Nocturnal Wakefulness and Suicide Risk in the Australian Population

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ABSTRACT

Objective: Temporal patterns for suicide over a 24-hour period have shown mixed results among prior studies. However, analyses of 24-hour temporal patterns for wakeful actions including suicidal behavior should adjust for expected sleep requirements that inherently skew such activities to conventional wakeful times. This study analyzed the time-of-day for suicide cases from the Australian population for the year 2017, adjusting for expected sleep patterns. Identification of time-of-day trends using this methodology may reveal risk factors for suicide and potentially modifiable contributors.

Methods: The Australian National Coronial Information System database was accessed, and data for completed suicide were extracted for the most recent completed year (2017). Time of suicide was allocated to one of four 6-hourly time bins across 24 hours, determined from time last seen alive and time found subsequently. Prevalence of suicide for each time bin was adjusted for the likelihood of being awake for each bin according to sleep-wake norms published from a large Australian community survey. Observed prevalence of suicide was compared to expected values predicted from likelihood of being awake across each time bin calculated as a standardized incidence ratio (SIR).

Results: For the year 2017, there were 2,808 suicides, of which 1,417 were able to be allocated into one of four 6-hourly time bins. When compared to expected values, suicides were significantly more likely to occur in the overnight bin (2301–0500; SIR = 3.93, $P < .001$).

Conclusions: Higher-than-expected rates of suicide overnight associated with nocturnal wakefulness may represent a modifiable risk factor for triggering suicide events.

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Suicide presents a substantial global public health problem, affecting both advanced and developing civilizations and culminating in more than 700,000 deaths per year worldwide.[1] In Australia, it is the leading cause of death between the ages of 15–44 years and accounts for the highest number of years of potential life lost, at approximately 105,730 years annually.[1] The need to further identify factors that predispose to or trigger suicide has become an increasing priority to inform suicide prevention strategies.

Time-of-day as a potential suicide risk factor has been previously explored, with studies producing mixed results. Some cohorts found that suicide occurred more frequently during the daytime[2,3] or varied temporally over the 24-hour period according to demographic factors.[4] However, another approach to this analysis has recognized that suicide enactment necessitates the wakeful state, for which the 24-hour temporal prevalence pattern is expected to be proportionally aligned with conventional wakeful hours. This approach proposes that 24-hour temporal analyses for wakeful activities should be adjusted for sleep requirements and based on the likelihood of being awake for a given time, as per community norms. This concept was first introduced by Perlis and coworkers,[5] who demonstrated in a United States national cohort that, when adjusted for expected likelihood of being awake for each given hour, suicide occurred 3.6-fold more frequently between the hours of 0000 (midnight) and 0600 than expected. This novel methodological approach may have exposed a temporal relationship between suicide and time-of-day that was hitherto obscured.

The findings of Perlis and coworkers[5] demonstrating higher-than-expected rates for overnight suicide may have a number of plausible contributing factors. First, the nighttime may create greater opportunity to avoid contact with other people, which is factored into the planning of suicide. Drugs and alcohol may increase impulsive actions and may have an evening predisposition. Furthermore, emerging evidence purports that nocturnal wakefulness may itself directly create a set of environmental and emotional contexts that may confer immediately heightened risk for triggering suicide among predisposed individuals.[5] Nocturnal wakefulness was shown to be positively associated with suicidal ideation in a US community sample.[6] Nocturnal wakefulness may potentially accentuate perceptions of isolation and loneliness.[7] There is also evidence of a circadian influence on

Clinical Points

- The time-of-day distribution of suicide remains unclear with mixed findings from prior studies. Analyses of the temporal pattern of wakeful actions across a 24-hour period need to adjust for the necessary requirement of sleep, which, if unaccounted for, acts to skew the relationship to conventional wakeful times.
- The demonstration of a higher-than-expected nocturnal prevalence of suicide raises the possibility that wakefulness during the nighttime presents a potential modifiable target in suicide prevention.

frontal lobe domains for executive functioning and impulse control that shows diminished activity at night[8] and in the context of sleep deprivation.[9] The tendency toward the evening timing for consumption of disinhibiting substances including alcohol identified among suicide cases may further potentiate this risk.[10] Further indirect support for the relationship between nocturnal wakefulness and suicide risk is provided by studies independently linking insomnia to suicidal ideation and suicide enactment.[11] Symptoms of insomnia are mediated by reported nocturnal wakefulness and its consequences. Sleep difficulties, which often precede and exacerbate other empirically identified downstream suicide risk factors,[11–13] are modifiable and hold considerable promise as a suicide prevention target.

