

The risk of repeated self-harm and suicide after emergency department presentation with self-harm in mental health presenters: a retrospective cohort study with data linkage in Queensland, Australia



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Summary

Background Presentation to the emergency department (ED) with an index episode of self-harm is recognised as a risk factor for subsequent repeated self-harm and suicide. We describe demographic and clinical characteristics of adults (>18 years) presenting with mental health problems and self-harm to EDs in Queensland, Australia, and identify risk factors associated with repeated self-harm and suicide.

Methods This was a state-wide retrospective cohort study of adults presenting with an index self-harm presentation to any of the 27 public EDs in Queensland, Australia, over six years (1st January 2012 to 31st December 2017). We linked ED records with a state-wide death register. Primary outcomes were re-presentation with self-harm, or death by suicide. We constructed a multivariable Cox regression model to identify independent risk factors for re-presentation with self-harm, or death by suicide. We calculated the risk of repeated ED presentation for self-harm and suicide at 12- and 24-months.

Findings During the study period, 43,797 individuals presented to Queensland EDs with a self-harm related diagnosis. Half of the cohort were female (n = 20,980, 47.9%) and under age 35 (n = 23,871, 54.5%). A quarter (n = 10,991; 25.1%) had a repeated episode of self-harm and 515 (1.2%) died by suicide. Socioeconomic disadvantage, arrival by ambulance, self-presentation, small/medium hospital size, less-urgent triage category, not admitted status and

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previous mental health or physical health visits were associated with a re-presentation with self-harm. Suicide was associated with male sex, older age, and hospital admission. The repeated self-harm risk was 18.9% (95%CI, 18.5%–19.3%) at 12-months and 24.3% (95%CI, 23.9%–24.7%) at 24-months. The suicide risk was 0.7% (95%CI, 0.6%–0.7%) at 12-months and 1.0% (95%CI, 0.9%–1.1%) at 24-months.

Interpretation One in four people re-presented to ED with self-harm. Suicide was particularly associated with older males. Implementing evidence-based interventions to support people presenting to ED with self-harm should be a public health priority.

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Keywords: Data linkage; Emergency department; Mental health; Intentional self-harm; Suicide

Research in context

Evidence before this study

People who present to the emergency department (ED) with intentional self-harm are at increased risk of re-presentation with self-harm, and of death by suicide. A 2019 cohort study by Knipe et al. in Sri Lanka examined risk of repeated self-harm and suicide following an index presentation of self-harm in 2259 individuals. There was a higher risk of repeated self-harm in men than women (hazard ratio 2.0, 95%CI 1.3–3.2, $p = 0.0021$) and in individuals age over 56 years compared with those aged 10–25 years (hazard ratio 16.1, 95%CI 4.3–59.9, $p = 0.0027$). The study was conducted in a low-middle income country. To our knowledge, there are no similar large-scale studies conducted in the Australasian region.

Added value of this study

Previous studies have focused on a select number of hospitals or single sites. From a cohort of mental health presenters, we examined every public ED presentation in the state of Queensland, Australia, over a six-year period (2012–2017). For those individuals presenting to ED with mental health problems and intentional self-harm, we linked ED

presentations to death records to allow for longitudinal follow up. To our knowledge, this is the first study to examine such a large number of presentations (43,797 adults) over an extended time frame. During the observation period 10,991 (25.1%) individuals re-presented with self-harm and 515 (1.2%) died by suicide. Older male adults were at particular risk of death by suicide following index ED presentation with self-harm. We identified the ED short stay unit as a target for future intervention for self-harm and suicide prevention.

Implications of all the available evidence

Re-presenting to ED with self-harm is common, warranting continued efforts to enhance holistic and integrated continuity of care for this group of patients, their families, and clinicians. We identified older males as being at particular risk for subsequent death by suicide following an index self-harm presentation. Patients admitted to the ED short stay unit following their index self-harm presentation were less likely to re-present with self-harm. Our findings are consistent with previous research. The ED short stay unit offers a location for future intervention in self-harm and suicide prevention.

Introduction

Globally each year, over ~700,000 people die by suicide.¹ For each suicide, there are ~20 suicide attempts.² In Australia in 2021, there were 3144 suicide deaths,³ exceeding deaths due to influenza and pneumonia (2287 deaths in 2020) and cardiac arrhythmia (2401 deaths in 2020).⁴ The direct and indirect economic costs of suicide and suicide attempts have been estimated at AU\$1.6–6.0 billion annually.⁵ Presentations to the emergency department (ED) with self-harm have been linked to subsequent death by suicide.⁶

The ED is a major point of contact for people with mental health problems (including self-harm). It may be the only option for people seeking help in a mental

health crisis.^{7–9} Previous studies undertaken in Sri-Lanka and England have described the link between people presenting to ED with self-harm and the increased risk of repeated self-harm and death by suicide.^{10–12} These studies have focused on a select number of hospitals or a particular region and highlighted the importance for awareness regarding the association between ED attendance and subsequent suicide. The examination of a large region within Australia would help to understand the risk of repeated self-harm and suicide associated with an initial ED presentation of self-harm.

