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Accuracy of Death Certificate Data in Reporting Suicide in the United States

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Walden University
2020

Abstract

Accuracy of Death Certificate Data in Reporting Suicide in the United States

by

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MPH, University of Utah, 2008

BS, Weber State University, 2004

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Suicide is one of the leading causes of death in the United States. Death certificates are currently being used by public health professionals and policy makers as a main source of public health surveillance data on suicide. The accuracy of death certificates in tracking and reporting suicides has not been well quantified or evaluated in the United States. Death certificates from other countries have been found to under-report suicide. The purpose of this study was to evaluate the accuracy of death certificates in reporting suicides in the United States. The National Violence Death Reporting System (NVDRS) collects information on all violent deaths from multiple sources including medical records, law enforcement reports, and vital records. Suicide cases recorded in the NVDRS data from 2003 through 2017 were used as a reference standard to evaluate the accuracy of death certificates in reporting suicide in the United States (n = 201,912). Using a multifactorial conceptual framework and a quantitative cross-sectional design, several risk factors were analyzed to determine if they influenced the accurate reporting of suicide on the death certificate. Using a binomial logistic regression model, 13.4% (Nagelkerke R^2 = .134) of the variation in accuracy can be attributed to age, race, marital status, education, method of suicide, substance abuse status, year, and state. This study establishes that the death certificate is highly accurate (99.57%) at reporting suicide deaths overall. Therefore, death certificate data can be used as an accurate data source upon which to base public health decisions, interventions, and tracking. It is important that policy and intervention decisions be based on accurate data to effectively and efficiently influence social change.

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Dedication

To my parents, Ned and Kathleen Palmer: your faith and belief in my ability to succeed has been instrumental throughout my life; Thank you for watching out for me from above. To my daughters, Emma and Amelia Palmer: this has been a difficult journey, may the completion of it be an example to you that you can do anything you set your mind to; I believe in you. To my wife, Linda Palmer: without your love, support, and patience, this would not have been possible; I love you forever and always.

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My wife, Linda Palmer, has been my chief editor throughout my educational journey. The number of hours spent reading and proofing papers and this dissertation have not gone unnoticed. She is ultimately the one who made this possible by supporting me, being my rock, and taking care of our family.

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Chapter 1: Introduction to the Study

Suicide is a leading cause of death among residents in the United States (Safe States Alliance, 2017). Data from 2018 show suicide as the 10th leading cause of death for residents in all age groups, and the second leading cause of death for those ages 10-34 years (National Center for Injury Prevention and Control, 2020). Death certificate data have been used as a major data source to track suicide occurrence and inform public health interventions at both the national and local level (Office of the Surgeon General & National Action Alliance for Suicide Prevention , 2012; Weber Morgan Health Department, 2015). However, the accuracy of death certificates in reporting suicides in the United States has not been evaluated. Effective and efficient interventions to influence social change must be evidence based and grounded with accurate data (Lovelace et al., 2015). The purpose of this study was to quantify the accuracy of U.S. death certificates in reporting suicides in Utah. This chapter will provide an overview of the background, problem, purpose, and significance of this study. The hypotheses, conceptual framework, nature, and limitations of the study will also be discussed.

Background

Suicide is a national health issue, with suicide prevention and research among top health priorities in the United States (Olfson et al., 2017). It is important to use high quality accurate data when formulating responses and planning interventions for public health problems (Szklo & Nieto, 2014). The accuracy of death certificates has been evaluated for several different causes of death (German et al., 2011; Mieno et al., 2016; Perera, Stewart, Higginson, & Sleeman, 2016). Researchers studying the accuracy of

