



Postmortem toxicological findings in child suicides: A 23-year retrospective study in Sweden

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ABSTRACT

Globally, suicide is a leading cause of mortality among teenage children and adolescents. Alcohol and other substances of abuse may influence both the decision to commit suicide and the choice of method. However, only few studies focused on toxicological findings in child suicides. The aim of this study was to map postmortem toxicological findings in child suicides in Sweden. Data on age, sex, suicide method and toxicology in 500 suicides (age 8–17 years) in 2000–2022 were retrieved from the National Board of Forensic Medicine database. Descriptive statistical analyses were performed to examine associations between sex, age, suicide method and toxicology findings. Positive toxicological findings were present in 210 cases (42 %), most frequently among deaths from poisoning and jumping from a high place. Licit drugs were the most common substances (30 %), followed by alcohol (14 %). Antidepressants were the most frequently detected licit drugs and were significantly more common in females ($p = 0.002$). Among toxicology positive cases, hypnotic sedatives were detected in 15 % of cases, narcotic analgesics in 9 %, and central stimulants in 6 %. Alcohol was equally common in both sexes, with a mean blood alcohol concentration (BAC) of 1.15 g/L. More than half (57 %) of the alcohol positive cases had BAC levels ≥ 1 g/L. The most common alcohol combinations were with narcotic analgesics and central stimulants. Illicit drugs were rare ($n = 14$), mainly cannabis. These findings offer insights into child suicides and may inform future suicide prevention strategies targeting children.

1. Introduction

Suicide among children, adolescents, and young adults is a major global public health concern. For those aged 15–19 years, it is the third leading cause of death for females, and the fourth for males [1]. Although overall suicide rates are declining globally, in Europe, and in Sweden [2], age-specific trends reveal concerning patterns. In Sweden, suicide rates have increased among 20–29-year-olds (2006–2020) [2] and among children (< 18 years) (2000–2018) [3]. A similar increase in child suicide rates has also been noted in several other countries, including Brazil [4] and the USA [5].

In Sweden, the suicide rate among individuals aged ≥ 15 years was 14 per 100,000 population in 2024 and was somewhat higher than in most of other Nordic countries [2]. The child (< 18 years) suicide rate averaged 22 cases per year in Sweden, corresponding to 1.1 per 100,000 children annually, and the proportion of males was only slightly higher than that of females [3]. International variations in child and adolescent

suicide rates may be influenced by differences in sociodemographic, health and cultural factors, as well as by varying prevention work.

Research on child suicides is limited, especially for those under 15 years [6]. Most studies group children with adolescents or young adults, making it difficult to identify age-specific trends and risk factors [6]. Suicidal thoughts and behaviors in children are often underestimated due to assumptions about their cognitive immaturity. However, children begin to understand the finality of death and the concept of suicide appears in 8–9-year-olds [7].

Suicide rates and sex disparities widen with age [6]. While adult suicides are predominantly male [2], no sex differences appear in the ages < 18 years [3]. Suicide methods differ by age; children more often use violent means, with hanging the most common globally [6]. In Sweden, hanging and jumping or lying before moving object are the most frequent methods [3], whereas adults use hanging or poisoning [2]. In the USA, poisoning suicides have recently increased among younger age groups [8].

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Postmortem toxicology is a cornerstone in medicolegal death investigations, offering insights into the cause and manner of death. In suicides, toxicological findings help identify patterns that inform prevention strategies. Despite calls for more holistic child suicide research, comprehensive toxicological studies remain scarce, highlighting a critical gap [9].

The aim of this national study was to explore and map postmortem toxicological findings to expand the understanding of factors related to child suicides. Specifically, the study aimed to: a) examine the prevalence of toxicological findings in child suicides from 2000 through 2022, b) assess the relationship between toxicological findings, sex and age, and c) examine the relationship between toxicological findings and suicide method.

2. Material and methods

2.1. Swedish National Board of Forensic Medicine

In Sweden, all (suspected) unnatural deaths must be reported to the police. These cases are then referred to one of the six regional units of the National Board of Forensic Medicine (NBFM), the authority responsible for medicolegal investigations and forensic autopsies. All forensic procedures at the NBFM follow standardized protocols for autopsy and sample collection. During autopsy, biological specimens (fluid and tissue samples) are routinely collected and sent to the centralized Unit of Forensic Toxicology in Linköping, which is accredited under the international standard ISO/IEC 17025 since 1996 [10]. All findings undergo verification using multiple analytical methods to produce quantitative results for each detected compound. These methods include immunohistochemistry, gas chromatography mass spectrometry, and liquid chromatography mass spectrometry. The results are stored in a nationwide database, allowing for comprehensive retrieval of case-specific information.