In adults presenting with mental health problems and self-harm to public EDs in the state of Queensland,

Australia, over a six-year period (2012–2017), with linked ED and death records, we aimed to:

1. Examine the demographic profile and ED clinical characteristics;
2. Calculate the risk of repeated ED presentation with self-harm at 12- and 24-months after the index self-harm ED presentation;
3. Calculate the risk of suicide at 12- and 24-months after the index self-harm ED presentation;
4. Identify independent risk factors for repeated self-harm and suicide.

Methods

Study design, participants, and setting

This was a retrospective cohort study embedded within a larger study focussed on all mental health-related ED presentations made by adults (≥ 18 years) to all public EDs in Queensland, Australia over a six-year period from January 1, 2012, to December 31, 2017. Derived using retrospective data from the larger study, the sample for the present study comprised adults with ≥ 1 self-harm presentation (which we defined as: ED ICD-10 Diagnosis code X60-X84: intentional self-harm; R45.81: suicidal ideation) to any ED over the 6-year period. The primary outcomes were repeated self-harm ED presentation and death by suicide. This study was approved by the Gold Coast Hospital and Health Service (GCHHS) and Griffith University Human Research Ethics Committees (HREC/17/QGC/243, Project ID 37433).

Time at risk was from the self-harm index presentation to the right-censoring date. For repeated ED presentation with self-harm, the right-censoring date was the first repeated self-harm presentation date, death date (in months), or study end date (31st December 2017). For death by suicide, the right-censoring date was the death date or study end date.

Procedures

ED data (from Queensland's Emergency Data Information System and Emergency Data Collection¹³) and death data (from Queensland's Registry of Births, Deaths, and Marriages¹⁴) used for this study were derived from the larger mental health study whereby Data Linkage Queensland¹⁵ had independently and probabilistically linked ED records and state death records. This linkage encompassed the principal diagnoses (ICD-10-AM codes) of F40-48 Neurotic disorders, F10-F19 Substance use disorders, T38-T51 Poisoning, F00-F09 Organic disorders, X60-84 Intentional self-harm, F30-F39 Mood Disorders, R45 Emotional state, F99 Unspecified mental disorder, F20-F29 Schizophrenia, other diagnoses consistent with mental health problems (F50-F59, F60-F69, F90-F98, F80-F89, and F70-F79), and Queensland-specific presenting complaint codes (provisional

diagnoses assigned on triage) consistent with mental health problems (11002: anxiety/agitation, 30005: suicidal-homicidal ideation, 9038: overdose/toxic exposure, 30000: mental health, 30003: mood disturbance, 30001: addition/dependency, 16003: hallucinations, and 30002: eating disorder).

From the ED data, data relating to the index self-harm presentation were used and included the person identifier, event identifier, presentation date and time, patient demographics (sex, age, post code), and ED characteristics (principal diagnosis [ICD-10 AM], mode of arrival, triage category, episode end status).

ED and death data were linked via a person identifier. From the death register, the following variables were used: person identifier, date of death, age group, and underlying cause of death (ICD-10-AM), which included specific causes of suicide.

Data from the index ED presentation were coded as follows. Age was recoded into 10-year age categories. Triage was the Australasian Triage Scale (ATS) categories (1: most urgent, should receive immediate assessment and treatment to 5: non-urgent, should receive assessment and treatment within 2 h).¹⁶ Residential postcodes were used to ascertain residential remoteness and socioeconomic disadvantage. Residential remoteness (major cities, inner regional, outer regional, remote, very remote) was classified using the Accessibility/Remoteness Index of Australia (ARIA), which categorises geographic regions by service centre proximity.^{17,18} Socioeconomic disadvantage (quintiles: 1-most disadvantaged to 5-least disadvantaged) was classified using the Index of Relative Socio-Economic Disadvantage (IRSD).¹⁹ We mapped facility peer groups (i.e., type of hospital: principal referral and women's hospitals, large hospitals, medium hospitals, small acute hospitals) using Australian Institute of Health and Welfare categories.²⁰ Mode of arrival (ambulance, self-presentation, police) and episode end status (not admitted to hospital, admitted to ED short stay unit (SSU) or observation ward, admitted to other hospital ward) was categorised following earlier work.²¹

The two factors of ED visits of other mental health and physical health visits during the study period (categorised as $n = 0$ or ≥ 1 visit) were derived using the person identifier, event identifier, and principal diagnosis. These visits could occur before or after the index self-harm presentation. Mental health visits excluded the index presentation and repeated self-harm presentation and were based on the principal diagnoses and presenting complaint codes used for linkage/the larger cohort study and are listed above. Physical health visits were all other visits that were not defined as intentional self-harm or mental health.

Statistical analysis

Descriptive statistics (frequencies and percentages) were used to analyse the demographics of the cohort and

index self-harm presentation characteristics. The incidence of repeated self-harm and suicide were calculated using incidence rates (IRs, 95% CI) (*n* per 100 person-years).