death certificates in reporting cancer deaths, cardiac deaths, and deaths due to pneumonia have found that misclassification and the inappropriate sequencing of death codes are a major problem (Cheng, Lin, Lu, & Kawachi, 2012; Falci et al., 2018; German et al., 2011; Gjertsen, Bruzzone, Vollrath, Pace, & Ekeberg, 2013). These inaccuracies can cause under- or over-reporting of conditions, influencing the accuracy of public health surveillance data (Centers for Disease Control and Prevention [CDC], 2003; Cheng, Chang, et al., 2012). The accuracy of death certificates in reporting suicide has been evaluated in other countries but has not been evaluated in the United States (Bakst, Braun, Zucker, Amitai, & Shohat, 2015; Churruca, Draper, & Mitchell, 2018). This section will present the background of suicide in the United States. In addition, the use of death certificates as a data source, and the evaluation of the accuracy of death certificates will be discussed.

Suicide in The United States

Suicide rates in the United States have been increasing since 2006 (Olfson et al., 2017). Even though the increase has slowed in recent years, the rate of suicide in some states such as Utah remains significantly higher than the national rate. When comparing age-adjusted suicide rates in the United States from 2015 to 2017, Utah was ranked number five (Utah Department of Health, 2016). Previous studies about suicide have focused on the relationship with religion and accurately classifying opioid overdose deaths (Donaldson, Larsen, Fullerton-Gleason, & Olson, 2006; Hilton, Fellingham, & Lyon, 2002). However, the general accuracy of death certificates in reporting suicide has not been formally evaluated. Without formal evaluation it is impossible to know if

suicides are being under-reported, over-reported, or reported accurately on death certificates.

Death Certificates as a Data Source

In the United States, death certificates have been used to track deaths and cause of death at the national level since 1900 (National Research Council Committee on National Statistics, 2009). These valuable epidemiologic data have been used for decades to track mortality related public health problems and formulate interventions to improve them. The accuracy of death certificates in reporting cause specific deaths such as cancer has been evaluated (Falci et al., 2018; Govindan, Shapiro, Langa, & Iwashyna, 2014; Mieno et al., 2016). Previous studies have identified factors, such as the training of the person completing the death certificate, that can contribute to the inaccurate classification of cause of death or underlying cause of death (Falci et al., 2018; Govindan et al., 2014; Mieno et al., 2016). Efforts to improve the accuracy and efficiency of vital records reporting, including death certificates, are ongoing and have been since the system was established (Foreman, Naghavi, & Ezzati, 2016; National Center for Health Statistics (U.S.), 2018; National Research Council Committee on National Statistics, 2009)). There have not, however, been any published reports or studies evaluating the accuracy of death certificates in reporting suicide in the United States.

Gap

There is a gap in the literature with regard to the accuracy of death certificate data in the United States specifically related to the classification of suicide deaths. Quantifying the accuracy of this data source will allow public health leaders to be

confident in the decisions they are making based on these data and will inform efforts to improve the quality of death certificate data. The need to supplement death certificate data with other secondary administrative data sets is explored. It is important to base policy on accurate data and therefore important to quantify the quality and accuracy of data sources (Shi & Singh, 2011). Suicide-related policy and interventions, specifically at the local level, have used death certificates as a major source of data (Weber Morgan Health Department, 2016). It is, therefore, important to assess the accuracy of death certificates as a source of suicide surveillance data.

Significance

Policy and intervention activities, specifically at the local level, are being based on data obtained through death certificates (Weber Morgan Health Department, 2016). It is important to base policy on accurate data and therefore important to quantify the quality and accuracy of a data source (Hoagwood et al., 2015). The results from an analysis of the accuracy of death certificate data in reporting suicide can be used as a tool for social change. Having accurate data is not only important to the formulation of policy and interventions, but it is also important in the evaluation of the effects that these new policies and interventions have after implementation. Local health departments, non-governmental organizations such as philanthropic foundations, policy makers, and community leaders will benefit from this evaluation. Providing accurate and informative data to these stakeholders will ultimately benefit the citizens of the United States, who may have their life saved by evidence-based effective suicide prevention efforts. Accurate data are key to positive social change. The results of this research have the

potential to inform decisions to invest resources in collecting primary data on suicide, supplementing death certificate data with other secondary administrative data sets, or maintaining the current methods of using death certificate data alone.

