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Morbidities associated with suicide mortality in the United States of America according to education using death certificates from 2010 to 2019.

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Abstract:

Objectives: To identify relationships between multiple causes of death information and a decedent's sex and education in suicide compared to accidental deaths.

Methods: Based on the USA Mortality Multiple Cause-of-Death Public Use Record from 2010 to 2019, we performed correspondence analyses to visualise the relationships between comorbidity and sex-education profiles of individuals who died by suicide, and logistic regression models to estimate the odds that a comorbidity group is associated with suicide death relative to accidental deaths

Results: Sex and education are important factors of comorbidity registration in suicide deaths, but sex explains most of it. Having a high school degree was differentiated from other educational level groups among males' suicide deaths. Poisoning due to drugs and medication, mood disorders, and other mental and behavioural disorders are more associated with females while neoplasms and injuries are associated with male suicides. Schizophrenia, mood disorders, and anxiety, dissociative and non-psychotic disorders have higher odds of suicide compared to accidental death.

Conclusions: This study highlights the need for adapted prevention among sex-educational groups to prevent suicide due to their differences in registered comorbidity.

Highlights:

- Schizophrenia, mood disorders, and anxiety, dissociative and non-psychotic disorders have higher odds of being registered in a suicide death compared to an accidental death.
- Age-standardised suicide rates are higher for lower educational levels for both males and females, but males present distinct profiles of morbidities in suicide whereas education had a greater influence on females.

Introduction

Suicide is reported by the Centers for Disease Control and Prevention as one of the leading causes of death in the USA with more than 49,000 deaths annually [1]. Suicide rates in the USA increased by around 35% from 2000 to 2018 [2]; while decreasing worldwide [3]. Since 2016 suicide has been the second leading cause of death for the 10-34 age group and a leading one for most working age groups [4, 5]. Suicides have been identified to be higher among individuals with an education lower or equal to a high school degree, especially among those aged 45 years old and older, the highly educated were identified as those with lower suicide mortality [6, 7].

Studies of suicide mortality focus mainly on the underlying cause (UC) of death recorded by official statistics, meaning that the remaining or contributing causes are not considered. Several studies have highlighted the underestimation of suicide using official statistics [2, 4]. Measuring suicide mortality may be challenging due to the possible assignment of the case to another cause (e.g., changes in autopsy rates [8] data loss or limitations in the system of collecting and compiling data [9]). Recording a suicide manner of death requires concrete evidence [4, 10], which can be difficult to establish for certain methods of suicide, for instance, poisoning, prone to higher misclassification [11, 12]. For instance, the contemporary drug overdose epidemic has led to difficulties in determining the intent (intentional or unintentional) behind overdose deaths [2].

The UC by itself does not record the circumstances that would lead to the death [4]. Thus, using all causes of death listed in death certificates can help to better understand multi-morbidities and circumstances associated with suicide deaths.

The use of Multiple Causes of Death (MCOD) in the study of suicide deaths has been relatively unexplored, both in terms of multi-morbidities associated with suicide and suicide as a contributing cause. However, while suicide deaths, attempts, or behaviours among patients with a specific disease have extensively been studied [13–15], population-level assessments are limited. An analysis of MCOD in suicides has been performed by Ruzicka et al. (2005) by using disorders registered in Australian death certificates to estimate health impairments associated with suicides [16]. Results showed that besides mental illnesses and disorders, HIV

and cancer were the most probable conditions differentiating suicide from unintentional injury morbidities [16]. In a replication using the US population, Rockett et al. (2007) found that females had more morbidities registered than males, the prevalence of physical comorbidity increased with age, and depression and mood disorders were considerably more frequently reported among suicides [17]. Both studies used a comparative group of accidental deaths. Neither included injury, poisoning and other consequences of external causes in their analyses (International Classification of Diseases 10th revision codes [ICD-10] from S00 to T98) nor did they stratify the odds by sex and socio-demographic variables. An American replication using data from 1999 to 2003 [18] highlighted both racial-ethnic differences in comorbidity (e.g., schizophrenia and mood disorder were present in all groups while cancer was only present in the White and the Black groups and nervous system disease in the Hispanic group) and the underreporting of psychopathologies in suicide death certificates. Overall, the three studies highlighted differences in suicide comorbidities, more likely due to the registration practices of comorbidities in death certificates for specific socio-demographic characteristics than the actual causality of diseases. While suicide mortality is known to be avoidable through prevention strategies and facilitating access to mental health care, there is still a need to strengthen the knowledge of MCOD data and develop targeted prevention interventions [3]. To our knowledge, the scarce literature on suicide using MCOD has overlooked the relationship between morbidities and educational attainment.

