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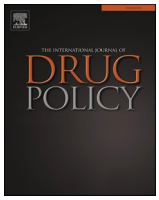

Research Paper

20-year trends in Australian methamphetamine-related deaths, 2001–2020

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ABSTRACT

Background: Over the past two decades methamphetamine-related harms have increased in Australia. Previous analysis of methamphetamine-related deaths has covered limited timeframes, and largely focused on drug-toxicity deaths. This paper examines long-term trends in methamphetamine-related deaths over 20 years, including deaths due to a range of specific causes.

Methods: Descriptive analyses were conducted on Australian methamphetamine-related deaths (2001–2023) by cause, extracted from the National Coronial Information System, an online database containing deaths reported to coroners in Australia and New Zealand. Joinpoint trend analyses were used to assess changes over time between 2001 and 2020 (with data from 2021 to 2023 likely incomplete and thus excluded).

Results: Unintentional drug toxicity was the cause of 49.8 % of methamphetamine-related deaths, intentional self-harm (including toxicity) 23.3 %, unintentional injury 15.1 %, natural causes 9.6 %, and assaults 2.3 %. Between 2001 and 2020, joinpoint analysis showed three trend change points among all-cause methamphetamine-related mortality rates, resulting in four distinct periods: two periods where they increased (2001–2006 – annual percentage change (APC) = 15.4 %; 2009–2016 – APC 25.5 %), and two where they decreased (2006–2009 – APC = –11.8 %; 2017–2020 – APC = –2.9 %). Similar patterns were evident among rates of intentional self-harm and unintentional injury. Deaths caused by unintentional drug toxicity saw two trend change points (2011, 2016), and rates increased across all three periods. Natural cause deaths had three trend change points (2007, 2010, 2015), and rates continued to rise after 2015, largely driven by increases in circulatory diseases.

Conclusion: Cause-specific models highlighted diverse trends. Recent trends show unintentional drug toxicity deaths have slightly increased, intentional self-harm stabilised, and unintentional injury and assault deaths have declined. Deaths from natural causes involving methamphetamine continued to increase, highlighting a public health concern and a potential need for early circulatory disease screening among people who use methamphetamine.

Introduction

Australia is estimated to have one of the highest rates of amphetamine dependence globally (Degenhardt et al., 2017; Man et al., 2022), and there have been significant increases in the volume and frequency of recent amphetamine seizures at Australian borders, culminating in a record high (5271 kg across 1377 seizures) during the 2019/20 year (Australian Criminal Intelligence Commission, 2021). The 2019 Australian National Drug Strategy Household Survey (NDSHS) estimates that 5.8 % of Australians have used amphetamines in their lifetime, with 1.3 % using it in the past year (Australian Institute of Health and Welfare (AIHW), 2020). While past-year use has declined over time, frequent use among those who have used it has increased sharply (AIHW, 2020). Amphetamines use may be two to four times higher than NDSHS estimates due to limitations caused by non-response bias, the exclusion of populations without a residential address (Chan et al., 2022), and the stigmatisation of amphetamine in Australia, which is thought to lead to under-reporting (Chalmers et al., 2016).

Methamphetamine is now the predominant form of amphetamine used in Australia (from this point on, methamphetamine will be used to refer to both amphetamine and methamphetamine) (United Nations Office on Drugs and Crime, 2022). The types of methamphetamine used have also changed, with a shift away from the use of the powder form to the crystalline form, which escalated dramatically in 2010 due to rising

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purity coupled with reduced price and increased availability (Scott et al., 2015). Compared to other forms, crystal methamphetamine is associated with an increased risk of dependence (Courtney & Ray, 2014) and health-related harms (Degenhardt et al., 2017). Methamphetamine now ranks second in terms of drug-related hospitalisations (behind alcohol), contributing to 8.2 % of all drug-related hospitalisations (AIHW, 2023b), and is the second largest reason for entering drug treatment (behind alcohol), accounting for almost one-quarter of treatment episodes in 2021–22 (AIHW, 2023a). There has been a four-fold increase in methamphetamine-related drug toxicity deaths observed over the last 20 years in Australia, with deaths reaching a record high (2.4 deaths per 100,000) in 2020 (Chrzanowska et al., 2023). The rise in methamphetamine-related deaths in Australia is part of a broader international trend of increasing methamphetamine use and mortality (UNODC, 2022). The United States (US) has seen a dramatic escalation in drug overdose deaths involving methamphetamine, rising from 547 cases in 1999 to 32,537 in 2021 (Hedegaard et al., 2021), and an increase in the co-involvement of methamphetamine and opioids in drug overdose deaths (Hoopsick & Yockey, 2023).