Risk (%) of re-presentation to ED with self-harm or death by suicide was calculated using Kaplan–Meier estimators as 100% minus survival (%). From the survival curves, we extracted estimated risk at 12- and 24-months post-index self-harm presentation.¹⁰

To identify risk factors for repeated self-harm and suicide, unadjusted and multivariable-adjusted hazard ratios (HRs) with 95% CIs were calculated from Cox regression modelling. The multivariable model adjusted for all measured patient and event characteristics. Reference categories were separately selected for each variable and for repeated self-harm and suicide based on the smallest unadjusted non-zero IR for each stratum/outcome grouping.

Analyses were performed using Python 3.9.4 (pandas, numpy, PIL modules) and R 4.0.5 (survival, adjusted Curves, ggplot2 libraries).

An extensive sensitivity analysis was conducted examining interchangeability of X60-X84 and R45.81 codes.

Role of the funding source

The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of

the manuscript; and decision to submit the manuscript for publication.

Results

Cohort description and demographics

In 2012–2017, 43,797 adults presented to public EDs in Queensland with self-harm, representing ~20% (*n* = 222,669) of all people diagnosed with a mental health problem in the ED during this time (Fig. 1). Approximately one quarter (*n* = 10,991, 25.1%) re-presented to ED with self-harm during the study period. Of these patients, the majority (74.9%) re-presented for self-harm only once during the study period (Supplemental eFig. 1). Approximately 1 in 100 patients (*n* = 515, 1.2%) died by suicide during the study period. Most deaths by suicide were from hanging, strangulation, or suffocation (X70; 58.1%), followed by poisoning (X60-X69, 24.9%) (Supplemental eFig. 2).

Approximately half of patients presenting to ED with an index presentation of self-harm were male (52.1%), were between 18 and 34 years of age (54.5%), resided in major cities (47.9%), arrived by ambulance (48.8%), and presented to large hospitals (41.7%) (Fig. 2). The two most socioeconomically disadvantaged quintiles were more frequently represented (43.1%) than were the two least disadvantaged quintiles (32.1%). The most common triage was category 3 (urgent, see within 30 min), assigned to 63.4% of patients. Most patients were

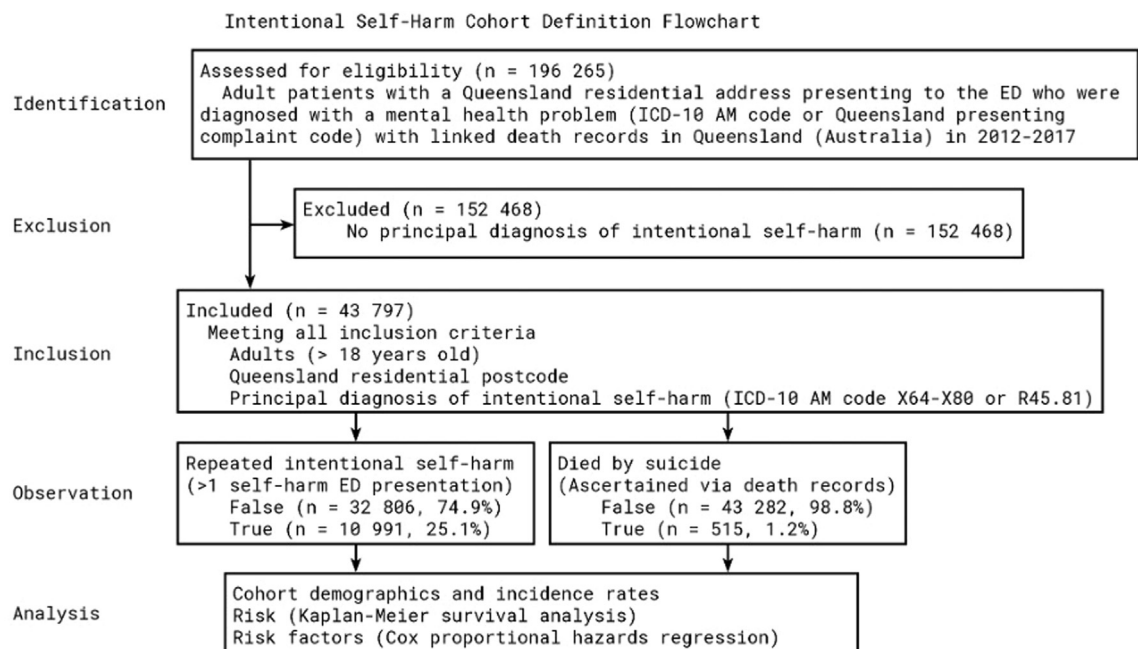


Fig. 1: Flow diagram of included patients. From the larger mental health cohort data linkage, those without a principal diagnosis of self-harm were excluded and those with a principal diagnosis of self-harm were retained.