This paper aims to descriptively assess the contributing morbidities associated with suicide mortality in the USA according to socio-demographic characteristics such as sex, age, and educational level. To do so, we examine the morbidities associated with suicide in comparison with other external causes of mortality, considering accidents as a comparator and using MCOD data.

Data

Analyses have been carried out using the individual-level Mortality Multiple Cause-of-Death Public Use Record of the United States from 2010 to 2019. Data are available open-access at the Division of Vital Statistics of the Centers for Disease Control and Prevention.

Deaths are coded following the ICD-10. The COVID-19 pandemic introduced significant changes, notably health inequities, quality and access to prevention care [19]. Consequently, data from 2020 and subsequent years are excluded to prevent potential biases in suicide MCOD analysis and to ensure the solidity of a pre-covid baseline for further analysis. Education was registered as the highest diploma obtained and grouped into four categories: High school degree or less, bachelor's or associate degree, master's or more, and unknown (10.9% of females and 11.4% of males). Suicides were considered when the UC was registered with codes X60-X84 and X87.0 and accidental deaths within V01-X59, and X85-X86.

Considering the specificity of suicide and self-harm intent in younger ages [20], and the use of education as the highest diploma, decedents under 25 years old have been excluded from the analyses. Deaths with no age registered (0.02% of females and 0.05% of males) were also excluded. The final study groups present a total of 376,911 suicides (292,992 males and 83,919 females), and 1,285,941 accidents (808,487 males and 477,454 females).

Comorbidities registered in the death certificates were grouped into 18 main groups, which belong to three main categories: mental and behavioural disorders, diseases, and injuries. Groups are presented in Table 1.

Table 1: *Classification of morbidities according to the ICD-10 with corresponding codes*

Mental and behavioural disorders	**Diseases**	**Injuries**
Substance use disorders (F10-F19)	Infectious and parasitic diseases (A-B-U)	Injuries (S00-T19)
Schizophrenia (F20-F29)	Neoplasms (C)	Poisoning by drugs, medicaments, and biological substances (T36-T50)
Mood disorders (F30-F39)	Nervous system (G)	Poisoning by nonmedicinal substances (T51-T65)
Anxiety, dissociative and non-psychotic disorders (F40-F48)	Circulatory system (I)	Asphyxiation (T71)
Other mental and behavioural disorders (F0,	Respiratory system (J)	Other and unspecified effects of external causes

F5-F9)		(T2—T34-T6—T8, V-Z)
	Digestive system (K)	
	Symptoms, signs not elsewhere classified (R)	
	Other diseases (D-E, H, L-Q)	

To avoid the duplication of certain profiles, the calculation of the occurrence of morbidities was carried out based on presence and non-presence. An individual with two or more morbidities belonging to the same group (e.g., three different neoplasms) counted only once as being affiliated with the considered comorbidity (i.e., has a registration of neoplasms).

Methods

Three independent analyses have been performed.

Firstly, we computed the age-standardised suicide rates (ASDR) yearly and for each sex-education profile using the 2000 USA standard, the Human Mortality Database [21] for yearly exposure per age group, and the American Community Survey 1-year Estimates Public Use Microdata sample with PUMS person weight for exposure per education. ASDR among the unknown education category were not estimated because their population exposure is not available.

Secondly, we produced a correspondence analysis (CA), to visualise the relationship between and within the sex-education profiles of decedents and the registration of a given comorbidity. CA is a principal component analysis performed on a contingency table created from categorical data and can be used to uncover associations between categorical variables. Essentially, it allows us to reduce a large number of categories into a smaller number of principal axes that explain a large proportion of the variation in the data [22]. We used CA to represent the relationship and contribution of each variable to the analysis. Correspondence analysis has already been used in the analysis of comorbidity and death certificates [23, 24]. Results are presented as a symmetric plot.

Thirdly, we estimated the odds that a given morbidity is associated with suicide compared to accidental deaths using logistic regression. To do so, we used a comparative group composed of accidental deaths. Several logistic regressions stratified by sex have been performed, one for each comorbidity group presented in Table 1. The dependent variable for each model is the presence of a given comorbidity in the death certificate. The independent variables were 5-year age groups, education (reference: *Bachelor*), place of death (*Home*), race (*non-Hispanic White*), autopsy (*Yes*), marital status (: Married) and UC (*Accident*s).

Analyses were carried out on R 4.3.1.

Results

Descriptive Statistics

ASDR were higher for males and among individuals with (or less than) a high school degree with 7.65 (95% CI[1]: 5.94-9.36) deaths per 100,000 females and 29.38 (CI: 26.02-32.73) per 100,000 males (Table 2). Individuals with a master's degree or higher have the lowest rates, with respectively 4.56 (CI: 3.24-5.88) and 13.44 (CI: 11.16-15.71).