People who die from methamphetamine-related causes in Australia are disproportionately male, and deaths occur in metropolitan (major cities) and regional areas (outside major cities), and to a lesser extent in remote areas (furthest from major cities) (Darke, Kaye, & Duflou, 2017; Kaye et al., 2008). The most common cause of methamphetamine-related death in Australia and internationally is methamphetamine toxicity (Darke, Kaye, & Duflou, 2017). The specific mechanisms of these deaths can vary between individuals, but are commonly associated with seizures, cardiac arrhythmias, and respiratory failure, with cardiovascular incidents being particularly prevalent (Darke et al., 2008; Dominic et al., 2022; Hassan et al., 2016). Methamphetamine places high demands on the cardiovascular system as it rapidly increases heart rate and blood pressure (Fleury et al., 2008). Australian research shows a significant proportions of people who have died from methamphetamine-related causes have pre-existing cardiovascular disease (Darke, Duflou, & Kaye, 2017). In addition, methamphetamine was implicated in 1.6 % of all completed suicides in Australia between 2009 and 2015, with this figure increasing during the period (Darke, Duflou, & Kaye, 2017). A recent large-scale cohort study in Taiwan found that individuals with methamphetamine use disorders were 16.3 times more likely to die by suicide than the general population (Lee et al., 2021).

Methamphetamine use and the subsequent 'comedown' period can also result in the impairment of decision-making and deterioration of fine motor skills (Hart et al., 2012; Mizoguchi & Yamada, 2019), increasing the risk of unintentional injuries. Individuals who use methamphetamine have been found to be over five times more likely to be involved in fatal motor vehicle collisions as a driver and over six times more likely to sustain driving-related injuries than people who do not use methamphetamine (Elvik, 2013).

Previous Australian research on methamphetamine-related deaths has been limited to shorter timeframes (2000–2005 and 2009–2015) (Darke, Kaye, & Duflou, 2017; Kaye et al., 2008), a single jurisdiction (Lewis et al., 2021a), or a single cause of death (e.g. drug toxicity) (Chrzanowska et al., 2023). This study extends earlier research by exploring trends nationally over a 20-year period from 2001 to 2020 to provide a comprehensive picture of methamphetamine-related deaths over time and by cause in Australia. Given the market changes that have occurred since 2001, this research employs statistical models to identify linear trends and pinpoint specific times when these trends have changed.

Aims

Specifically, this study aims to:

1) Characterise methamphetamine-related deaths in Australia by cause, circumstances (e.g. history of injecting drug use, geographic location), and sex from 1 January 2001 to 31 July 2023;
2) Examine trends in methamphetamine-related deaths across a 20-year period from 2001 to 2020;
3) Model changes in trends in methamphetamine-related deaths by cause; and
4) Examine trends in methamphetamine-related deaths by age and by sex (supplementary analyses).

Methods

Design

This research involves a retrospective analysis of trends in all deaths that involved methamphetamine in Australia from 1 January 2001 to 31 July 2023, according to cause of death categories. Given the length and complexity of coronial investigations, the recorded number of deaths in the latter years of this study may be underestimated. To ensure the completeness of the data, trend analysis was only conducted on data between 2001 and 2020.

NCIS

Data was obtained from the National Coronial Information System (NCIS), an online national database containing information on 'reportable deaths' in Australia from 1 July 2000 (Queensland from 1 January 2001) and New Zealand data from 1 July 2007. A death is required to be reported to the coroner if it is unforeseen or unexplained, is caused by an accident or injury, occurs while the individual is in care or custody, or involves an individual whose identity is unknown (Dunstan, 2019). The NCIS includes demographic information about the individual, contextual details of the circumstances surrounding the death, the medical cause of death, and up to four investigation-generated full-text reports (autopsy, police, findings, and toxicology) where available (Saar et al., 2017).

Deaths where the coroner determined that methamphetamine or amphetamine was considered to have caused or contributed to the death (referred to as methamphetamine-related deaths) were extracted from the NCIS. Only cases that were closed (i.e., the coronial investigation was complete) and involved people over the age of 15 were included. Search strategies included word searches of the medical cause of death, where the coroner mentioned methamphetamine or amphetamine and searches by drug class where methamphetamine or amphetamine was coded. Cases were excluded if the presence of amphetamine could be ascribed solely to other related substances such as 3,4-methylenedioxymethamphetamine (MDMA), 3,4-methylenedioxyamphetamine (MDA), 3-methoxy-4,5-methylenedioxyamphetamine, (MMDA), or dextroamphetamine (dexamphetamine), or if another person's methamphetamine use caused the death.