Confirmatory studies exploring time-of-day influences on suicide risk are now important in the validation of them as a potential modifiable risk factor. It is unclear if findings from Perlis and coworkers[5] are specific to the United States due to regional social, demographic, or mode-of-death factors or if the 24-hour temporal pattern of suicide is generalizable to other countries. For example, the United States reports half of all suicides to be firearm related,[14] which differs significantly to other countries, including Australia. Ready access to firearms, recognized for their relative ease of facilitating suicidal ideation into action, may influence the relationship between suicide and nocturnal wakefulness. If a similar 24-hour temporal pattern for suicide is reproducible in other countries, it would provide further support for the case to more vigorously investigate potentially modifiable factors that underpin this observation. The aim of this study was to explore the 24-hour temporal pattern for completed suicides among an Australian cohort using a methodological approach that adjusts for sleep patterns derived community norms.

METHODS

Ethics approval was obtained (Reference CF/198108) to access the Australian National Coronial Information System database held by the Victorian State Coroner (https://www.ncis.org.au) to investigate the temporal pattern of suicide across a 24-hour period for the most recently available year (2017). This database stores documentation for all completed suicides in Australia.

Finalized and closed reports for completed suicides for 2017 were included in the analysis. Demographic data, medical history, and encoded descriptive details of the suicide cases were block extracted from the national database. Medical history data, sourced from the individual medical record held by the primary care physician, were extracted for each case. These data included documentation of prior mental health disorders, sleep disorders, drug usage, and previous suicide attempts. Additional information was manually entered individually by the researchers from detailed police and coronial reports. This included information recorded as to time last seen prior to suicide enactment and time found subsequently. Cases were excluded if the cause of death was not established as suicide or the coronial case was not finalized. Individuals were excluded from the 24-hour temporal analysis if allocation of the time of suicide into a pre-determined 3- or 6-hourly time bin (see the following paragraph) was not able to be determined.

Time of suicide enactment is distinct from time of death. Information for precise time at which a suicide enactment occurred was not recorded in the national database, and a time range was determined by the researchers from analysis of police and coronial reports and other documentation based on time last seen (TLS) prior to suicide and time found (TF) subsequently. TLS was established from reported interaction with witnesses or, when applicable, time of last electronic messaging, video footage, or other confirmatory evidence that the subject was alive at an identifiable time. Time of suicide enactment was allocated into 1 of 4 pre-determined 6-hourly time bins (2301–0500, 0501–1100, 1101–1700, and 1701–2300). In instances for which documentation of TLS and TF provided a sufficiently narrow time window, cases were further allocated into one of eight 3-hourly bins (2301–0200, 0201–0500, 0501–0800, 0801–1100, 1101–1400, 1401–1700, 1701–2000, and 2001–2300). Allocation to a time bin with a high level of certainty was performed if both TLS and TF data were contained within the limits of 1 of the 6-hourly or 3-hourly time bins. If TLS or TF crossed 1 of the boundaries separating 2 time bins, subjects were allocated into the bin corresponding to the middle position between TLS and TF. These subjects formed a separate category as having a moderate certainty for the allocated time bin. If the TLS and TF data crossed 2 boundaries separating adjacent 6-hourly time bins, they were considered low certainty for estimation in that time bin and excluded from the subsequent 24-hour temporal analysis. The primary endpoint was tested for the pooled moderate/high certainty 6-hourly time bin as well as the 6-hourly (high certainty) and 3-hourly time bins. Post hoc extended subgroup analysis was performed on the pooled 6-hourly moderate/high certainty groups.