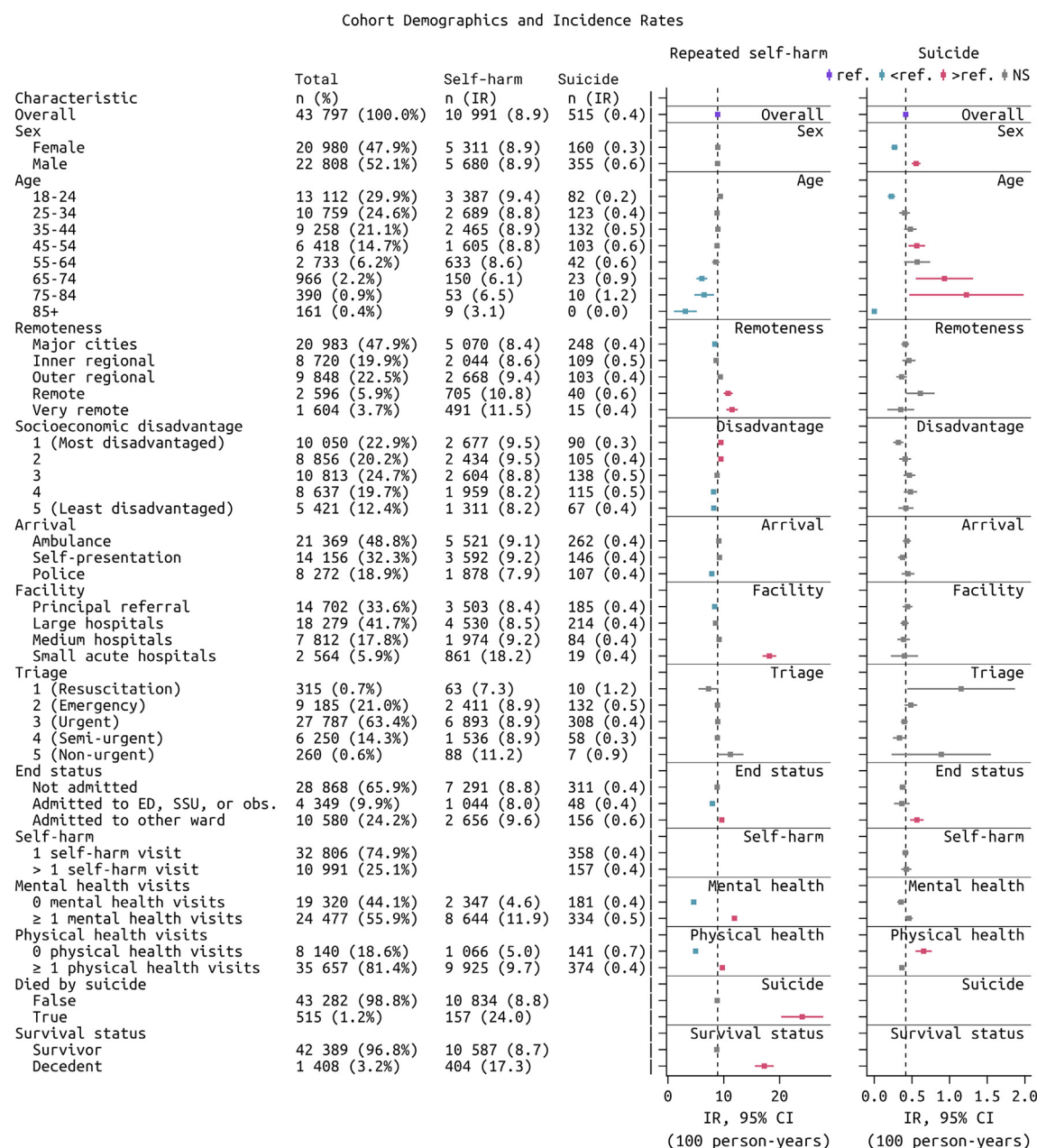


Fig. 2: Cohort demographics and Incidence Rates (IRs) of repeated self-harm and suicide. 'Self-harm' column is those patients with repeated episode of self-harm. 'Suicide' column is those patients who subsequently died by suicide. Red indicates higher IRs (normalised by person-time) compared with overall. Blue indicates lower IRs. 95% CIs are presented in [Supplemental eTable 1](#). n = number; IR = incidence rate; 95% CI = 95% confidence interval; NS = non-significant; Ref. = reference.

discharged from the ED (65.9%), 34.1% were admitted (24.2% admitted to hospital, 9.9% admitted to ED SSU or observation unit).