Categorisation of deaths

Keyword searches of the medical cause of death fields and mechanism of death coding were used to categorise cases. The manner of death was classified as 1) unintentional drug toxicity, 2) intentional self-harm (including toxicity), 3) natural causes, 4) unintentional injury, and 5) assault (Table 1). Assaults are included as methamphetamine use has been found to be an independent risk factor for violence perpetration and victimisation (Foulds et al., 2020).

Data collected

Information on age, sex, marital status, geographic location, and settings of the incident and death were extracted. Investigation-generated full-text reports (autopsy, police, and findings) linked to

Table 1
Definitions for methamphetamine-related death categories.

Cause of death	Definition
Unintentional drug toxicity	Unintentional drug toxicity was defined as cases where the coroner listed methamphetamine or amphetamine toxicity as the underlying cause of death or cases with generic phrases like "drug overdose", "drug toxicity", "mixed drug toxicity", etc., listed in the underlying cause of death, and methamphetamine was present in toxicology at death.
Intentional self-harm	Intentional self-harm deaths are those where the coroner determined the deceased intentionally self-inflicted harm with the intention of deliberately ending their life, or where the deceased intentionally self-inflicted harm, regardless of whether the anticipated outcome was death, and methamphetamine was present in toxicology at death.
Unintentional injury	Unintentional injury deaths are those where the coroner has determined the underlying cause of death was unintentional, involved an event causing injury and methamphetamine was present in toxicology at death.
Natural causes	Natural cause deaths are those where the coroner has determined the underlying cause of death was attributable to a pre-existing disease, and contributory causes included methamphetamine. Natural cause deaths were further classified from the medical cause of death into categories (e.g. circulatory system diseases) based on the International Classification of Diseases (ICD, 10th revision) (World Health Organization, 2019).
Assault	Assault cases were those where the coroner identified assault was the cause of death and methamphetamine was present in toxicology at death.

cases were used to ascertain specific characteristics of the deaths, including factors such as the position of the deceased within the vehicle during a motor vehicle collision or recorded history of injecting drug use. Recorded history of injecting drug use was determined through the identification of puncture marks in autopsy reports or the recorded discovery of evidence at the scene by police that indicated recent (e.g., needles and syringes) or historical evidence of injecting drug use.

Statistical analysis

Data analysis was conducted using Stata 17 (StataCorp, 2021). Chi-square tests were performed to determine whether there was a significant association between sex and each cause of death. Mortality rates (per 100,000 population) were calculated using the latest Australian Bureau of Statistics population estimates from 30 June of each year (Australian Bureau of Statistics, 2023). To assess changes in mortality rates we used the Joinpoint Regression Program (Version 5.0.2) for deaths between 2001 and 2020 (Joinpoint Regression Program, 2023). This software applies weighted least-squares regression models to the rates on a log-transform scale and assesses the optimal number of change points (i.e. points where the trend changes) in the data series. Weighted Bayesian Information Criterion (WBIC) was used to select the model of best fit, and model significance was set at an overall alpha level of 0.05. The Minimum APC Difference Worth Detecting (MADWD) was not prespecified. Sensitivity analysis was conducted with the MADWD set at 0.01, 0.5, 2, 5, and 10, and no differences were found in the statistical significance of the findings.

Ethics

Ethics approval for this study was received from The Alfred Ethics Committee (61044) and from the Justice Human Research Ethics Committee (CF/20/4121) for the use of NCIS data.

Results

Demographics

A total of 8812 deaths were identified between 1 January 2001 and 31 July 2023. Of these, 77.4 % (6817) were males. The median age at death was the same (37 years) for men and women. The median age increased from 29 in 2001, to 44 in 2022. At the time of death, 26.9 % (n = 2370) of people were employed and 46.6 % (n = 4111) were unemployed. Nearly a quarter of individuals (24.3 %, n = 2145) were known to be married or in a de facto relationship, and 35.6 % (n = 3136) had never married. Just under half (45.0 %, n = 3965) had a recorded history of injecting drug use. Most deaths occurred in major cities (63.6 %, n = 5609), a minority (22.7 %, n = 1997) in regional areas, and rarely (2.1 %, n = 181) in remote areas. The majority of deaths (59.2 %, n = 5215) took place at a residential address, followed by public places (19.9 %, n = 1751), and health services (16.1 %, n = 1417).