The null hypothesis for a temporal pattern of suicide presumes that each clock hour has equal risk. However, this is not likely to be the case. The analysis of the temporal pattern of wakeful activities across a 24-hour period required adjusting for likelihood of being awake for each

Table 1. Demographic Data Related to Completed Suicides in 2017[a]

Variable	Total (n = 2,808)	Time of Suicide Allocated to 6-Hourly Time Bin[b]: High Certainty (n = 818)	Moderate Certainty (n = 599)	High/Moderate Certainty Pooled (n = 1,417)
State				
ACT	60 (2.1)	14 (1.7)	12 (2.0)	26 (1.8)
New South Wales	881 (31.4)	254 (31.1)	179 (29.9)	433 (30.6)
Northern Territory	47 (1.7)	11 (1.3)	16 (2.7)	27 (1.9)
Queensland	766 (27.3)	238 (29.1)	163 (27.2)	401 (28.3)
South Australia	207 (7.4)	33 (4.0)	39 (6.5)	72 (5.1)
Tasmania	65 (2.3)	22 (2.7)	16 (2.7)	38 (2.7)
Victoria	510 (18.2)	164 (20.0)	103 (17.2)	267 (18.8)
Western Australia	272 (9.7)	82 (10.0)	71 (11.9)	153 (10.8)
Age, y				
< 25	375 (13.4)	139 (17.0)	105 (17.5)	244 (17.2)
25–49	1,418 (50.5)	435 (53.2)	291 (48.6)	726 (51.2)
50+	1,015 (36.1)	244 (29.8)	203 (33.9)	447 (31.6)
Sex				
Female	687 (24.5)	188 (23.0)	141 (23.5)	329 (23.2)
Male	2,121 (75.5)	630 (77.0)	458 (76.5)	1,088 (76.8)
Employment status				
Employed	973 (34.7)	295 (36.1)	203 (33.9)	498 (35.1)
Home duties	21 (0.7)	7 (0.9)	6 (1.0)	13 (0.9)
Prisoner	3 (0.1)	1 (0.1)	1 (0.2)	2 (0.1)
Retired/pension	532 (18.9)	124 (15.2)	109 (18.2)	233 (16.4)
Student	128 (4.6)	54 (6.6)	36 (6.0)	90 (6.4)
Unemployed	727 (25.9)	193 (23.6)	161 (26.9)	354 (25.0)
Other	6 (0.2)	0 (0)	3 (0.5)	3 (0.2)
Unknown	418 (14.9)	144 (17.6)	80 (13.4)	224 (15.8)
Marital status				
Divorced	217 (7.7)	47 (5.7)	23 (3.8)	70 (4.9)
Married/de facto	938 (33.4)	341 (41.7)	244 (40.7)	585 (41.3)
Never married	772 (27.5)	213 (26.0)	181 (30.2)	394 (27.8)
Separated	330 (11.8)	86 (10.5)	56 (9.3)	142 (10.0)
Widowed	111 (4.0)	18 (2.2)	21 (3.5)	39 (2.8)
Unknown	440 (15.7)	91 (11.1)	96 (16.0)	187 (13.2)
Indigenous origin				
Indigenous	126 (4.5)	42 (5.1)	35 (5.8)	77 (5.4)
Non-Indigenous	2,298 (81.8)	682 (83.4)	491 (82.0)	1,173 (82.8)
Unknown	384 (13.7)	94 (11.5)	73 (12.2)	167 (11.8)

[a]Values are shown as n (%).
[b]Six-hourly bin high certainty group denotes subjects in which time last seen alive (TLS) and time found (TF) post–suicide enactment were both within the boundaries of 1 of 4 predefined time bins: 2301–0500, 0501–1100, 1101–1700, and 1701–2300. The 6-hourly bin medium certainty group denotes subjects in which TLS or TF post–suicide enactment crossed 1 boundary for 1 of the 4 time bins (bin allocated from the midpoint between TLS and TF).
Abbreviation: ACT = Australian Capital Territory.

time bin. The rationale for this methodology is described in detail in the sentinel publication[5] and subsequent narrative review[15] published by the coauthors of the current article. Data for percentages of the Australian population expected to be awake across any hour were estimated from the sleep/wake patterns of a sample of 1,966 subjects who provided completed sleep diary data from a national survey[16] sampling 2,044 invited participants conducted in March and April 2019 that reflected a broad composite of the Australian adult community.