Table 2. *Age-adjusted death rates per 100,000 and crude distribution of suicide (underlying cause) per sex and education, United States 2010-19 for individuals aged 25 years old or older at death*

[1] All confidence intervals are 95%

	Females (N=83,919)		Males (N=292,992)	
	ASDR	**Crude distribution**	**ASDR**	**Crude distribution**
High school graduate or GED, or less	7.65 (5.94-9.36)	47,816 (56.98%)	29.38 (26.02-32.73)	189,367 (64.63%)
Associate or bachelor's degree	6.52 (4.93-8.10)	20,861 (24.86%)	19.92 (17.15-22.69)	52,964 (18.08%)
Master's, doctorate, or professional degree	4.56 (3.24-5.88)	6,092 (7.26%)	13.44 (11.16-15.71)	17,386 (5.93%)
Unknown	Inapplicable	9,150 (10.90%)	Inapplicable	33,275 (11.36%)

Note: Unknown diploma exposure was not available and represents 11.4% of male suicides and 10.9% of female suicides. 95% Confidence interval for all rates.

Source: Deaths from the United States Mortality Multiple Cause-of-Death Public Use Record 2010 to 2019, National Vital Statistics System, National Center for Health Statistics, CDC. Exposures from the American Community Surveys 1-Year Estimates Public Use Microdata sample with PUMS person weight. Standardisation based on the 2000 United States standard population.

The most registered comorbidity among suicides corresponds to injuries, which are present in up to 53.2% of male' suicides and up to 28.5% of female' (Bachelor) (Figure 1). Asphyxiation represented an important share of morbidities, ranging from 16.5% (Master or more) to 21.5% (High school or less) for males, and from 14.1% (Unknown) to 17.9% (Master or more) for females. The registration of poisoning by drugs, medicaments, or biological substances was found in up to 8.4% of males (Master or more), and 25.6% of females (Unknown education).

The main UC among suicides was firearm discharge (codes X72, X73, and X74), representing 56.9% (N=166,738) of male suicides and 32.1% (N=26,926) of females. The prevalence of hanging, strangulation, and suffocation (X70) is respectively 25.0% (N=73,368) and 22.7% (N=19,082). The major difference between males and females is the extent of intentional self-poisoning (from X60 to X69). The deaths registered within those codes (i.e., regardless of the nature of the substance) represented 36.0% (N=30,200) of female suicides, while it only

accounted for 10.7% (N=31,442) of males (see supplementary materials, Table A).

Correspondence Analysis

The dimensions displayed in Figure 2 considering sex and education explain 99.2% of the variance (97.5% D1, and 1.7% D2), making it appropriate to capture most of the information. D1 is defined by poisoning (drugs & medicaments) and high school diplomas, and D2 by males and asphyxiation. Similarities within the row points (profiles) or the column points (morbidities) can be interpreted by their distance, the closer together the row points are, the more similar they are. Identically, the closer a column point is to another one, the more similar they are. To interpret the relation between a row and a column point (i.e., comorbidities and sex-education profiles) we use the angle created by the line drawn from each point to the origin. An acute angle means that they are highly associated, and obtuse angle is translated by a weak association. The significance of the CA was assessed using the chi-square (88622.11).

Firstly, we can observe that the female education groups (♀) are more distinct from the other profiles than the males(♂), as shown in Figure 2. For example, the angles connecting the Injuries points and the female categories have obtuse angles, which indicates that the association between being a female and having injuries registered at death is negative. On the contrary, Injuries and the male categories share an acute angle which means that their association is strong. The profile points are separated into two groups based on sex, meaning that the similarities of sex-education profiles are led by sex and not education.

Poisoning due to drugs and medication, mood disorders, and other mental and behavioural disorders are associated with females. The angles are acute, which is interpreted as a highly probable association between the comorbidity record and the female profiles. The registration of neoplasms and injuries is more associated with males, which can be explained by the greater number of suicides by firearm among males (e.g., registration of open wounds). Females without higher education share a higher probability of association with registered diseases of the digestive system, and other/unspecified diseases. To facilitate the understanding of sex and educational patterns, an additional asymmetric plot with vectors

can be found in the supplementary material Figure A.

The contributions to each dimension are presented in supplementary materials Table B and Table C.