Fig. 2 depicts IRs for repeated self-harm ED presentation and death by suicide (see [Supplemental eTable 1](#) for IRs and 95% CIs). For repeated self-harm, the overall IR was 8.9 per 100 person-years (95% CI

8.7–9.1). When considering demographic or ED characteristics, IRs for repeated self-harm were significantly higher than the overall IR for people residing in outer remote and very remote locations, those in the two most disadvantaged quintiles, those presenting to small acute hospitals, those admitted to hospital wards, and those who subsequently died by suicide. IRs were also higher

for persons with previous or subsequent mental health ED visits and physical health ED visits. Such visits were more likely to occur after ($n = 214,519$ visits, 72.5%) rather than before the index self-harm presentation ($n = 81,389$ visits, 27.5%). Compared with the overall cohort, repeated self-harm IRs were significantly lower for people 65 years or older, in the two least disadvantaged quintiles, and in those admitted to the ED, SSU or observation ward.

The overall IR of suicide was 0.4 per 100 person-years (95%CI 0.4–0.5). Contrasted with this overall IR, IRs were significantly higher for males, patients 65–84 years of age, patients admitted to other hospital wards and patients with no physical health ED visit. IRs were significantly lower for females and patients aged 18–24 years.

The risk of repeated self-harm and suicide at 12- and 24-months

Fig. 3 depicts the adjusted risk of repeated intentional self-harm and suicide (see Supplemental eTable 2 for the 95%CI). The overall repeated self-harm risk was 18.9% (95%CI, 18.5%–19.3%) at 12-months and 24.3% (95%CI, 23.9%–24.7%) at 24 months. Compared with this overall risk, risks were increased at both 12- and 24-months for people aged 18–24 years, those presenting to a small acute hospital and those with other physical and mental health ED visits. By contrast, also compared with the overall rate, the risk was lower for those aged 55 years or older, patients who arrived at the ED by police, patients admitted to the ED, SSU or observation ward, and patients with no previous mental or physical health visits.

The overall suicide risk was 0.7% (95%CI, 0.6%–0.7%) at 12-months and 1.0% (95%CI, 0.9%–1.1%) at 24-months. Risks were significantly higher for males, who had point estimates of risk approximately double that of females at both 12- and 24-months. Risks were also significantly higher at 12- and 24-months for patients aged 65–74 years and those with no previous physical health visit. Risks were significantly lower at 12- and 24-months for females and for patients aged 18–24 and 85+ years old.

Risk factors for Re-presentation to ED with self-harm and suicide

Fig. 4 depicts independent risk factors for ED re-presentation with self-harm and subsequent death by suicide (Supplemental eTable 3 presents the HR and 95%CI; Supplemental eFig. 3 present the unadjusted results). For repeated self-harm, risk factors were ages <85 years, outer regional locations, high socioeconomic disadvantage (quintiles 1 and 2), arrival by ambulance, self-presentation, presentation to small acute and medium sized hospitals, all triage categories less urgent than resuscitation, not being admitted to ED, and a previous mental or physical health ED visit. For suicide,

the risk factors were male sex, age >24 years, ATS 1 (see immediately), 2 (see within 10 min) and 5 (non-urgent, see within 2 h) categories, socioeconomic groups 3 and 4, admission to hospital, and a mental health visit, and no physical health visit.

Supplemental eFigs. 4 and 5a–C demonstrate the interchangeability of X60-84 and R45.81 codes, and present an example of the extensive sensitivity analysis conducted.

Discussion

This study examines the demographic and clinical characteristics of adults presenting to EDs with self-harm in Queensland, Australia, and follows the trajectory of repeated ED presentation for self-harm or death by suicide within the six-year study period. Of 43,797 adults who presented to the ED with intentional self-harm, one in four re-presented with repeated self-harm, and 1.2% died by suicide.

The risk of repeated self-harm at 12-months for adults in our study (18.9%) was similar in magnitude to previous studies. A 2014 meta-analysis estimated overall 12-month repeated self-harm of 16.3% (95%CI 15.1–17.7).²² These findings are similar to those from other high income countries, and higher than the 3.3% (95%CI 2.4–3.9) noted in studies conducted in low and middle income countries.^{10,22} We found no association between repeated self-harm and sex. However, male sex was associated with an increased likelihood of suicide at both 12- and 24-months follow-up. This is consistent with suicide mortality in the Queensland general population where males represent over 70% of suicide deaths.²³

Individuals aged 65–84 with an index self-harm presentation were twice as likely to die by suicide at 12- and 24-months, compared to 18–24 year olds, a finding reflective of trends noted in other countries including England.¹¹ Our work demonstrates that older males are at particular risk of suicide following an index presentation with self-harm. A recent systematic review of aftercare for older adults after self-harm identified opportunities to enhance care in this area, including aftercare engagement and a focus on individual context.²⁴ In older adults suicide is associated with bereavement, isolation and somatic illness.^{25,26} A holistic and comprehensive approach is thus recommended.