The responsible forensic pathologist determines manner of death (e.g., suicide) based on a combination of autopsy and toxicology findings, medical and social history and contextual and circumstantial analysis. If the forensic pathologist cannot sufficiently determine the manner of death, it is classified as *undetermined*.

2.2. Study sample and analysis

Study samples comprise cases of child (< 18 years) suicides in the period from 2000 through 2022. Data were retrieved from the NBFM database, including variables such as sex, age, date and place of death, cause of death, description of circumstances, and toxicological results. Permission for data extraction was obtained by NBFM.

In the 514 identified child suicide cases, a toxicology analysis was performed in 500 cases. The remaining 14 cases were excluded, likely representing death after prolonged hospital care.

To examine toxicological findings in relation to age, the sample was divided into two age groups based on social and psychological development, differences in suicidal behaviour between younger and older adolescents [11], and the previously reported increase in psychopathology in older adolescents [12]: younger children (< 16 years), and older teenagers (16–17 years). A blood alcohol (ethanol) concentration (BAC) below 0.2 g/L was considered alcohol negative, as small amounts of alcohol can be produced postmortem [13–15]. A “toxic” blood level implies an association with serious symptoms, while a “lethal” blood level signifies relationship to fatal outcome [16].

SPSS (version 30 for Windows) was used for descriptive statistical analyses. The Chi2 test was used to determine association between the variables sex, age groups, suicide method and toxicology findings. A Fisher-Freeman-Halton exact test was used instead of Chi2 test if values were below 5. P-values < 0.05 were considered statistically significant.

3. Results

3.1. General findings

This study included 500 child suicides (< 18 years) in Sweden in 2000 through 2022. Of these, 276 were males and 224 were females. Victims aged 8–17 years, of which 22 were < 13 years. Toxicological analyses were positive in 210 cases and negative in 290 (Table 1). There was a significant association between sex and positive toxicology ($p = 0.001$); females were more likely to have positive toxicology (Table 1).

The proportion of cases where a licit drug and alcohol were detected increased with age (Tables 2 - 3). However, the association between toxicological findings and age group was not statistically significant. Majority of victims < 13 years (68 %) had negative toxicology. Positive and negative toxicology varied significantly across suicide methods, with higher proportion of positivity among poisonings and jumping from a high place than among other method groups (Table 1).

3.2. Licit and illicit drugs

Licit drugs, including those given in emergency medical care and over-the-counter medicines, were the most frequent findings in the

Table 1

Toxicological findings in child suicides by sex, age group and suicide method, Sweden 2000–2022. Toxicology positive/negative refers to the detection of drugs (licit, illicit, and amphetamine), alcohol and carboxyhemoglobin in postmortem analysis.

Demographics and suicide method	N/N of all study cases (%)	Toxicology	
		N positive/N total positive (%) N positive/N all in sex/age/method group (%)	N negative/N total negative (%) N negative/N all in sex/age/method group (%)
Sex ^a			
Males	276/500 (55 %)	97/210 (46 %) 97/276 (35 %)	179/290 (62 %) 179/276 (65 %)
Females	224/500 (45 %)	113/210 (54 %) 113/224 (50 %)	111/290 (38 %) 111/224 (50 %)
Age group ^b			
< 16 years	213/500 (43 %)	82/210 (39 %) 82/213 (38 %)	131/290 (45 %) 131/213 (62 %)
16–17 years	287/500 (57 %)	128/210 (61 %) 128/287 (45 %)	159/290 (55 %) 159/287 (55 %)
Mean/median age (years)		15.6 (16)	15.3 (16)
Suicide method ^c			
Hanging	306/500 (61 %)	126/210 (60 %) 126/306 (41 %)	180/290 (62 %) 180/306 (59 %)
Jumping/lying before moving object	89/500 (18 %)	24/210 (11 %) 24/89 (27 %)	65/290 (22 %) 65/89 (73 %)
Jump from a high place	40/500 (8 %)	23/210 (11 %) 23/40 (58 %)	17/290 (6 %) 17/40 (42 %)
Poisoning	20/500 (4 %)	20/210 (10 %) 20/20 (100 %)	0 0
Firearm	29/500 (6 %)	7/210 (3 %) 7/29 (24 %)	22/290 (8 %) 22/29 (76 %)
Others ^d	16/500 (3 %)	10/210 (5 %) 10/16 (62 %)	6/290 (2 %) 6/16 (38 %)
N total/N of all study cases (%)	500/500 (100 %)	210/500 (42 %)	290/500 (58 %)