Odds ratio

The odds that a given morbidity is present in suicides compared to accidents are presented in Table 3. Five morbidities' presence were significantly associated ($p<0.001$) with higher odds of being registered as a suicide compared to an accident. Asphyxiation presented the highest odds with 24.62 (CI: 23.66, 25.63) among females and 19.20 (CI: 18.83, 19.63) among males. The four others were injuries (respectively 1.31 [CI: 1.29, 1.34] and 2.82 [CI: 2.79, 2.85]), schizophrenia (2.35 [CI: 2.04, 2.71] and 2.25 [CI: 2.06, 2.46]), mood disorder (7.53 [CI: 7.18, 7.89] and 12.18 [CI: 11.67, 12.72]) and anxiety, dissociative and non-psychotic disorders (2.86 [CI: 2.59, 3.15] and 3.41 [CI: 3.17, 3.66]). No comorbidities from the disease group presented significant odds of being registered in a suicide compared to an accident. We observed little difference between males and females, with the same morbidity groups presenting significantly higher/lower odds of being registered in a suicide compared to an accident.

***Table 3**. Odds ratio from the logistic regression models, United States 2010-19 for individuals aged 25 years old or older at death*

Comorbidity (ICD-10)	Odds ratio	
	Females	**Males**
Injuries	**1.31** (1.29, 1.34)	**2.82** (2.79, 2.85)
Poisoning by drugs, medicaments, and biological substances	0.32 (0.31, 0.33)	0.06 (0.06, 0.06)
Poisoning by nonmedicinal substances	0.71 (0.70, 0.73)	0.36 (0.36, 0.37)
Asphyxiation	**24.62** (23.66, 25.63)	**19.20** (18.83, 19.63)
Other and unspecified effects of external causes	0.51 (0.49, 0.53)	0.23 (0.23, 0.24)
Infectious and parasitic diseases	0.17 (0.15, 0.19)	0.14 (0.12, 0.15)
Neoplasms	0.46 (0.41, 0.50)	0.85 (0.80, 0.89)
Nervous system	0.67 (0.64, 0.71)	0.65 (0.63, 0.67)
Circulatory system	0.20 (0.19, 0.20)	0.13 (0.13, 0.13)
Respiratory system	0.21 (0.20, 0.22)	0.14 (0.14, 0.15)
Digestive system	0.29 (0.27, 0.32)	0.17 (0.16, 0.18)
Symptoms, signs not elsewhere classified	0.39 (0.37, 0.41)	0.30 (0.29, 0.31)
Other diseases	0.27 (0.26, 0.28)	0.16 (0.15, 0.16)
Substance use disorders	0.20 (0.19, 0.20)	0.09 (0.09, 0.09)
Schizophrenia	**2.35** (2.04, 2.71)	**2.25** (2.06, 2.46)
Mood disorders	**7.53** (7.18, 7.89)	**12.18** (11.67, 12.72)
Anxiety, dissociative and non-psychotic disorders	**2.86** (2.59, 3.15)	**3.41** (3.17, 3.66)
Other mental and behavioural disorders	0.39 (0.35, 0.43)	0.29 (0.27, 0.32)

Note: Odds ratios are controlled by age (5-year age group), educational level (highest diploma using Bachelor as a reference – other categories being High school degree or GED or less, Master's, doctorate, or professional degree, and Unknown), and race (as a categorical variable including Hispanic, non-Hispanic whites as a reference, non-Hispanic black, non-Hispanic Asian and pacific islander, non-Hispanic Native American and Alaska Native, and Unknown). Accidental deaths were used as a reference to estimate the odds that a given comorbidity is associated more with suicide deaths.
Source: Deaths from the United States Mortality Multiple Cause-of-Death Public Use Record 2010 to 2019, National Vital Statistics System, National Center for Health Statistics, CDC.

Discussion

Our study found that sex and education were significant factors explaining the disparities in comorbidities registered in suicide deaths in the USA. Sex was found to be the main explaining variable in comorbidities registered at death compared to education. Poisoning by drugs and medicaments, other diseases, other mental and behavioural disorders, mood disorders and anxiety and non-psychotic disorders were associated with females; while injuries, neoplasm, and asphyxiation were associated with males. Education was more important in distinguishing profiles among males. Overall, schizophrenia, mood disorders, and anxiety, dissociative and non-psychotic disorders were significantly more likely to be registered as a comorbidity of suicide compared to accident, controlling for education and other socio-demographic variables. It is important to remember that although all the regression odds were significant, the results from the CA do not provide the association's significance.