Problem

Based on data from 2018, suicide is among the leading causes of death in the United States (National Center for Injury Prevention and Control, 2020). Deaths by suicide have been increasing since 2006 (Olfson et al., 2017). Suicide rates in the United States rose from 12.3 per 100,000 in the 1999-2001 time period to 15.4 per 10,000 in the 2014-2016 time period (Stone et al., 2018). Specific states, such as Utah, have experienced this at a more acute level. During 2008-2009, 6.8% of Utahans reported having suicidal thoughts comparted to the national average of 3.7% (Crosby et al., 2011). The suicide rate in Utah in 2015 was 24.5 per 100,000 compared to a national rate of 15.7 per 100,000 (Utah Department of Health, 2016). This public health issue warrants targeted research and intervention. Currently many state and local health departments use death certificate data as a major source for suicide surveillance (Ivey-Stephenson, Crosby, Jack, Haileyesus, & Kresnow-Sedacca, 2017; Utah Department of Health, 2016; Wilcox et al., 2016). However, death certificate data have been found to underreport suicide in other countries; additionally, other causes of death such as cancer and dementia have been found to be underreported in the United States (Bakst, Braun, Zucker, Amitai, & Shohat, 2015; German et al., 2011; Perera, Stewart, Higginson, & Sleeman, 2016). Bask et al. (2015), found the sensitivity of classification of suicide on death certificate in Tel Aviv to be underestimated by 29.4%. A third study, which used review of clinical

and autopsy records to assess the accuracy of cause of death assignment on the death certificate found that accuracy varied according to cause of death (Mieno et al., 2016). Based on this information, the incidence of suicide in the United States may be higher than expected due to underreporting.

There is a gap in the literature with regard to the accuracy of death certificate data in the United States related to the classification of suicide deaths. Quantifying the accuracy of this data source will allow public health leaders to be confident in the decisions they are making based on these data and will inform efforts to improve the quality of death certificate data. It is important to base policy on accurate data and therefore important to quantify the quality and accuracy of data sources (Shi & Singh, 2011).

Purpose

The purpose of this study was to quantify the quality of death certificate data in the United States, specifically related to the accurate reporting of suicide, by comparing it with data from the National Violent Death Reporting System (NVDRS), which collects data on suicides from multiple sources including medical records abstraction, law enforcement records, as well as administrative data such as death certificates (Paulozzi, Mercy, Frazier, & Annest, 2004). The NVDRS data include the original cause of death from the death certificate as well as an updated cause of death as assigned by the NVDRS abstractor (National Center for Injury Prevention and Control, 2016). Having both of these pieces of information in one dataset allowed this study to be conducted using one dataset without the need for matching records or merging datasets. Additional details

about the NVDRS data and how they were used in this study can be found in Chapter 2 and Chapter 3. The scope of this study was focused on an assessment of the accuracy of death certificate in reporting suicide in the United States rather than an identification of risk factors or etiology of suicide. Important decisions are being based on death certificate data. Knowing the quality and accuracy of these data will provide confidence in the data or will provide insight into the need for supplementary data to ensure accuracy. The results from this study will be used to inform future researchers' data source selection decisions.

Research Questions and Hypotheses

RQ: Using the NVDRS as the standard, what is the accuracy of death certificates in reporting suicide in the United States?

RQ1: What is the level of agreement between manner of death reported as suicide in the NVDRS and manner of death reported as suicide on the death certificate?

$H_0$1: The proportion of suicide cases misclassified by the death certificate is equal to or less than 0.01%.

H_a1: The proportion of suicide cases misclassified by the death certificate is greater than 0.01%.