Statistical Analysis

The key endpoint was the prevalence of suicide observed for each time bin compared to the expected prevalence for that time bin derived from population sleep/wake data expressed as a standardized incidence ratio. The proportion of the population awake in the Australian national survey was used to compute the expected number of suicides in each time bin for comparison to observed values. Comparisons of observed and expected proportions of suicides across time bins were performed using the χ^2 goodness-of-fit test. A significant result would indicate that at least one time bin was different from the rest. To evaluate the degree to which the prevalence at each time bin deviated from expected, standardized incidence ratios (SIRs) and the corresponding 95% confidence intervals (CIs) were estimated using previously described methodology.[5] Subgroup analyses for age categories, sex, alcohol intake, previous suicide attempt, mode of death, and prior sleep history were performed and compared to age- and sex-matched subsets from the national survey cohort. Effect sizes were determined by calculating the phi (ϕ) value by taking the square root of

Table 2. Descriptive Data for Completed Suicides in 2017[a]

Variable	Total (n = 2,808)	Time of Suicide Allocated to 6-Hourly Time Bin[b]		High/Moderate Certainty Pooled (n = 1,417)
		High Certainty (n = 818)	Moderate Certainty (n = 599)	
Poor sleep reported	389 (13.9)	100 (12.2)	97 (16.2)	197 (13.9)
Prior suicide attempt	843 (30.0)	248 (30.3)	179 (29.9)	427 (30.1)
Diagnosed mental illness				
Yes	1,666 (59.3)	485 (59.3)	360 (60.1)	845 (59.6)
No	867 (30.9)	253 (30.9)	177 (29.5)	430 (30.3)
Suspected	275 (9.8)	80 (9.8)	62 (10.4)	142 (10.0)
Known history of drug use	668 (23.8)	201 (24.6)	149 (24.9)	350 (24.7)
Positive toxicology results				
Alcohol	998 (35.5)	256 (31.3)	216 (36.1)	472 (33.3)
Benzodiazepines	833 (29.7)	234 (28.6)	173 (28.9)	407 (28.7)
Cannabis	347 (12.4)	128 (15.6)	67 (11.2)	195 (13.8)
Methamphetamine	269 (9.6)	83 (10.1)	61 (10.2)	144 (10.2)
Opioids	513 (18.3)	128 (15.6)	89 (14.9)	217 (15.3)
Antidepressants	902 (32.1)	229 (28.0)	190 (31.7)	419 (29.6)
Antipsychotics	390 (13.9)	120 (14.7)	80 (13.4)	200 (14.1)
Poisons	116 (4.1)	24 (2.9)	28 (4.7)	52 (3.7)
Mode of suicide				
Asphyxia (hanging)	1,510 (53.8)	397 (48.5)	400 (66.8)	797 (56.2)
Drug toxicity	401 (14.3)	57 (7.0)	69 (11.5)	126 (8.9)
Firearm	146 (5.2)	64 (7.8)	17 (2.8)	81 (5.7)
Other	897 (31.9)	364 (44.5)	130 (21.7)	494 (34.9)

[a]Values are shown as n (%).
[b]Six-hourly bin high certainty group denotes subjects in which time last seen alive (TLS) and time found (TF) post–suicide enactment were both within the boundaries of 1 of 4 predefined time bins: 2301–0500, 0501–1100, 1101–1700, and 1701–2300. The 6-hourly bin medium certainty group denotes subjects in which TLS or TF post–suicide enactment crossed 1 boundary for 1 of the 4 time bins (bin allocated from the midpoint between TLS and TF).

the result of dividing the χ^2 value by the sample size. Small, medium, and large effect sizes were reported as 0.2, 0.4, and 0.8, respectively.

