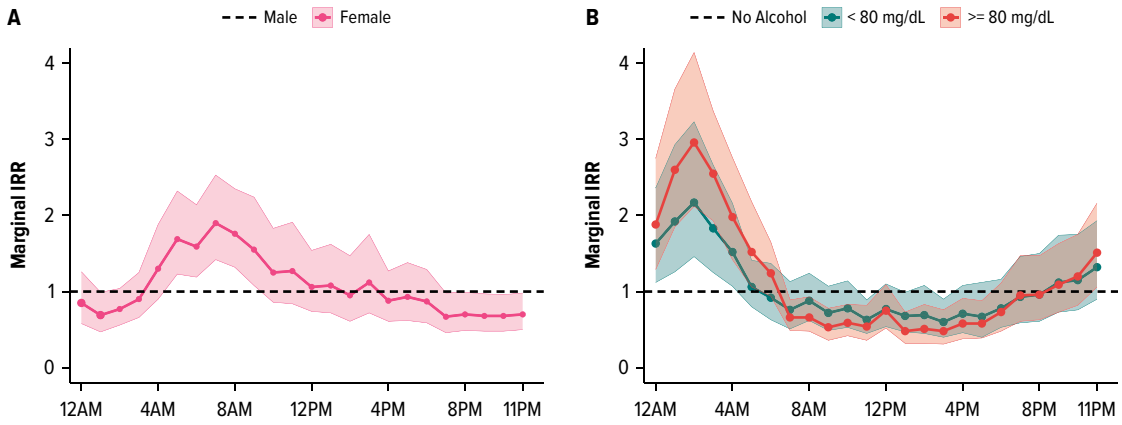
Marginal IRRs for Suicide by Significant Time-by-Subgroup Interactions[a]



[a]Hourly IRRs varied by age (A–C), ethnicity (D), blood alcohol level (E), and current partner conflict (F). The reference groups are individuals aged 45–54 years (the age group with the greatest number of suicides), non-Hispanics, those with a negative blood alcohol level, and those with no current partner conflict. The shaded bands reflect 95% CIs, and the black dotted horizontal line represents an IRR of 1.
Abbreviation: IRR = incidence risk ratio.

Figure 3.

Marginal IRRs for Homicide by Significant Time-by-Subgroup Interactions[a]



[a]Hourly IRRs varied by sex (A) and blood alcohol level (B). The reference groups were males and those with a negative blood alcohol level. The shaded bands reflect 95% CIs, and the black dotted horizontal line represents an IRR of 1.
Abbreviation: IRR = incidence risk ratio.

difficult to interpret; the risk period is substantially delayed compared to other groups, and there are no clear neurobiological reasons why women would experience greater risk at this time. A more detailed examination of individual homicide cases may be needed to identify sex-specific factors that contribute to risk, although one possibility may involve opportunity to approach potential victims during early working hours.

Several null results are worth discussing. First, in contrast with McCarthy and colleagues,[6] individuals with military service did not differ substantially in their

suicide risk patterns. There are technical differences between studies, but the most likely explanation is methodological: McCarthy et al analyzed veterans and civilians separately rather than as a formal interaction, which is the recommended approach.[57] Second, there was no significant interaction between cannabis intoxication and suicide timing. Cannabis testing may reflect consumption up to 30 days previously, and thus a positive result may not reflect acute intoxication. Acute cannabis intoxication is known to impair aspects of executive functions, especially impulse control, and thus an analysis of subjects with acute intoxication may yield different results.[58,59] Third, there was no difference in risk among those with and without prior suicide attempts. One explanation is methodological—cases where data on prior suicide attempts were missing were inappropriately categorized as not having prior suicide attempts. Alternatively, past suicidal ideation/attempts are distal risk factors that do not contribute to acute changes in suicide risk. Finally, individuals with current depressed mood did not experience increased nighttime suicide risk. One possibility is that the NVDRS measure of current depressed mood may be too broad or inaccurate to capture individuals experiencing dysregulated mood at the time of death. This is especially relevant given the lack of psychiatric diagnoses (eg, bipolar disorder or borderline personality disorder). Alternatively, nocturnal wakefulness may create an antidepressant effect through partial or total sleep deprivation.[60,61] Mood regulation may yet contribute to risk during nocturnal wakefulness, but its effect was not evident here.