Cause of death

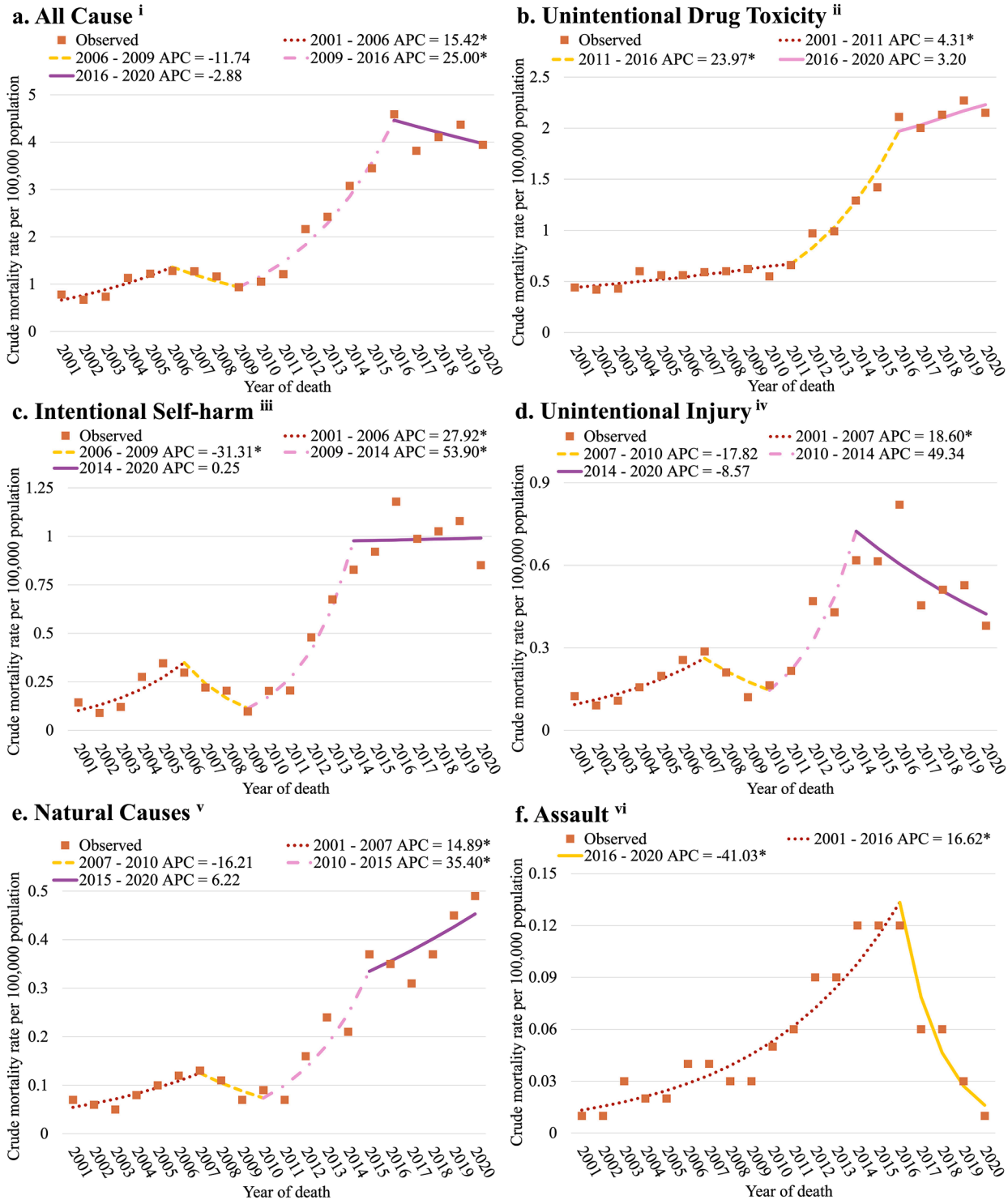
The primary cause of death was drug toxicity (49.8 %) and the majority of these (86.5 %) were determined as unintentional (Table 2).

Table 2
Circumstances of death among Australian methamphetamine-related fatalities.