RESULTS

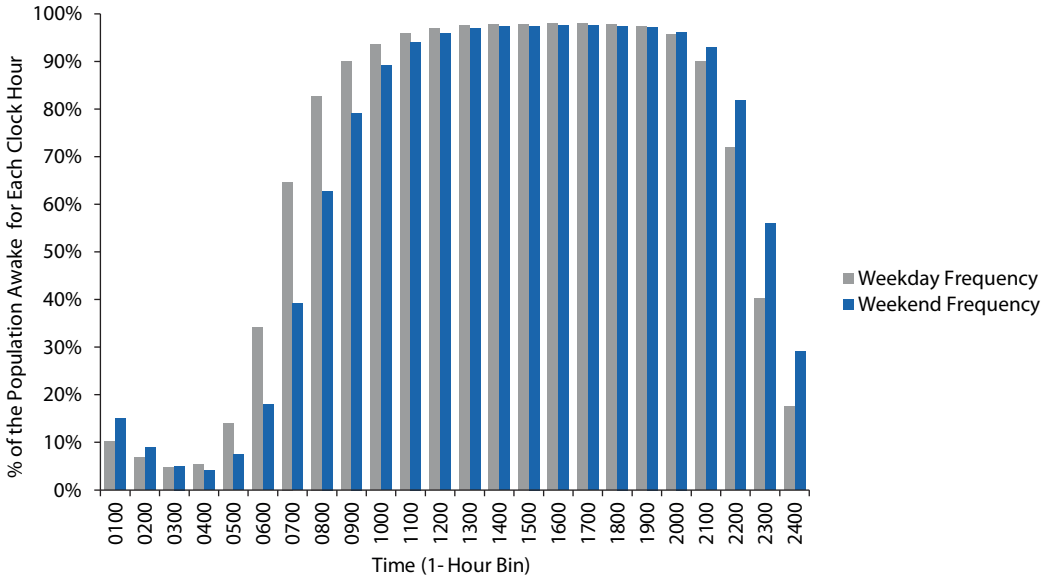
A total of 2,808 cases were analyzed from the 2017 Australian National Coronial Information System database for death by suicide. Demographic details and background information for these cases are provided in Tables 1 and 2. The male-to-female ratio was 3.1:1. Known prior mental health disorders represented 59.3% of the cohort, whereas 30.9% had no known history of mental illness. Prior drug use was documented in 23.8% of subjects. A history of sleep disturbance was recorded in 13.9%. Suicide by hanging was the most prevalent mode (53.8%), and firearms were used infrequently (5.2%).

Of the total cohort, there were 1,417 cases able to be allocated into 1 of the 4 pre-determined 6-hourly bins according to the time of suicide enactment. Demographic differences between cases included in the analysis compared to those in which time of suicide enactment was not able to be allocated into a time bin are shown in Tables 1 and 2. From among the 1,417 cases, 818 subjects were allocated into a 6-hourly bin with high certainty and the remaining 599 subjects allocated into a 6-hourly bin with medium certainty. Of the total included in the analysis, 608 were able to be allocated into a 3-hourly time bin.

Figure 1 depicts the probability of being awake for each clock hour from Australian population survey data.[16] Tables 3 and 4 provide the raw and adjusted data for time of suicide allocated to the 6- and 3-hourly time bins. When adjustment was made for the likelihood of being awake based on population norms, individuals were significantly more likely to enact suicide between the hours of 2301 and 0500 than predicted (pooled high/medium certainty groups: SIR = 3.93, $P < .001$; high certainty group: SIR = 3.64, $P < .001$; medium certainty group: SIR = 4.32, $P < .001$; Table 3). Furthermore, there was a lower-than-expected rate of suicide for the time bins 1101–1700 (SIR = 0.86, $P = .002$) and 1701–2300 (SIR = 0.87, $P = .006$). Among cases for which time of suicide was allocated into 3-hourly bins, there was a much greater likelihood of suicide between the hours of 0201 and 0500 (SIR = 6.00, $P < .001$) than expected (Table 4).