Our findings were not reflective of previous research that indicated suicide rates were higher in rural areas than in metropolitan areas.²⁷ This difference may reflect our cohort comprising people who presented to ED with intentional self-harm, some of whom subsequently died by suicide, rather than a cohort comprising people who died by suicide (many who may not attend an ED). Our findings did show that individuals presenting to small acute hospitals had a higher risk of repeated self-harm than those presenting to other hospital groups. This

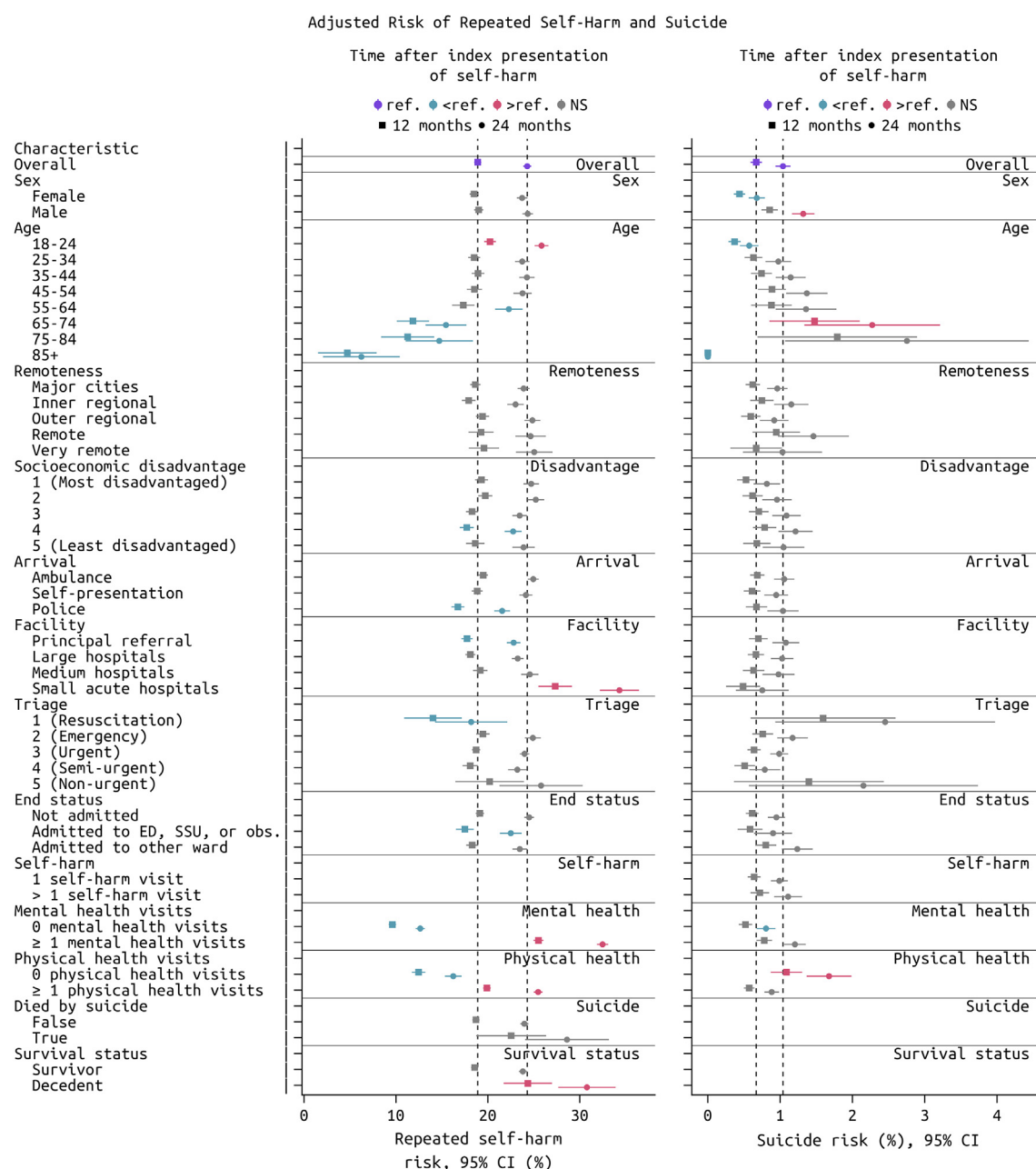


Fig. 3: Adjusted risk of repeated self-harm and suicide at 12- and 24-months following index ED presentation. This figure reflects the incidence rates of self-harm and suicide. Contrasts are with the overall rate, separately for 12- and 24-months. Red indicates higher risk compared with overall, and blue indicates lower risk compared with overall. Reference categories are calculated separately. Each factor includes two data points: the risk of the event (repeated self-harm or suicide) at 12 months (represented by square markers) and 24 months (represented by circular markers). To prevent conceptual circularity and multicollinearity, the intentional self-harm factor was excluded as a predictor of intentional self-harm events. Similarly, factors indicating survival status and death by suicide were excluded as predictors of suicide events. 95% CI = 95% confidence interval; NS = non-significant; Ref. = reference.

could reflect the greater resources available in tertiary centres and points to the need for continued efforts to support people in rural/remote communities in access and treatment options for mental health issues, including self-harm.^{6,27}

We observed an association between socioeconomic disadvantage and repeated self-harm but not for death by suicide. The literature in this area is largely equivocal. A 2017 systematic review found an association between social disadvantage and suicidal behaviour in