Circumstances of death	Males n (%)	Females n (%)	All n (%)
Unintentional drug toxicity**	**3581 (47.5)**	**1149 (57.6)**	**4385 (49.8)**
Methamphetamine toxicity	609 (8.9)	160 (8.0)	769 (8.7)
Mixed drug toxicity **	2627 (38.5)	989 (49.6)	3616 (41.0)
Intentional self-harm **	**1645 (24.1)**	**404 (20.3)**	**2049 (23.3)**
Hanging **	1135 (16.7)	266 (13.3)	1401 (15.9)
Poisoning *	256 (3.8)	103 (5.2)	359 (4.1)
Drowning	54 (0.8)	9 (0.5)	63 (0.7)
Shot by firearm **	62 (0.9)	0 (0.0)	62 (0.7)
Contact with stationary object	38 (0.6)	9 (0.5)	47 (0.5)
Other **	100 (1.5)	17 (0.9)	117 (1.3)
Unintentional injury **	**1110 (16.3)**	**218 (10.9)**	**1328 (15.1)**
Motor vehicle collisions **	772 (11.3)	160 (8.0)	932 (10.6)
Four wheeled vehicle occupant	532 (7.8)	152 (7.6)	684 (7.8)
Driver *	465 (6.8)	107 (5.4)	572 (6.5)
Passenger **	57 (0.8)	46 (2.3)	103 (1.2)
Motorcycle rider **	248 (3.6)	7 (0.4)	255 (2.9)
Bodily injuries *	118 (1.7)	21 (1.1)	139 (1.6)
Drownings *	69 (1.0)	9 (0.5)	78 (0.9)
Other *	151 (2.2)	28 (1.4)	179 (1.7)
Natural causes[a]	**663 (9.7)**	**180 (9.0)**	**843 (9.6)**
Circulatory system diseases **	506 (7.4)	94 (4.7)	600 (6.8)
Ischemic heart diseases **	344 (5.1)	50 (2.5)	394 (4.5)
Cardiomegaly	57 (0.8)	10 (0.5)	67 (0.8)
Cardiomyopathy	42 (0.6)	14 (0.7)	56 (0.6)
Other	140 (2.1)	41 (2.1)	181 (2.1)
Cerebrovascular diseases **	64 (0.9)	48 (2.4)	112 (1.3)
Intracerebral haemorrhage **	26 (0.4)	22 (1.1)	48 (0.5)
Other cerebrovascular diseases **	39 (0.6)	25 (1.3)	64 (0.7)
Respiratory diseases	45 (0.7)	17 (0.9)	62 (0.7)
Kidney-related diseases	29 (0.4)	12 (0.6)	41 (0.5)
Other	64 (0.9)	16 (0.8)	80 (0.9)
Cases with a single disease	530 (7.8)	145 (7.3)	675 (7.7)
Cases with multiple diseases	133 (2.0)	35 (1.8)	168 (1.9)
Assault	**158 (2.3)**	**44 (2.2)**	**202 (2.3)**
Stabbed	77 (1.1)	14 (0.7)	91 (1.0)
Other	81 (1.2)	30 (1.5)	111 (1.3)
Undetermined	**5 (0.1)**	**0.00 (0)**	**5 (0.1)**
Total	6817 (100.0)	1995 (100.0)	8812 (100.0)

[a] It was possible for cases to have multiple natural causes listed as the medical cause of death; ** p = <0.001; * p = <0.05.

While 17.5 % of these deaths were solely attributed to methamphetamine toxicity, the remainder (82.5 %) involved a combination of drugs. Opioids were present in 79.8 %, benzodiazepines in 40.5 %, and antidepressants in 28.4 % of these cases. The majority of those dying from drug toxicity had a recorded history of injecting drug use (65.4 %). Intentional self-harm accounted for 23.3 % of deaths, predominantly hangings (68.4 %). This form of self-harm was notably prevalent among males aged 30 to 40. Antidepressants were present in the systems of 18.8 % of these individuals at the time of death, while antipsychotics were found in 10.2 %. Unintentional injuries were responsible for 15.0 % of all deaths, with motor vehicle collisions (69.5 %) being the primary cause. Among these, drivers of four-wheeled vehicles constituted 60.2 %



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
[i] Final Selected Model: 3 changepoints; [ii] Final Selected Model: 2 changepoints; [iii] Final Selected Model: 3 changepoints;
[iv] Final Selected Model: 3 changepoints; [v] Final Selected Model: 3 changepoints; [vi] Final Selected Model: 1 changepoints.

Fig. 1. Trends in Australian methamphetamine-related mortality rates by cause of death, 2001-2020.

andmotorcycle drivers comprised 32.1 %. Natural cause deaths involving methamphetamine made up 9.6 % of cases, the two most common diseases being circulatory system diseases and cerebrovascular diseases. Notably, 20 % of natural cause deaths involved more than one disease, underscoring the comorbidity within this group. Although less frequent, assaults where the victim had traces of methamphetamine in their blood at death accounted for 2.3 % cases.

Temporal trends

Between 2001 and 2020, the Joinpoint analysis identified three significant changes in the trend of all-cause methamphetamine-related mortality rates, resulting in four distinct phases (Fig. 1a). From 2001 to 2006, all-cause mortality rates increased significantly, with an annual percentage change (APC) of 15.4 %, which means mortality rates increased 0.8 per 100,000 population over this period. This upward trend halted in 2006, marking the first changepoint, when mortality rates decreased by an APC of –11.8 % between 2006 and 2009. The second changepoint occurred in 2009, with a significant increase in mortality rates of 0.5 per 100,000 population (APC = 25.5 %) between 2009 and 2016. The last changepoint occurred in 2016, followed by a decrease in mortality rates to 2020, with an APC of –2.9 %.