^a $\chi^2 = 11.88$, $df = 1$, $p = 0.001$

^b $\chi^2 = 1.86$, $df = 1$, $p = 0.172$

^c $\chi^2 = 46.46$, $df = 5$, $p < 0.001$

^d drowning, suffocation, cutting

Table 2

Blood alcohol concentration (BAC) in child suicides by sex, age group and suicide method, Sweden 2000–2022.

Demographics and suicide method	Alcohol (ethanol) in blood - positive		
	N/N toxicology positive	BAC mean (range)	N/N all in sex/age/method group
Sex^a			
Males	38/96 ^e (40 %)	1.19 (0.21–2.44)	38/276 (14 %)
Females	30/111 ^f (27 %)	1.11 (0.2–2.5)	30/224 (13 %)
Age group^b			
< 16 years	17/80 ^g (21 %)	1.15 (0.3–2.4)	17/213 (8 %)
16–17 years	51/127 ^h (40 %)	1.13 (0.2–2.5)	51/287 (18 %)
Mean/median age (years)	16.2 (16)		
N Total	68/207 ^{g, h} (33 %)		
Suicide method^c			
Hanging	38/126 (30 %)	1.15 (0.2–2.5)	38/306 (12 %)
Jumping/lying before moving object	10/21 ⁱ (48 %)	0.96 (0.2–1.8)	10/89 (11 %)
Jump from a high place	9/23 (39 %)	1.67 (0.8–2.4)	9/40 (22 %)
Poisoning	5/20 (25 %)	0.56 (0.2–1.4)	5/20 (25 %)
Firearm	4/7 (57 %)	1.26 (0.7–1.9)	4/29 (14 %)
Others ^d	2/10 (20 %)	0.9 (0.3–1.5)	2/16 (12 %)
N/N all study cases		1.15 (0.2–2.5)	68/500 (14 %)
N total/N toxicology positive	68/210 (32 %)		

^{e,h} 1 excluded, no blood specimen^{f, g} 2 excluded, no blood specimen^a positive vs. negative $\chi^2 = 3.67$, $df = 1$, $p = 0.055$ ^b positive vs. negative $\chi^2 = 7.95$, $df = 1$, $p = 0.005$ ^c positive vs. negative Fisher-Freeman test, $p = 0.309$ ^d drowning, suffocation, cuttingⁱ 3 excluded, no blood specimen

overall material, with 148 positive cases (30 %). Licit drug positive cases also accounted for 70 % of all with positive toxicology (Table 3). Prescription medicines for somatic health problems were rarely detected (< 5 cases). Among all positive cases, 27 % tested positive for substances other than licit and illicit drugs, such as alcohol, carboxyhemoglobin or amphetamine. Amphetamine ($n = 8$) could not be classified as licit or illicit drug due to insufficient information regarding potential prescription use (e.g., ADHD medication). Toxic levels of amphetamine were detected in 2 cases.

The mean age of licit drug positive cases was 15.4 years (median 16 years). Among toxicology positive cases, licit drugs were significantly more common in females ($p = 0.001$) and in the younger age group ($p = 0.011$), as well as in poisonings and hangings, though this was not statistically significant ($p = 0.062$) (Table 3). Among victims younger than 13 years, 32 % tested positive for licit drugs, such as antidepressants, central stimulants, and drugs used in emergency medical care; each drug group had fewer than three cases. Among licit drug positives, additional positivity for alcohol was more common in males and the older age group (Table 3). Almost one-fourth (24 %) of poisoning deaths were positive for both licit drugs and alcohol, a combination that was more common than in other suicide methods (Table 3).

Antidepressants were the most commonly detected licit drug group (41 %), followed by hypnotics (15 %), narcotic analgesics (9 %) and central stimulants (6 %) (Table 4). Overall, 17 % of cases tested positive for antidepressants: 26 % of females, 11 % of males, 16 % of the younger and 18 % of the older group. All drug groups were more common in females than in males (Table 4), with significant association for antidepressants and for hypnotics.