RQ2: How does the accuracy of U.S. death certificate data in reporting suicide vary by method of suicide, age group, sex, transgender status, sexual orientation, race, marital status, geographic region, history of mental illness, substance abuse, year of suicide, state of suicide, or education?

$H_0 2$: The accuracy of death certificate data in reporting suicide does not vary by method of suicide, age group, sex, transgender status, sexual orientation, race, marital status, geographic region, history of mental illness, substance abuse, year of suicide, state of suicide, or education.

$H_a 2$: The accuracy of death certificate data in reporting suicide does vary by method of suicide, age group, sex, transgender status, sexual orientation, race, marital status, geographic region, history of mental illness, substance abuse, year of suicide, state of suicide, or education.

Individual sub-hypotheses for each variable:

$H_0 2_1 - H_0 2_{13}$: The accuracy of death certificate data in reporting suicide does not vary by [method of suicide ($H_0 2_1$), age group ($H_0 2_2$), sex ($H_0 2_3$), transgender status ($H_0 2_4$), sexual orientation ($H_0 2_5$), race ($H_0 2_6$), marital status ($H_0 2_7$), geographic region ($H_0 2_8$), history of mental illness ($H_0 2_9$), substance abuse ($H_0 2_{10}$), year of suicide ($H_0 2_{11}$), state of suicide ($H_0 2_{12}$), or education ($H_0 2_{13}$)].

$H_a 2_1 - H_a 2_{13}$: The accuracy of Utah death certificate data in reporting suicide does vary by [method of suicide ($H_a 2_1$), age group ($H_a 2_2$), sex ($H_a 2_3$), transgender status ($H_a 2_4$), sexual orientation ($H_a 2_5$), race ($H_a 2_6$), marital status ($H_a 2_7$), geographic region ($H_a 2_8$), history of mental illness ($H_a 2_9$), substance abuse ($H_a 2_{10}$), year of suicide ($H_a 2_{11}$), state of suicide ($H_a 2_{12}$), or education ($H_a 2_{13}$)].

RQ3: How does the accuracy rate with regard to suicide related manner of death assigned on the death certificate, change by year from 2005-2017?

H_o3: The accuracy of suicide related manner of death assigned by death certificate does not vary by year from 2005 - 2017.

H_a3: The accuracy of suicide related manner of death assigned by death certificate does vary by year from 2005-2017.

Conceptual Framework

Suicide is a multifactorial public health problem that has been explored extensively. The evaluation of the accuracy of vital records such as death certificates has also been researched and conducted by many investigators both nationally and internationally. The results from these previous studies and the methods used by these investigators has been used to create a conceptual framework for this study. In summary, the framework identifies factors and variables that are important to the accurate reporting of suicide on death certificates. Some of the important factors include geographic location of the death, method of suicide, and the training or background of the person classifying the death. This study focused on the factors related to the decedent and circumstances of the death, leaving the factors related to the person classifying the death for future study. The framework also summarizes methods used by previous studies to evaluate the accuracy of vital records including the use of secondary data sets such as the NVDRS. The framework is presented in detail in Chapter 2.

Nature of the Study

Quantitative, retrospective cross-sectional study methodology was used to assess the accuracy of death certificates in reporting suicide in Utah. The NVDRS database, detailed in Chapter 3, contains cause of death from the death certificate as well as an

updated cause of death as assigned by the NVDRS abstractor based on data from additional sources that was used to quantify the quality of the death certificate data. The presence of these two variables in one dataset allowed for the validation of death certificate data without the need matching records or merging datasets. Variables of interest included age, sex, method of suicide, race, sexual orientation, education, and geographic location of suicide.

Definitions

Accuracy: For the purpose of this study, accuracy refers to the reporting of suicide as a cause or manner of death on the death certificate when a suicide has actually occurred. Conversely, accuracy also refers to the exclusion of suicide as a cause or manner of death when in fact a suicide did not occur.