Risk Factors for Repeated Self-Harm and Suicide (Adjusted)

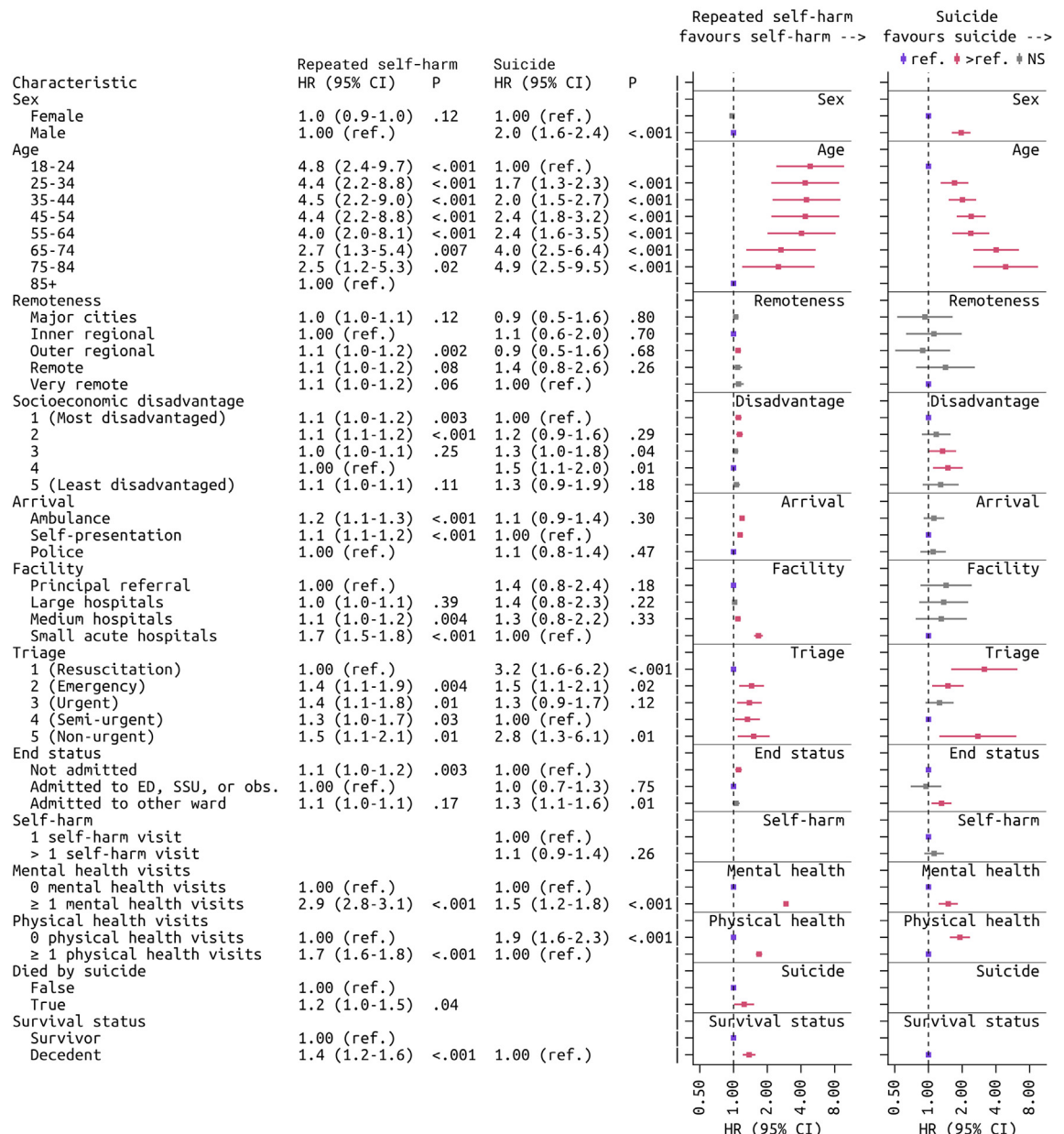


Fig. 4: Adjusted risk factors for repeated self-harm and suicide, Cox regression analysis. This figure presents HRs (95% CIs) based on multivariable Cox regression analysis for time to first repeat self-harm and time to suicide from the index self-harm presentation. All variables were entered simultaneously into a Cox regression with the most pragmatic category chosen as the reference. The vertical dotted line is a HR of 1.00. HR = hazard ratio; 95% CI = 95% confidence interval; NS = non-significant; P = p-value; Ref. = reference.