Combination of antidepressants was rare ($n = 4$). Fluoxetine was the most common drug in victims of all suicide methods, except for poisoning (Fig. 1), and the most common antidepressant with toxic blood levels (Table 5). Toxic and lethal blood levels were common for

Table 3

Licit drugs in child suicides by sex, age group and suicide method, Sweden 2000–2022.

Demographics and suicide method	Licit drugs positive			
	N/N all licit positive (%)	N/N toxicology positive (%)	N/N all study cases in sex/age/method group (%)	N alcohol positive/N licit positive (%)
Sex^a				
Males	57/148 (39 %)	57/97 (59 %)	57/276 (21 %)	8/57 (14 %)
Females	91/148 (61 %)	91/113 (81 %)	91/224 (41 %)	8/91 (9 %)
Age group^b				
< 16 years	66/148 (45 %)	66/82 (80 %)	66/213 (31 %)	3/66 (5 %)
16–17 years	82/148 (55 %)	82/128 (64 %)	82/287 (29 %)	13/66 (20 %)
Suicide method^c				
Hanging	92/148 (62 %)	92/126 (73 %)	92/306 (30 %)	8/92 (9 %)
Jumping/lying before moving object	14/148 (9 %)	14/24 (58 %)	14/89 (16 %)	1/14 (7 %)
Jump from a high place	15/148 (10 %)	15/23 (65 %)	15/40 (38 %)	1/15 (7 %)
Poisoning	17/148 (11 %)	17/20 (85 %)	17/20 (85 %)	4/17 (24 %)
Firearm	2/148 (1 %)	2/7 (29 %)	2/29 (7 %)	0/2 (0 %)
Others ^d	8/148 (5 %)	8/10 (80 %)	8/16 (50 %)	2/8 (25 %)
N total/N all toxicology positive		148/210 (70 %)		16/210 (8 %)
N total/N all study cases			148/500 (30 %)	16/500 (3 %)

^a positive vs. negative $\chi^2 = 11.88$, $df = 1$, $p = 0.001$ ^b positive vs. negative $\chi^2 = 6.48$, $df = 1$, $p = 0.011$ ^c positive vs. negative Fisher-Freeman test, $p = 0.062$ ^d drowning, suffocation, cutting

narcotic analgesic (Table 5). Paracetamol in toxic levels was detected in 3 cases. Most of the poisoning deaths ($n = 16$) related to licit drugs and/or illicit drugs had one drug, or a combination of two substances, at toxic or lethal level.

Among the 14 cases positive for illicit drugs, 9 were males and 5 were females, with a mean age of 16.5 (median 17). Nine were negative for licit drugs, and 11 were negative for blood alcohol content. Cannabis was the most detected illicit drug ($n = 11$), while MDMA, cocaine and heroin were detected in less than 3 cases each. Hanging was the most common method among those who tested positive for illicit drugs (57 %), followed by jumping/lying before moving object (14 %) and poisoning (14 %). None of the victims younger than 13 years tested positive for illicit drugs.

Among all cases that tested positive for licit and illicit drugs, most involved only a single drug (Fig. 2).

3.3. Alcohol

Alcohol (ethanol) was the second most common finding, detected in blood of 77 victims. Nine of these cases had a BAC < 0.2 g/L and were classified as alcohol negative, and 8/9 were negative for other substances. Finally, alcohol was positive in 14 % of all study cases, or 32 % among those with positive toxicology (Table 2).

More than half (57 %) of all alcohol positive cases had BAC levels ≥ 1 g/L, predominantly older teenagers. The mean BAC was 1.15 g/L, similar in both sexes and highest in those who jumped from a high place (Table 2). 10 % of all study cases who tested alcohol positive, tested negative for licit or illicit drugs; the mean BAC among these was 1.2 g/L

Table 4
Drug groups in child suicides, Sweden 2000–2022.