For unintentional drug toxicity mortality rates, two trend changepoints were identified. Between 2001 and 2011, drug toxicity deaths increased significantly, with an increase in mortality rates of 0.2 per 100,000 population (APC = 4.3 %) (Fig. 1b). Deaths during this period were predominantly attributed to mixed drug toxicity, occurring among young men aged 20 to 30 (Supplementary Figs. 1 and 6). The first changepoint occurred in 2011, when the rates of drug toxicity deaths increased significantly between 2011 and 2016, an increase of 1.3 per 100,000 population (APC = 24.0 %). The increase was seen among males and females; however these deaths occurred disproportionately among males. Deaths among individuals aged between 30 and 49 were highest during this period. Heroin was the most frequently involved substance in mixed drug toxicity deaths. There was also a notable increase in the involvement of antidepressants and benzodiazepines in these deaths over the period. The second changepoint occurred in 2016, when the increase in drug toxicity deaths slowed to an APC of 3.2 %.

The analysis of intentional self-harm deaths reveals three trend changepoints. From 2001 to 2006, there was a significant increase in rates of self-harm deaths, an increase of 0.2 per 100,000 population (APC = 25.5 %) (Fig. 1c). The first changepoint occurred in 2006, when there was a significant decline in deaths (APC of –31.5 %) between 2006 and 2009. The second changepoint occurred in 2009, with a significant increase in mortality rates of 0.9 per 100,000 population (APC = 52.7 %) between 2009 and 2014. Notably, within deaths attributed to self-harm, there was a 9.1-fold increase in deaths from hanging. The third changepoint occurred in 2014, when the trend appeared to stabilise (APC = 0.25 %).

There were three trend changepoints found among deaths attributed to unintentional injuries. There was a significant increase in these deaths between 2001 and 2007, an increase of 0.2 per 100,000 population (APC = 18.6 %) (Fig. 1d). This increase is mainly attributed to increased collisions involving four-wheeled vehicles and these deaths were most prevalent among people aged 20 to 29 (Supplementary Fig. 8). The first changepoint occurred in 2007, when there was a decline in these deaths (APC = –17.8 %) between 2007 and 2010. The second changepoint occurred in 2010, with an increase between 2010 and 2014 (APC = 49.3 %). However, this was not statistically significant. Deaths were most prevalent among individuals aged 20 to 29 during this period. There were notable increases in motor vehicle collisions, including a 2.9-fold rise in fatalities from four-wheel vehicle collisions and a 4.5-fold rise in motorcycle collisions during this period. This trend reversed from 2014 to 2020 (APC = –8.6 %).

There was an overall increase in mortality from natural causes between 2001 and 2020 and three trend change points were identified. Between 2001 and 2007, there was a significant rise in these deaths, an increase of 0.1 per 100,000 population (APC = 14.9 %) (Fig. 1e). The first changepoint occurred in 2007, and between 2007 and 2010 there was a slight decline (APC = –16.2 %). The second changepoint occurred in 2010, with rates significantly increasing between 2010 and 2015 by 0.3 per 100,000 population (APC = 35.4 %). This increase mainly involved people in their 40s and 50s who died from circulatory system diseases (Supplementary Fig. 9). The rise in these deaths predominantly occurred among males (Supplementary Fig. 4). The third change point occurred in 2015, after which the rate of increase slowed (APC = 6.2 %).

There were lower rates of fatal methamphetamine-related assaults and analysis of trends identified two change points. A significant increase of 0.1 per 100,000 population (APC = 16.6 %) occurred between 2001 and 2016 (Fig. 1f). This increase occurred mainly among males in their 20s and 30s (Supplementary Fig. 10). The trend significantly decreased in 2016 (APC = –41.0 %).

Discussion

Australia experienced an increase in methamphetamine-related mortality between 2001 and 2020, with trend changepoints identified in 2006, 2009, and 2016. Increases are particularly marked between 2009 and 2016, and are largely driven by increases in drug toxicity deaths (an APC of 23.92 % from 2011). The significant increase druing this period aligns with changes in patterns of use, with an increase in regular use of high purity crystal methamphetamine across different populations (Degenhardt et al., 2017; Man et al., 2022; Price et al., 2023; Scott et al., 2015). Increased availability of methamphetamine at lower prices has ostensibly driven an escalation in methamphetamine dependence and experiences of harmful effects related to methamphetamine use (McKetin et al., 2006; McKetin et al., 2021; Scott et al., 2015; Scott, 2023).