The neurobiological mechanisms discussed here do not act in isolation. Disrupted sleep is a transdiagnostic marker of psychiatric illness,[62] and nocturnal wakefulness in vulnerable individuals may further increase the risk for dysregulated behaviors. Bipolar disorder, for instance, is characterized by altered rest/activity patterns,[63] and acute loss of sleep due to nocturnal wakefulness may precipitate mania.[64] The hypervigilance and nightmares of posttraumatic stress disorder may produce nocturnal wakefulness[65,66] in addition to predisposing patients to dysregulated emotional and behavioral responses. In both cases, disrupted sleep may play a role in suicidal behaviors.[67–69] Nocturnal wakefulness also occurs during an altered psychosocial landscape in which social services are closed, friends and family are asleep, and other coping strategies are unavailable. The modest increase in overnight suicide risk among individuals with partner conflicts may emerge from limited emotional self-regulation and feelings of thwarted belongingness and social isolation that contribute to suicidal thinking.[42,70] Nocturnal wakefulness may also create inadvertent opportunities for dysregulated behaviors: a violent altercation may progress to homicide because no one is present to call law enforcement, or a teenager may attempt suicide because their caregivers are asleep. Indeed, social services that might prevent dysregulated behaviors (eg, calling a therapist or peer support and escaping to a friend's house) may be unavailable at night.

The strengths of this study include the sample size and breadth of the NVDRS data as well as representative estimates of wakefulness from the ATUS. That said, the present study has a few limitations. Individuals with suicidal behavior are more likely to be awake at night,[8,9] and estimating population wakefulness from the ATUS may skew risk profiles since habitual sleep timing may differ by the presence of suicidal thinking. Future studies should derive estimates of wakefulness from more representative sources. Additionally, the NVDRS occasionally coded missing data as a negative response (ie, current depressed mood or partner conflict, prior suicidal ideation, or suicide attempt). This inappropriately obscures missingness and raises statistical power, so comparisons on these factors may not be accurate. Indeed, substantial missingness requires caution in interpreting some results (eg, alcohol and cannabis), as missing data may obscure significant patterns in hour-by-hour risk.

The outcomes presented here should be considered population-level estimates of risk that cannot be applied directly to individual cases because of the limitations of the available case data. As highlighted above, psychiatric disorders involve substantial disruptions in sleep and increase risk for suicide, and thus affected individuals may have greater vulnerability to nocturnal wakefulness. However, data related to psychiatric diagnoses within the NVDRS are derived from forensic reports (and thus susceptible to reporting bias) and demonstrated severe missingness (80% or more for all diagnoses). The consequence of this is that (1) the data do not accurately reflect who does or does not have a particular mental condition, and (2) there are insufficient data to adequately evaluate variations in hourly risk patterns for these conditions. Psychotropic substances ranging from drugs of abuse to prescription medications (particularly benzodiazepines and sedative-hypnotics) can also affect both sleep/wake patterns and suicide risk.[71] Autopsy testing for substances beyond alcohol and cannabis was not reported until 2013, however, and thus these data are not sufficiently representative (or present large enough subsamples) for further analysis. Finally, individual-level data on sleep continuity, chronotype, medical diagnoses, and socioeconomic status were not available for analysis, even though these factors are known to affect sleep and suicide risk.

Conclusion

Nearly 19% of suicides and 36% of homicides occur at night, a time when individuals may be sleep-deprived and awake when their circadian rhythms are promoting

sleep. In accordance with the Mind after Midnight hypothesis, the present study demonstrated a disproportionate nighttime risk for suicide and homicide after accounting for population wakefulness. Additional studies are needed to clarify whether evidence-based interventions to improve sleep and reduce nocturnal wakefulness can reduce risks and, in so doing, prevent these tragic outcomes.

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