Drug groups (number of positive results)	N cases ≥ 1 drug(s)/N toxicology positive cases (%)	N cases ≥ 1 drug (s)/N study cases (%)	N males /N toxicology positive males (%)	N females /N toxicology positive females (%)	N alcohol positive in a drug group/N alcohol positive study cases (%)	N alcohol positive in a drug group/N drug group (%)
Antidepressants:	87/210 (41 %)	87/500 (17 %)	29/97 (30 %)	58/113 ^a (51 %)	7/68 (10 %)	7/87 (8 %)
Amytriptyline (1)						
Citalopram (11)						
Fluoxetine (45)						
Mirtazapine (4)						
Sertraline (27)						
Venlafaxine (2)						
Vortioxetine (2)						
N/N licit drug positive cases (%)	87/148 (59 %)					
Hypnosedatives^b (Benzodiazepines, neuroleptics, sedatives/anxiolytics):	31/210 (15 %)	31/500 (6 %)	8/97 (8 %)	23/113 ^c (20 %)	3/68 (4 %)	3/31 (10 %)
Alimemazine (9)						
Alprazolam (3)						
Aripiprazole (1)						
Clonazepam (2)						
Clozapine (1)						
Haloperidol (1)						
Hydroxyzine (5)						
Lithium (1)						
Nitrazepam (1)						
Olanzapine (2)						
Oxazepam (2)						
Propiomazine (4)						
Risperidone (3)						
Zopiclone (5)						
Zolpidem (1)						
Zuclopenthixol (1)						
Quetiapine (1)						
N/N licit drug positive cases (%)	31/148 (21 %)					
Narcotic analgesics^d (Opioids/ opiates):	18/210 (9 %)	18/500 (4 %)	6/97 (6 %)	12/113 ^e (11 %)	4/68 (6 %)	4/18 (22 %)
Codeine (5)						
Dextropropoxyphene (6)						
Morphine (2)						
Oxycodone (4)						
Tramadol (6)	18/148 (12 %)					
N/N licit drug positive (%)						
Central stimulants (except for amphetamine):	12/210 (6 %)	12/500 (2 %)	5/97 (5 %)	7/113 ^f (6 %)	2/68 (3 %)	2/12 (17 %)
Methylphenidate (11)						
Atomoxetine (1)						
N/N licit drug positive cases (%)	12/148 (8 %)					

^a positivity females vs males $\chi^2 = 9.87$, $df = 1$, $p = 0.002$

^b 11 not included, positive due to emergency medical care

^c positivity females vs males $\chi^2 = 6.08$, $df = 1$, $p = 0.014$

^d 6 not included, positive due to emergency medical care

^e positivity females vs males $\chi^2 = 1.30$, $df = 1$, $p = 0.253$

^f positivity females vs males $\chi^2 = 0.10$, $df = 1$, $p = 0.746$

(range 0.21–2.5).

In overall study material, similar proportions of males and females were alcohol positive (Table 2). Alcohol was more commonly detected in the older age group (Table 2), and all victims < 13 years tested negative for alcohol. The highest percentage of alcohol positive cases was found among poisoning deaths and those who jumped from a high place, but the association between suicide method and alcohol positivity was not statistically significant (Table 2). Among toxicology positive cases, the highest share of alcohol positives was found in those who died from firearm injury (Table 2).

The combination of positive alcohol findings and licit drugs was most common for narcotic analgesics and central stimulants and least common for antidepressants (Table 4).

4. Discussion

This national longitudinal study offers a comprehensive view of toxicological findings in suicides among children. The prevalence of licit

drugs indicates a relationship to mental health issues, while alcohol may have had a proximal role in the suicide act in many cases.

Large-scale studies with toxicological data in child suicides are scarce [17]. Most research has been limited by small samples [18], narrow regions [19,20], or by grouping children with adults [20–28], obscuring child-specific patterns. Some studies with mixed age groups focus on suicide methods [15,23,25,29], or specific substances [22,27], but few have examined combination of drugs and alcohol [9], with exceptions in Ireland [26], Iran [23], and Sweden [15,29]. Variations in study design and scope obstruct comparisons by age, sex, or suicide method. Given the unique risk factors in under-age suicides, more targeted research is essential to guide effective, age-appropriate prevention efforts.

4.1. General findings

In this study, in 42 % of cases, one or more substances were detected, with higher rates among females. Substance positivity increased with



Fig. 1. Most frequent drugs (top 3) by suicide method in child suicides, Sweden 2000–2022. Ilicit drugs, over the counter drugs and drugs in emergency medical care are not included. For suicide methods Jump from a high place and Others, several other drugs detected with < 3 cases.

age, as previously reported [25,26] and was most common in poisonings and jumping from a high place, suicide methods more frequent among females [3]. Brazilian data showed a similar 43 % positivity rate in suicide victims aged 10–19 years, with higher rates in poisonings and hangings [24], though males were more often positive.

4.2. Licit and illicit drugs

In children, licit drugs were the most commonly detected substances, unlike adults where alcohol dominated [15,21,25], likely due to legal age restrictions for alcohol. As expected for the young population, prescription drugs for somatic conditions were rarely detected. Licit drugs, particularly antidepressants, were more common among females, consistent with previous findings [21,22,30,31], females' more frequent healthcare contact before the suicide [30,32] and their higher depression rates [33]. In contrast, males exhibit a greater mental health stigma

and less willingness to seek help [34].