Cause of death: A data element collected by death certificate and NVDRS that captures the circumstances (physical, medical, environmental etc.) that led to the death (Centers for Disease Control and Prevention, 2003; National Center for Injury Prevention and Control, 2016).

Manner of death: A classification or grouping of cause of death such as natural, homicide, or suicide. This is a grouping or classification variable used by both death certificate and NVDRS to group causes of death by intent or etiology (Centers for Disease Control and Prevention, 2003; National Center for Injury Prevention and Control, 2016)

Method of suicide: The means used to complete suicide such as firearm, suffocation, poisoning, jumping/falling etc.

Psychological autopsy: A type of autopsy that is focused on the psychological and social circumstances leading up to a death (Botello, Noguchi, Sathyavagiswaran, Weinberger, & Gross, 2013). Referred to by some as a medicolegal autopsy. This type of autopsy is performed by a trained expert, usually with a background in psychology. In addition to information from the clinical autopsy, medical, legal, and school records are used in addition to information obtained through personal interviews with witnesses and relatives of the deceased (Botello, Noguchi, Sathyavagiswaran, Weinberger, & Gross, 2013; Moskos, Olson, Halbern, Keller, & Gray, 2005).

Assumptions

The major assumption for this study is that the NVDRS data are a valid and accurate gold standard that can be used to evaluate the accuracy of U.S. death certificates in reporting suicides in the US. The death certificate must be completed within five days of the death (National Center for Health Statistics (U.S.), 2018). The cause of death on the death certificate can be amended if additional information becomes available such as an autopsy. NVDRS abstractors collect data about violent deaths retrospectively often accessing the records several months or up to a year after the death (Crosby, Mercy, & Houry, 2016). This delay allows the many different source records accessed by NVDRS abstractors to be complete and final. The National Center for Injury Prevention and Control at the Centers for Disease Control and Prevention (CDC) have established comprehensive NVDRS data collection standards and data validation procedures. These standards and procedures must be followed by each state that contributes data to the NVDRS (Crosby, Mercy, & Houry, 2016). This robust data source has been used to

assess the accuracy of death certificates in reporting other violent deaths such as homicides and poisonings (Anna E. Austin et al., 2016; Donaldson et al., 2006). Additionally, NVDRS has been used to evaluate the accuracy of demographic variables on the death certificate such as veteran status (Bahraini et al., 2012). The findings from these previous studies provide proof of concept and supporting evidence for making the assumption that the NVDRS database can be used as an accurate reference standard.

Scope and Delimitations

The scope of this study included the accuracy of U.S. death certificates in reporting suicide using NVDRS data as the standard. Study variables were limited to factors surrounding the decedent and circumstances surrounding the death; the credentials and training of the person classifying the death will be assessed in a future study. This study is limited to deaths occurring in states that participate in the NVDRS, therefore the results may not be extrapolated beyond this group of states. The results do, however, provide meaningful information about the accuracy of death certificates in report suicides that occur in these states. This study was not intended to measure or report on suicide as a public health problem, rather validate or quantify the accuracy of death certificates in reporting suicide deaths. This study will not contribute to the body of knowledge surrounding suicide and associated risk factors but will add to the body of knowledge around accurately capturing suicide using vital records, specifically the death certificate.

Limitations

This study has limitations. The scope of the study was limited to only data from states that contributed data to the NVDRS, this will limit the external validity of the study

to suicide deaths reported in these states. Additionally, the data source selected for this study is the NVDRS. This dataset is being used as a reference or gold standard. The NVDRS employs many different techniques to ensure data quality and accuracy, however the accuracy of the results for this study are directly linked to the accuracy of the NVDRS data (National Center for Injury Prevention and Control, 2016). For example, transgender status was included as a variable in this study. This data element has only been collected by NVDRS since 2013 and is based on several source documents, some of which are anecdotal (Haas & Lane, 2015; National Center for Injury Prevention and Control, 2016). The NVDRS collects data elements, such as transgender status, that are not collected by vital records or other public health surveillance sources in an effort to understand the contribution to violent deaths. While these data elements may be subject to data quality or accuracy issues, the NVDRS dataset is one of the only sources for this important information (Haas & Lane, 2015).