The 24-hour temporal pattern of suicide was evaluated by age, sex, alcohol consumption, prior suicide attempt, mode of death, and prior sleep history for the combined high/medium certainty 6-hourly bins (Table 5) after adjusting for likelihood of being awake. The pattern of higher-than-expected rates of suicide between 2301 and 0500 was demonstrated across all subgroups. Suicide in conjunction with the ingestion of alcohol demonstrated the strongest relationship to the 2301–0500 time bin (SIR = 6.03, $P < .001$). Drug intoxication as the mode of suicide also demonstrated a high prevalence of suicide in the overnight time bin (SIR 5.7, $P < .001$) Effect size measured by ϕ for subgroup analysis is depicted in Table 5. This analysis demonstrated a clinically important effect of the 2301–0500 time bin on suicide enactment for all subgroups. The most pronounced

Figure 1. Proportion of Population Self-Reported Sleep-Wake Times From 2019 Australian Community Survey (N = 1,966)[a]



[a]Data from Appleton et al.[16]

Table 3. Time of Suicide Allocated to 6 Hourly Time Bins[a]

Time Bin	Cohort Total 2017 (n = 2,808)	Pooled High/ Moderate Certainty Unadjusted (n = 1,417)	SIR Adjusted	*P*	95% CI	High Certainty Unadjusted (n = 818)	SIR Adjusted	*P*	95% CI	Moderate Certainty Unadjusted (n = 599)	SIR Adjusted	*P*	95% CI
2301–0500	599 (21.3)	217 (15.3)	3.93	< .001	3.42–4.47	116 (14.2)	3.64	< .001	3.00–4.33	101 (16.9)	4.32	< .001	3.52–5.21
0501–1100	477 (17.0)	359 (25.3)	0.92	.1	0.82–1.01	198 (24.2)	0.88	.06	0.76–1.00	161 (26.9)	0.97	.73	0.83–1.13
1101–1700	637 (22.7)	452 (31.9)	0.86	.002	0.79–0.95	265 (32.4)	0.88	.03	0.78–0.99	187 (31.2)	0.85	.02	0.73–0.97
1701–2300	407 (14.5)	389 (27.5)	0.87	.006	0.79–0.96	239 (29.2)	0.93	.23	0.81–1.05	150 (25.0)	0.79	.004	0.67–0.93
Excluded	688 (24.5)												

[a]Values are shown as n (%) unless otherwise noted. Raw and standardized incidence ratio (SIR) values adjusted for proportion of population awake expected for each corresponding time bin.

Table 4. Time of Suicide Allocated to 3-Hourly Time Bins[a]

3-Hour Time Bin	High Certainty, Unadjusted (n = 608), n (%)	SIR Adjusted	*P*	95% CI
2301–0200	24 (3.9)	1.56	.05	1.2–2.25
0201–0500	50 (8.2)	6.00	< .001	4.45–7.78
0501–0800	105 (17.3)	1.67	< .001	1.36–2.0
0801–1100	85 (14.0)	0.81	.05	0.65–0.99
1101–1400	101 (16.6)	0.90	.32	0.73–1.09
1401–1700	93 (15.3)	0.83	.07	0.67–1.01
1701–2000	85 (14.0)	0.76	.01	0.61–0.93
2001–2300	65 (10.7)	0.81	.09	0.62–1.01

[a]Raw and Standardized Incidence Ratio (SIR) adjusted for proportion of population awake expected for each corresponding time bin.

effect size for this association was again demonstrated for related alcohol consumption (effect size = 1.05).

DISCUSSION

This study demonstrates a disproportionately higher-than-expected number of suicides between the hours 2301 and 0500 when accounting for the percentage of people predicted to be awake across that time bin. Furthermore, for the subset allocated to a 3-hourly time bin, the 0201–0500 bin demonstrated the highest frequency of events when compared to expected. Finally, the daytime and evening time bins 1101–1700 and 1701–2300 showed lower-than-expected frequency of events. These findings are consistent across the age, sex, and mode-of-death categories. Subgroup analysis revealed that the coadministration of alcohol was much more likely to be associated with suicide at night.