Although mental health disorders are strongly linked to adult suicide, this association is less clear in children under 15 [6]. Scandinavian studies show that about one-third of youth who died by suicide received mental health care prior the death [30,35], and 63 % had psychiatric contact within 2 years before a suicide [32]. Despite these interventions, many children died from a suicidal act. The service received by children and adolescents with mental health conditions varies greatly across the European Region, including in terms of access, quality assessment and treatment [36]. The Swedish Health and Social Care Inspectorate (IVO) has highlighted that the availability of child and youth psychiatry services varies across the country and has emphasized the risks associated with long waiting times for assessment and treatment, calling for measures to address these issues [37].

Antidepressants were the most detected licit drugs, consistent with Australian [17], Finish [18] and the USA findings [17,19]. The high

Table 5

Postmortem blood concentration (mg/L) of antidepressants, hypnotosedatives and narcotic analgesics in child suicides. Drugs with $N \leq 3$ cases, and drugs due to emergency medical care are not included. N = number of cases.

Drug groups	N	Range	Mean	Q1 (25th percentile)	Q2 median	Q3 (75th percentile)	Reference for toxic and lethal levels (blood), mg/L ^a
<i>Antidepressants</i>							
Citalopram	11	0.1–0.6	0.2	0.1	0.1	0.3	0.48–5.9 toxic 3.2–49 lethal
Fluoxetine	45	0.04–7.6	0.8	0.2	0.4	0.8	0.9–2 toxic 1.3–33 lethal
Mirtazapine	4	0.2–7.5	0.2	0.1	0.2	0.2	0.2–2.3 toxic 2.6–9.3 lethal
Sertraline ^b	25	0.08–0.8	0.4	0.2	0.5	0.6	1–2.9 toxic 5.6–26 lethal
<i>Hypnotosedatives</i>							
Alimemazine	9	0.04–1	0.2	0.08	0.08	0.2	0.8 (10th percentile) - 3.8 (90th percentile), median 1.4 lethal ^c
Hydroxizine	5	0.04–0.2	0.08	0.05	0.05	0.1	0.1–1.4 toxic 0.7–39 lethal
Zopiclone	5	0.03–3.5	0.8	0.08	0.1	0.3	0.25–1.6 toxic 0.4–4.1 lethal
<i>Narcotic analgesics (Opioids/ opiates)</i>							
Codeine	5	0.02–6.7	1.5	0.2	0.3	0.4	0.5–1 toxic 1–48 lethal
Dextropropoxyphene	6	1.9–20	8.8	2.1	4.9	16.1	0.8–2 toxic 1–60 lethal
Oxycodone	4	0.02–8.2	2.1	0.06	0.1	2.2	0.2–2.4 toxic 0.1–53 lethal
Tramadol	6	1.2–75	19.9	2.6	6.6	23.4	1–24 toxic 1.3–89 lethal

^a Molina [70]

^b Sertraline - 2 cases excluded, muscle as specimen

^c Söderberg 2016, Group A: Certified death by intoxication with one single substance [53]

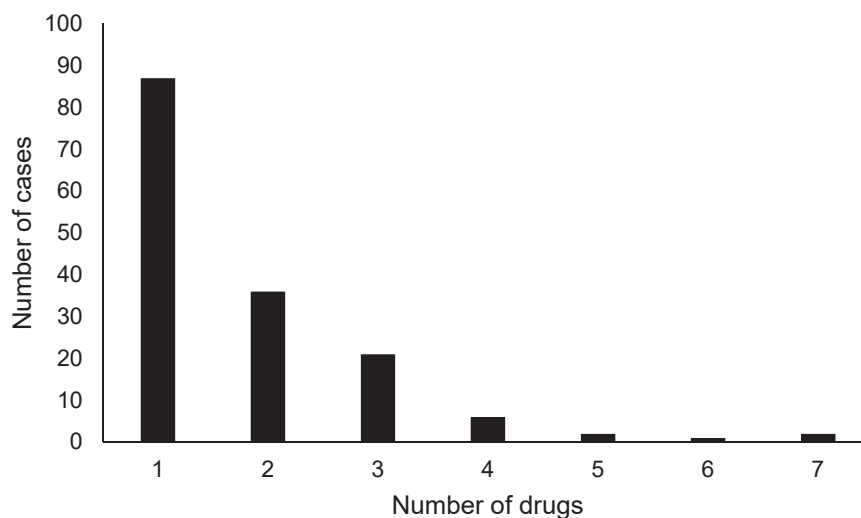


Fig. 2. Number of drugs in child suicide cases positive for licit and illicit drugs, in Sweden 2000–2022.