Compared to the study by Rockett et al. (2007), we observed smaller odds for mood disorders associated with suicide compared to accidents. Our OR adjusting for age, education, place of death, marital status, autopsy and race were 7.53 (CI: 7.18, 7.89) for females and 12.18 (CI: 11.67, 12.72) for males, which are lower than the excess likelihood adjusted for age and sex found in the previous study 34.59 (CI: 32.41, 36.92) [17]. This difference could be explained by the addition of our control variables, a general increase in the registration of these comorbidities for accidental deaths, a decrease in the quality of the registration of comorbidities at death, or a reduction in the suicide risk among individuals having mood disorders.

It is known that poisoning as an MCOD makes the classification of death more complicated [4, 25], especially when a long time elapses between the initial intentional poisoning and the death [26]. In the USA, unintentional poisoning mortality has been increasing since the mid-1980s [27], and the mortality rate increased by 128% from 2000 to 2009 [28]. The prescription drug epidemic [29, 30], and resulting mortality [23, 31] are well documented. Females tend to use less lethal methods to attempt suicide (i.e., the risk of dying from the attempt is lower compared to other methods), especially self-poisoning [32, 33], while males tend to use more lethal methods [34, 35]. The difference in the chosen method of suicide attempt, and the according difficulty to ascertain if a death is a suicide, could explain the lower tendency for poisoning comorbidities being registered as suicides compared to accidents. The odds that the presence of poisoning by drugs, medicaments, and biological substances among males registered in a suicide death compared to an accident was low (0.06 [CI: 0.06, 0.06]). A limitation lies in the misclassification of suicides in official statistics. The misallocation of the UC is likely to vary based on the sociodemographic characteristics of the decedent, such as education, age, state of residence, race-ethnicity, or sex. As a result, deaths recorded as accidents in the MCOD Public Use Record dataset may hide suicides, leading to potential biases in suicide comorbidity registration. The same bias exists with comorbidities, as their recording is influenced by the decedent's relationship with healthcare and vice-versa. Hence, females have more registered comorbidity as they are more likely to be in contact with healthcare services and to form a worse assessment of their health [36].

In this study, we chose to focus on sex-education profiles to explain potential differences in comorbidity registration. The results reveal a clear association between educational level and suicide rates. Individuals who have a higher education presented lower suicide rates, and individuals having no higher education had higher suicide rates. The CA results showed that sex explained most of the association between comorbidity and sex-education profiles. However, it appeared in the CA that having a high school degree (or unknown) was differentiated from other educational level groups among males' suicide deaths.

Another relevant element for discussion is that suicidal behaviours and methods of attempted suicide (fatal and non-fatal) differ according to the level of education [37]. As we decided to keep injuries as a morbidity group, if males tend to use more violent methods, then the

association of specific physical and mental diseases might have been hidden by the weight of this category. Yet, investigating the associations of sex-education profiles with the method of suicide was beyond the scope of this study. Advanced investigations on suicide methods should be carried out to better understand the relationship between education and suicide. Additionally, one limitation resides in the use of race-ethnicity as a covariate and not an analytical variable. It is known that the accuracy of race registration in death certificates is not homogeneous [38], as well as self-injury mortality is [39] per sex-race groups. We thus encourage future research to investigate interactions between race and education in suicides. We showed in this study that crossing morbidities with sociodemographic characteristics aided a better understanding of which morbidities are associated with specific decedents' profiles by suicide, compared with accidental deaths.

Conclusion

The results highlight that sex and education are important factors in external causes of death morbidities. The study also delved into the risk that a given comorbidity is associated with suicide compared to accidents. We observed that males present distinct profiles of morbidities in suicide. Significant associations with suicide were established between the presence of mental disorders such as schizophrenia, anxiety, dissociative and non-psychotic disorders, mood disorders and suicides. At the same time, no significantly higher odds were found for diseases. The results from this study highlight the need for adapted suicide prevention considering not only who but also how to address prevention in specific communities and populations. Accordingly, this study adds to the growing body of knowledge needed to develop suicide prevention efforts. Future studies are necessary to better understand how morbidities and contributing external causes of death interact together and within undetermined intent death or different types of unintentional deaths (e.g., poisoning).

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Patient and Public Involvement

This study used secondary data that is publicly available online (https://www.cdc.gov/nchs/data_access/vitalstatsonline.htm) and did not involve the recruitment of patients or members of the public. As a result, no patients or members of the public were directly involved in the design, conduct, reporting, or dissemination plans of this research.

Competing Interests Statement

The authors declare that they have no conflict of interest.

Ethical Approval Statement

The University of Southampton Ethics and Research Governance Online system granted ethical approval for this study under submission ID 100675.

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Contributorship Statement

CG conceptualized the study, conducted the analysis, and drafted the manuscript. As a guarantor, CG is responsible for the overall content. STL conceptualized the study, reviewed the manuscript, and provided critical comments. Both authors approved the final version of the manuscript.

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