Our findings are similar to those of Perlis and workers,[5] who first proposed adjusting for likelihood of wakefulness when examining temporal relationships for suicide. Their large US national sample revealed that suicide occurred 3.6-fold more frequently between the hours of 0000 (midnight) and 0600 than expected. Their findings indicated the hour in which suicide occurred most significantly more than expected was 0200–0259. Similarly, we found suicide occurred 3.9-fold more frequently than expected between 2301 and 0500, and the strongest association was in the 0201–0500 subgroup (SIR = 6.00, *P* < .001). The similarities

Table 5. Subgroups Analysis for Moderate/High Certainty 6-Hourly Time Bins[a]

Variable	6-Hourly Time Bin, SIR (95% CI)				Time Bins: Morning vs Afternoon vs Evening vs Night		
	Night: 2301–0500	Morning: 0501–1100	Afternoon: 1101–1700	Evening: 1701–2300	χ^2	ϕ	*P*
Overall					404.222	0.529	<.0001
Sex							
Female	4.20 (3.19–5.35)	0.79 (0.62–0.99)	0.87 (0.72–1.05)	0.90 (0.73–1.09)	145.118	0.664	<.0001
Male	3.74 (3.18–4.34)	0.96 (0.86–1.08)	0.86 (0.77–0.96)	0.85 (0.76–0.95)	328.125	0.549	<.0001
Age, y							
<25	2.74 (2.01–3.57)	1.08 (0.82–1.38)	0.70 (0.54–0.89)	0.91 (0.72–1.13)	62.099	0.504	<.0001
25–49	4.20 (3.47–4.99)	0.85 (0.73–0.98)	0.80 (0.69–0.91)	0.98 (0.86–1.11)	298.604	0.642	<.0001
50+	3.75 (2.81–4.83)	1.00 (0.83–1.18)	1.07 (0.92–1.23)	0.64 (0.51–0.78)	127.357	0.534	<.0001
Suicide method							
Asphyxia (hanging)	3.73 (3.08–4.44)	0.92 (0.80–1.05)	0.83 (0.73–0.94)	0.93 (0.82–1.06)	244.187	0.554	<.0001
Drug Toxicity	5.70 (3.79–8.01)	0.69 (0.44–0.99)	0.82 (0.58–1.10)	0.90 (0.63–1.22)	113.852	0.951	<.0001
Other	3.79 (2.97–4.71)	0.97 (0.82–1.15)	0.93 (0.80–1.08)	0.76 (0.63–0.90)	163.587	0.575	<.0001
Known prior suicide attempt?							
Yes	4.20 (3.28–5.25)	0.78 (0.63–0.95)	0.93 (0.78–1.08)	0.88 (0.73–1.05)	173.772	0.638	<.0001
No	3.81 (3.22–4.45)	0.98 (0.86–1.10)	0.84 (0.75–0.93)	0.86 (0.76–0.97)	314.653	0.564	<.0001
Positive toxicology results							
Alcohol	6.03 (4.96–7.20)	0.84 (0.69–1.01)	0.53 (0.43–0.64)	1.07 (0.91–1.24)	522.892	1.053	<.0001
No alcohol	2.88 (2.35–3.45)	0.95 (0.84–1.08)	1.03 (0.93–1.14)	0.77 (0.67–0.87)	145.091	0.392	<.0001

[a]Post hoc subgroup analysis, showing standardized incidence ratio (SIR) for observed rate of suicide occurring for each time bin compared to expected values after adjustment for likelihood of being awake across corresponding time period. Chi-square and phi values (effect size) assessing whether the distribution of suicide across the 24-hour period differed from chance accounting for the proportion of the population awake in subgroup analysis.

in the key findings between the two studies are demonstrated despite differences between the two cohorts, particularly in relation to firearm usage, which was low in Australia.