prevalence of antidepressants in suicides versus other child deaths [19] indicates highly vulnerable individuals in need of medical attention. Higher prescription rates [30] than reported as detected here may reflect non-adherence or discontinued treatment. Widespread pharmacotherapy non-compliance is documented in suicides [20,38,39], particularly in youths, who often drop out of treatment early [40]. Most cases here showed non-toxic levels, suggesting prescribed use, but missing prescription data may underestimate therapy prevalence.

SSRI use has increased among youth in Western countries [41], especially Sweden, where prescribing thresholds appear lower than in Norway and Denmark [42]. Swedish national guidelines reserve antidepressants for severe depression [43]. However, their role in suicide

prevention remains uncertain [44], and short-term risks must be balanced against potential long-term benefits. While antidepressant overdoses and lethal interactions are well-documented in adults [45], toxic levels found here in non-poisoning suicides (e.g. fluoxetine) may indicate complex suicides, warranting further study. Unlike sedatives and opioids, antidepressants were less often combined with alcohol, yet these combinations cause more severe outcomes in youth than alcohol alone [46].

Illicit drug presence in child suicides was low (3 %) in this study, slightly higher than in Finland [18], but lower than rates reported from the USA, New Zealand, and Australia (6–25 %) [17]. Cannabis was the most commonly detected illicit drug [17,18,28], especially in older

children, while potent illicit drugs like heroin and cocaine were rare. Cannabis use, especially heavy and long-term, was positively associated with suicidality in the general population [47]. The prevalence of illicit drugs increased with age, with higher prevalence in young adults than among children [48]. Illicit drug abuse was likely not present in the majority of our cases. Higher rates of illicit positive cases in other settings may reflect differences in age groups, drug availability, and socioeconomic factors; this study lacked medical records, however, limiting data on substance use history.

4.2.1. Poisonings

In Sweden, poisonings suicides are less common in children (4 %) [3] than in adults (33 %) [49] and typically involve prescription drugs like hypnotics and narcotic analgesics, often in combination [18]. Rarely prescribed to children, these may be obtained illicitly. Dextropropoxyphene, which is now banned in the EU and Sweden [50], and tramadol were involved in poisoning suicides here and elsewhere [15, 51, 52]. Alimemazine caused fatal poisonings in the overall population [53], but rarely in child suicides in the present study. Paracetamol, an age-restricted over-the-counter drug, appeared in poisoning cases here, while USA cases involved also ibuprofen [8], highlighting household medication risks. Regional variations in poisoning substances have been reported, reflecting differences in drug availability; Western cases involve medications [19, 54] whereas Asian cases more often involve pesticides [54]. Effective prevention requires safe storage at home, limiting prescription quantities, warnings, and national monitoring of prescribing practices.

4.3. Alcohol

Alcohol and substance misuse is strongly linked to increased suicide risk in young people [55–57], with even acute use increasing impulsivity and impairing coping [58, 59]. This can rapidly escalate suicidal intent into action [60], particularly in a developmentally vulnerable population of children and adolescents who are more impulsive and prone to violent methods [3]. Moreover, alcohol use before a suicide attempt can amplify the effects of central nervous system depressants, highlighting the need to assess alcohol use in suicide-risk evaluations [59].

Sweden has strict alcohol regulations for individuals under the age of 18. Beverages with > 3.5 % alcohol by volume can be purchased only from the state monopoly (Systembolaget) at > 20 years of age, while low-alcohol drinks and on-premises service require a minimum age of 18 years [61]. This creates greater barriers to adolescent access than in most European countries, where beer and wine can often be bought from the age of 16–17 years. In some US states, age limits are even higher. Overall, Sweden's age thresholds, enforcement, and state-controlled retail substantially limit alcohol availability for youths.

Alcohol was detected in 14 % of cases in this study, i.e. below the 30–40 % reported in children and adults elsewhere [9, 15, 17, 62–65]. Rates varied regionally: higher in Finland [18] and northern Sweden [66]. These study discrepancies may stem from variations in population size, age ranges, BAC cutoffs, drinking habits, or mental health factors. Moreover, Swedish youth alcohol consumption is now declining [67].