Our findings confirm previous Australian research that the age at methamphetamine-related death is climbing (Darke, Kaye, & Duflou, 2017; Lewis et al., 2021b). Importantly, we also show new evidence that these age patterns are not evident for unintentional injury-related deaths, especially motor vehicle accidents. The results show overall that men are overrepresented among methamphetamine-related deaths (77 % men), a trend observed across all drug-related deaths in Australia, however the gap is sightly more pronounced than for opioid-related deaths (68 % men) (Chrzanowska et al., 2023).

The high rates of polydrug use among methamphetamine-related drug toxicity is consistent with other drug-related mortality (Chrzanowska et al., 2023), reaffirming the increased risk associated with mixing methamphetamine with other drugs (Dai et al., 2022; Darke et al., 2008). Concurrent use of methamphetamine and other substances can significantly heighten methamphetamine toxicity (Darke et al., 2008). The increasing trend among mixed drug toxicity deaths is largely driven by greater involvement of opioids and benzodiazepines. The combination of respiratory depressants (such as opioids and benzodiazepines) and methamphetamine places increased pressure on the cardiovascular, respiratory, and central nervous systems, which can result in unpredictable outcomes, and increased risk of overdose (Al-Tayyib et al., 2017; Hoopsick & Yockey, 2023).

Between 2009 and 2014, there was a significant increase (APC of 53.9 %) in intentional self-harm deaths. People who use methamphetamine experience high levels of comorbid mental health conditions (Duncan et al., 2022). Despite the implementation of new strategies, reforms, and treatments to reduce rates of mental health conditions in Australia, there has been an overall increase in suicides over this period, suggesting the rise in methamphetamine-related suicide may be representative of broader mental health issues that have coincided with increases in methamphetamine use (Jorm, 2019). Potential gaps in the accessibility, awareness, or effectiveness of mental health treatment options for people using methamphetamine and concurrently experiencing mental health conditions, evidenced by the low detection of

antidepressant and antipsychotic drugs among intentional self-harm deaths.

Although smaller in number, significant increases in methamphetamine-related deaths attributed to natural causes were also recorded between 2010 and 2015, mainly attributed to circulatory system diseases. This is consistent with past Australian research (Darke, Kaye, & Duflou, 2017; Kaye et al., 2008). The increasing rates of circulatory system diseases are being driven by rises in ischemic heart disease among men and women in their 40s and 50s. The increasing trend could be partially explained by the aging demographic of people who use methamphetamine, combined with the potential cumulative impacts of regular methamphetamine use (Hassan et al., 2016). This trend mirrors international observations, with both the US and Canada reporting rising levels of cardiovascular disease, heart failure, and cardiomyopathy related to methamphetamine use, leading to increased hospitalisation and mortality (Batra et al., 2022; Dickson et al., 2021; Latif et al., 2023; O'Keefe et al., 2022). Previous research also suggests that cardiovascular disease is prevalent and largely unrecognised among other causes of death, and the impact of regular methamphetamine use on the cardiovascular system may result in death even long after cessation of drug use (Darke, Duflou, & Kaye, 2017). Actual rates of methamphetamine-induced circulatory system-related deaths may be significantly higher, as some cases may not have been reported to the coroner.

Significant increases were also recorded among deaths attributed to unintentional injury and assault, however, numbers were comparatively low.

Policy implications

The diverse nature of methamphetamine-related deaths and the changing demographics of these deaths suggest that reducing methamphetamine-related morbidity and mortality will require a series of targeted strategies designed to reach the specific populations experiencing these harms. The increasing rates of methamphetamine-related drug toxicity deaths show there is a clear need for evidence-based responses to methamphetamine-related overdose, such as the wider availability of supervised injecting facilities (SIFs) and drug consumption rooms (DCRs). These sites can provide people who use drugs with supervised use environments where trained staff can monitor their health, intervene in the case of an overdose, and offer critical health services (Caulkins et al., 2019). Additionally, SIFs and DCRs can serve as access points for other support services, including mental health, treatment, and social services. They can also increase distribution of harm reduction knowledge and resources (Hedrich, 2004). Currently there are only two SIFs in Australia, in Melbourne and Sydney (Ryan, 2023; van Beek, 2003).

There is a palpable need for integrated screening approaches and early management of circulatory system diseases services engaging with older people who use methamphetamine, in addition to traditional healthcare-based screening approaches. Community-based outreach screening has proven to be an effective strategy in identifying circulatory system diseases and associated risk factors within marginalised populations, including those from culturally and linguistically diverse backgrounds, rural areas and among people who are homeless (Alston et al., 2016; Banerjee et al., 2023; Soltani et al., 2021). This approach holds potential for application among communities of people who use methamphetamine, where it could significantly aid in early detection and intervention.