There are several explanations for these observations. One possibility is that the relative seclusion of the nighttime may present a set of conditions more favorable for a planned suicide. Another hypothesis proposes that nocturnal wakefulness is itself a risk factor for suicide and as such presents a potentially modifiable target.[6] The interpersonal theory of suicide postulates that suicide results from the combined effects of an increased desire for, and capability of, attempting suicide.[17] Suicidal desire is hypothesized to be attributed to a sense of thwarted belongingness or burdensomeness. Perceived thwarted belongingness may be heightened through a more acute sense of loneliness, exacerbated by nocturnal wakefulness. In addition, nocturnal wakefulness may more directly affect capability of suicide through hyperarousal, diminishing fear, and diminished impulse control, which are under circadian influence.[8] Our findings demonstrated that the higher-than-expected rates of suicide overnight were more pronounced in individuals who had consumed alcohol, potentially providing additive contributions to disinhibition and impulsive behavior. This observation may not necessarily be explained by a bias attributable to a social predisposition to evening alcohol consumption, as suicide was shown to be more likely to occur between the hours of 0201 and 0500 more so than in the 2301–0200 time bin. Although all modes of suicide demonstrated a pattern of higher-than-expected rates of suicide across the 2301–0500 time bin, the mode revealing the greatest overnight predisposition was suicide caused by drug toxicity, which may, again, infer higher rates of impulsive action as opposed to pre-planning.

The role of wakefulness as a triggering factor for suicide is a hypothesis that presupposes the timing of suicide would more frequently align directly with nocturnal wakefulness, a concept that has not garnered support from prior studies in which raw suicide patterns across a 24-hour period failed to demonstrate a nocturnal trend.[3] Similarly, our raw data do not depict an obvious trend toward nocturnal suicide. However, it is expected the prerequisite for sleep should inevitably skew the association to typical wakeful hours. By accounting for this, we expose a temporal pattern toward higher-than-expected rates of suicide overnight, which may present a potentially modifiable target. The significance of nocturnal wakefulness as a suicide risk factor may extend to insomnia syndromes, which are shown to be an independent predictor of suicide.[11] Several studies have shown that thwarted belongingness significantly accounts for the relationship between insomnia and suicidal ideation[7,18,19]

This study has a several limitations. In the Australian coronial database, no official attempt is made to estimate a precise time of suicide. Consequently, the time of suicide enactment was unable to be pinpointed and a range was determined by our research group by allocating into pre-specified time bins based on TLS and TF. Other studies examining time of suicide have adopted similar methodology.[2,3] This was addressed, when possible, by performing subgroup analysis on cases in which TLS and TF allowed for allocation to narrower (3-hourly) time bins. However, a time of suicide enactment was not able to be determined in nearly half the cases. We cannot exclude the possibility that, in cases in which there were longer timeframes for discovery of the suicide, there may have important differences affecting the findings. However, there are no major demographic differences observed among those included in the temporal analysis compared to ineligible cases that would suggest this would be likely.

One further limitation relates to the use of reported sleep habits of a general community sample to establish expected

rates of nocturnal activity leading to suicide among the index population. The collective or averaged prior sleep habits of the population with completed suicide are unknown, and attempts at producing a matched comparator sample require a level of assumption. It is possible that the sleep habits of the index population include higher rates of sleep disturbance than those of the general population. However, much of the established literature draws from cohorts with established sleep disturbance that predict suicidal thoughts and behaviors with no established bidirectional relationship to inform an estimation of sleep patterns of a heterogeneous suicide population.[20] Our findings provide a basis for future research to further describe the prevalence of sleep disturbance among suicidal populations that will incrementally advance our understanding of this relationship.

Finally, our research methodology is unable to attribute causation to our findings. While we provide evidence in support for the role of nocturnal wakefulness as a potential risk factor for suicide, it remains possible that the nighttime is an environment potentially of diminished contact with other people that may be conducive for enacting a pre-planned suicide, rather than a trigger factor itself. Nonetheless, our findings highlight the need for prioritizing further prospective research required to test this hypothesis.

As sleep is an essential biological function, its disruption has wide-ranging consequences on physical, cognitive, and mental performance. Nocturnal wakefulness, episodically or as a manifestation of an underlying sleep disorder, may affect aspects of cognition and behavior, which could lead to immediate effects on suicidal tendency. This risk association may contribute to the collective factors that predispose to or trigger suicide. Our findings support a case for more intensive work to better uncover the causal factors that underpin the association between nocturnal wakefulness and suicide risk.

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Additional information: The Australian National Coronial Information System database (https://www.ncis.org.au) is maintained by the Victorian state coroner. It is a confidential database that is accessible upon request for the purposes of research by a recognized research institute. Approvals for access to the database requires a research submission to the Victorian state coroner including ethics approval from local institute.

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