Europe, particularly among men.²⁸ However, the link between self-harm and disadvantage was not apparent in a recent long-term multicentre cohort study.¹¹ Variations in findings likely reflect the complexity of the issue, and point to a need for further research that encompasses broader social determinants of mental health.^{29,30}

Individuals admitted to the ED SSU or observation unit were significantly less likely to re-present with repeated self-harm compared with those discharged directly from the ED, or those admitted to inpatient hospital wards. It is possible that the treating clinician in these instances did not deem the presentations as high enough risk of suicide to warrant admission. This may

represent potential benefits of an SSU admission. The extent to which individuals who were discharged directly from the ED had mental health assessments and multi-disciplinary team input in their aftercare warrants further research. It has been noted previously that areas of the ED such as triage do not offer ideal settings for thorough psychological assessments.¹² Thus, it is possible that the individuals admitted to the SSU had a more thorough multi-disciplinary assessment than those discharged directly from the ED, while not being as high risk as the inpatient admissions. The ED SSU offers the opportunity for up to 24 h of admission, an extended period for input from mental health teams, social work, and other allied health specialties. The ED SSU can be utilised as a safe area for more complex inputs from healthcare and mental health professionals, and targeted inputs that take time can be coordinated more effectively.³¹

The higher rate of re-presentation among the cohort admitted to hospital from ED is recognised in the literature, and may reflect increased mental health burden among these individuals.³² Our data mirror existing literature suggesting that admitted patients are more likely to subsequently die by suicide.³² This reinforces the high risk of suicide among these individuals.

Limitations

This was a large, state-wide population study with up to six years of observation. ICD-10 coding is widely used in health research, however it is recognised to underestimate the actual incidence of intentional self-harm presentations.³³ We did not consider presentations classified outside of the specific codings, or where it was a secondary classification or present only in the presenting complaint. Furthermore, all the presentations considered in this study were drawn from the hierarchical parent group of adults presenting with mental health problems. As such, our findings can not be generalised to all individuals with self-harm, as not all people with self-harm have a mental health problem. Also, we may have under-estimated the incidence of self-harm and suicide.³⁴ While including these codes may have captured more individuals with self-harm, this approach may also have increased the number of false positives i.e., a broader definition might have identified more self-harm visits, but may have inadvertently included some non self-harm visits. However, in contrast to this point, our sample may potentially underrepresent the total population of those with self-harm in the community due to diagnostic overshadowing and the fact that not all individuals with self-harm present to the ED. Thus, the IRs in this study might be an underestimate of the true rates of intentional self-harm.

The study was conducted in one state and in a high-income country (Australia) and may be less

generalisable to other Australian states or territories and low- or middle-income countries. We used the index-self-harm presentation that occurred within our dataset, which may be arbitrary in the person's life. We cannot establish if this was a repeat self-harm event, or a true first incident event. As an observational data set, there is an inherent risk of bias. We aimed to minimise missing data and loss to follow up by virtue of the study design, i.e., using data linkage and death records. Missing data compromised <1% across variables. We believe the study design identifies all deaths by suicides; it is of course possible that patients may have presented to private EDs or out of state with subsequent self-harm episodes, although we believe this is unlikely to be a large number.

Our research included identifying risk factors for re-presentation with self-harm and death by suicide. Whilst some suggest that a focus on risk factors may be outdated,³⁵ the use of a large dataset spanning an extended time-frame (six years), enhanced accurate estimations of re-presentations. Our study was undertaken using data from a time-period pre-dating COVID-19. Given the noted impacts of COVID-19 on people's mental health, future research is warranted using more recent data to enable comparisons and further inform policy and practice.³⁶ The findings are broadly consistent with existing knowledge on this topic; reproducing these findings suggests the associations are genuine rather than spurious.

Conclusion

In this study over six years, individuals presenting to the ED with self-harm were at increased risk of re-presentation to ED with self-harm and death by suicide. The ED SSU or observation unit may offer a setting for targeted multi-disciplinary mental health inputs. Older age was associated with higher risk of suicide. Future work should focus on identifying successful interventions in ED settings for those presenting with self-harm. Holistic and integrated care can provide a platform to minimise the risk of subsequent self-harm and suicide.

Contributors

Richard Pellatt: Conceptualisation, methodology, visualisation, writing – original draft, writing – review & editing, project administration, supervision, funding acquisition; **David Painter:** conceptualisation, methodology, data curation, formal analysis, visualisation, writing – original draft, writing – review & editing, funding acquisition; **Jesse Young:** conceptualisation, methodology, data curation, formal analysis, writing – review & editing, supervision, funding acquisition; **Kairi Kølves:** conceptualisation, methodology, writing – review & editing, funding acquisition; **Gerben Keijzers:** conceptualisation, methodology, writing – review & editing, funding acquisition; **Stuart Kinner:** conceptualisation, methodology, writing – review & editing, funding acquisition; **Ed Heffernan:** conceptualisation, methodology, writing – review & editing, funding acquisition; **Julia Crilly:** conceptualisation, methodology, writing – original draft, writing – review & editing, supervision, funding acquisition.

All authors had full access to the data in the study and accept responsibility to submit for publication.

Data sharing statement

Data are not publicly available due to privacy and ethical restrictions. Researchers interested in accessing the data can contact the corresponding author.

Declaration of interests

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.lanwpc.2024.101263>.

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