In Australia and many other countries, mental health services and drug treatment services are often separate, meaning that people who use methamphetamine are not able to get the care they need for mental health conditions concurrent to treatment for their methamphetamine use (McKetin et al., 2019). To reduce the mental health harms and self-harm associated with the use of methamphetamine, there needs to be increased system and service level integration of mental health and drug treatment services. This could involve co-location of services and/or service providers offering collaborative care models (Wiktorowicz et al., 2019). These services need to tailor known evidenced-based suicide prevention strategies to make them acceptable, safe, and effective for people who use methamphetamine.

While recent years have seen an increase in methamphetamine-related treatment episodes (AIHW, 2023a), there remains a significant lack of evidence-based pharmacotherapy options for treating methamphetamine dependency and withdrawal, leaving a substantial gap in the available treatment options for people who use, and experience harm with, methamphetamine (Acheson et al., 2023; Lee et al., 2018). Mirtazapine (Keygan et al., 2023), lisdexamfetamine (Ezard et al., 2018), psilocybin (Knock et al., 2022), and oxytocin (Siefried et al., 2021) are all currently being trialled in Australia for treating methamphetamine dependence and withdrawal. Ongoing research is needed to identify if these treatment options are effective and acceptable to people who use methamphetamine.

Limitations

Investigating methamphetamine-related deaths presents challenges, as methamphetamine is redistributed post-mortem, which means that methamphetamine concentrations alone are insufficient to determine the cause of death without additional support from clinical or pathological findings (Lewis et al., 2021b). As with all mortality research utilising the NCIS, the classification of cases and identification of indicator variables was limited by the information provided in the cause of death and investigative reports. The length and complexity of coronial investigations suggest that the recorded number of deaths in the later years of this study might be an underestimation, which means that the rates could increase further. The inclusion of cases was restricted to deaths caused by the individual's methamphetamine use, and/or whether methamphetamine was detected in their blood at the time of death. Consequently, deaths indirectly caused by someone else's methamphetamine use were not considered. It is possible that cases with amphetamine listed in the drug class could be due to the metabolism of prescription amphetamines instead of illicit amphetamines. The classification of intentional self-harm deaths was determined by NCIS coding of intent, which is decided by the coroner's investigation and case circumstances. It is worth noting that the way intent is determined, and the cause of death articulated by the coroner, has evolved over time, potentially affecting observed trends. The estimates of history of injecting drug use may be higher as we relied on evidence of injecting drug use being found at the time of death, and there were differences in the type of evidence of injecting drug use each jurisdiction recorded.

Conclusion

This study provides a comprehensive analysis of methamphetamine-related mortality in Australia over a 20-year period from 2001 to 2020, a period marked by evolving methamphetamine markets. While there were brief periods of decline in methamphetamine-related deaths, the overall trend has been one of escalating harm, particularly among people in their 30s and 40s dying from mixed drug toxicity. This highlights the urgent need for greater accessibility of services that meet people where they are, such as SIFs and DCRs. The increase in methamphetamine-related suicides signals a critical gap in mental health care for people living with mental health conditions who also use methamphetamine. Services that come into contact with people who use methamphetamine need to be adequately resourced to address their co-occurring needs, with evidenced based strategies tailored for people who use methamphetamine. The continuing upward trend in natural cause deaths, particularly related to circulatory system diseases, raises concerns about the long-term health impacts of methamphetamine use. For services engaging with people who use methamphetamine, prioritising the prevention and treatment of circulatory system diseases is

essential. This underscores the need for holistic healthcare and harm reduction approaches that screen and assist individuals where they are during active methamphetamine use. This study emphasises the complexities of methamphetamine-related mortality in Australia, and calls for a multi-layered response that links education, harm reduction, health screening, mental health care, and long-term healthcare support that transcends traditional drug treatment paradigms.

Ethics approval

The authors declare that they have obtained ethics approval from an appropriately constituted ethics committee/institutional review board where the research entailed animal or human participation.

Ethics approval for this study was received from the National Coronial Information System (NCIS) via Justice Human Research Ethics Committee (M0444) and The Alfred Ethics Committee (61044).

CRediT authorship contribution statement

Oisin Stronach: Data curation, Formal analysis, Writing – original draft. **Paul Dietze:** Writing – review & editing, Supervision, Methodology. **Michael Livingston:** Writing – review & editing, Supervision, Methodology. **Amanda Roxburgh:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.drugpo.2024.104548.

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