Across studies of both children and adults, males were more often alcohol positive than females [15, 21, 63, 64]. In contrast, the present study found equal rates of alcohol positivity between sexes, similar to USA data on teens [12] and Finnish data on children under 18 years of age [18]. However, the BAC trend in certain subgroups of males suggests possible sex-based risk differences that warrant further study.

Alcohol was also more common among teens in the present study, while no preteens were alcohol positive – in line with patterns observed elsewhere [12, 18]. High BAC levels were common in both child and adult suicides, with higher levels among those under 25 than among older groups [15]. Moreover, alcohol alone was detected in one-tenth of cases here, making up most alcohol positive suicides, suggesting that alcohol may be a key contributing factor in such cases.

Studies show an inconsistent link between alcohol use and specific suicide methods [9, 26, 65]. While some report alcohol is tied to more lethal methods like firearms [12, 60], others link it to poisonings [45]. Our findings align with Finnish data [18], showing no significant such association, though firearm cases had the highest alcohol positivity among toxicology positive cases. Ultimately, alcohol consumption elevates suicide risk across all methods. Method differences likely reflect mean availability, cultural factors, and intoxication effects.

Despite Swedish laws [61] banning underage drinking, youth often obtain alcohol through peers, family, or illegal sources [68]. While it's unclear if children in this study who died by suicide would have acted differently if sober, the risk supports limiting teen access to alcohol and the findings call for stronger preventive efforts targeting alcohol use, particularly in at-risk youths.

4.4. Strengths and limitations

This nationwide study is one of the largest toxicological surveys of its kind. Only 14 cases lacked postmortem toxicology data, a minimal exclusion in a population-level study. Accordingly, toxicology results were available in 97 % of cases, all analyzed by a certified central laboratory and reviewed by a forensic pathologist (AR) for study purposes, ensuring an evenly high data quality. In contrast, only 41 % of suicides under 25 years age in Geneva had toxicology testing [28].

However, interpretation requires caution. Postmortem alcohol may result from microbial fermentation, making it difficult to confirm antemortem use. To reduce this risk, a 0.2 g/L BAC cutoff was applied, as recommended, instead of lower thresholds used in some earlier studies – though this still introduces potential bias, both for under- and over-presentation of alcohol positive cases. However, a few cases with BAC < 0.2 g/L would not significantly affect study results if classified as alcohol positive.

Amphetamines, possibly prescribed for ADHD, were excluded from licit/illicit classifications due to lack of medical records, but their low prevalence limits potential bias.

While the study's descriptive design limits causal conclusions, the large sample, consistent methodology, and high-quality data provide strong insights into the toxicological patterns of under-age suicides. However, the findings are based on Swedish data and may not generalize to countries with different social, cultural, or healthcare contexts. The limitation of register data is the lack of details from medical history and police reports.

5. Conclusions

Child and adolescent suicide is a global issue demanding multidisciplinary prevention. Our findings reveal missed opportunities to detect and address psychiatric and substance-related risks. The prevalence of antidepressants suggests significant mental health vulnerability. Despite treatment, many suicides occurred, indicating deeper systemic and/or individual challenges. The high rate of psychiatric care among children who died by suicide [30] further emphasizes the need to review treatment adherence and healthcare quality.

However, many children who died by suicide had no history of psychiatric care [30], revealing a gap in prevention and the urgent need for improved risk screening, timely care, consistent follow-up, school-based interventions, and sex-specific outreach – especially to improve male engagement [30, 32, 55, 56].

High BAC levels indicate alcohol's proximal role in many suicides, underscoring the need for early intervention, targeted screening, and integrated treatment approaches. Restriction of narcotic analgesics and hypnotics for children is also essential, enforced through safe prescribing practices, treatment monitoring [69] and black-market controls.

No agency currently conducts systematic toxicological evaluations in child suicides, limiting evidence-based prevention [9]. Routine

monitoring could provide valuable indicators of treatment adherence and substance misuse [9], while future research should focus on suicides without prior psychiatric care and alcohol's role in suicide method lethality.

CRedit authorship contribution statement

Anders Rietz: Writing – review & editing, Methodology, Formal analysis. **Mensura Junuzovic:** Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Anneli Jönsson:** Writing – review & editing, Investigation, Formal analysis.

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Declaration of Competing Interest

All authors declare no potential conflicts of interest.

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