Summary

Suicide is a major public health problem in the United States (National Center for Injury Prevention and Control, 2020). Current public health policy and resource allocation decisions related to suicide are being made based on data from death certificates (Utah Department of Health, 2016; Weber Morgan Health Department, 2016). The accuracy of death certificates in reporting suicides in the United States has not been systematically evaluated. Internationally death certificates have been found to underreport suicide (Bakst et al., 2015). Death certificates in the United States have been found to underreport deaths caused by other conditions such as cancer and pneumonia

(Falci et al., 2018; German et al., 2011; Perera et al., 2016). The purpose of this study was to evaluate the accuracy of death certificates in reporting suicide. Chapter 2 will present a literature review of previous studies along with the methods used to conduct the review. Additionally, a conceptual framework is proposed based on the methods and findings from previous studies that evaluated the accuracy of vital records and assessed the accurate reporting of suicide deaths.

Chapter 2: Literature Review

Introduction

Suicide has been increasing in the United States since 2000, particularly in the Western United States where rates rose from 22.90 deaths per 100,000 to 24.00 in 2009 (Rockett, Kapusta, & Coben, 2014; Rockett et al., 2012). This trend is specifically evident in Utah where suicide has become one of the leading causes of death (Utah Department of Health, 2016). A recent Epi-Aid report conducted by epidemiologists from theCDC documented an increasing suicide trend in Utah from 2011 to 2015 particularly among youth ages 10-17 years (Annor, Wilkinson, & Zwald, 2017). The national suicide rate among youth ages 10-17 years increased 23.5% during this period while the Utah rate increased 136.0% (Annor et al., 2017). The etiology of this alarming increase is unclear. Action is being taken by the CDC along with the State of Utah and other states affected by this increase to better understand the epidemiology of suicide (Cox & Eliason, 2018; Utah Suicide Prevention Coalition, 2017).

One aspect of understanding the epidemiology and tracking suicide in the United States is to understand and quantify the accuracy and validity of data sources being used. Death certificates are often used as the data source for studies, which become the basis for public health related decisions and resource allocation for issues such as suicide (Utah Department of Health, 2016; Utah Suicide Prevention Coalition, 2017). Death certificate data are timely, data are required to be collected and submitted within five days of death, with preliminary death certificate data available as soon as three to six months (National Center for Health Statistics (U.S.), 2018). It is important to assess the accuracy of data

sources used in such important and impactful decisions. Additionally, it is important to consider the value of combining different sources of data to establish a more comprehensive foundation upon which to build studies. The accuracy of cause of death as reported on the death certificate has been studied and identified as an area of concern related to specific types of death (Bakst et al., 2015; German et al., 2011; Mieno et al., 2016; Perera et al., 2016).

The NVDRS began collecting data from a limited number of states in 2003 (Crosby et al., 2016). The NVDRS has been incrementally adding states with a goal of collecting data from all 50 states. The data are collected at the state level and are collected from several sources including death certificates, medical examiner records, police reports, crime lab records, supplemental homicide reports, and medical records (Crosby et al., 2016). Data are collected on all unattended deaths and deaths reported as being due to violence or injury (National Center for Injury Prevention and Control, 2016). Potential cases are identified through cause of death codes on death certificate, medical examiner cases, and billing code reports from every hospital in the state (National Center for Injury Prevention and Control, 2016). This detailed information takes time to collect with the most current data being approximately 3 years old; this study used the most current data from 2003 through 2017 (CDC, 2017). While these data are not as timely as death certificates, they are collected using a detailed and rigorous process making it a potentially ideal source for assessing the accuracy of death certificate data.

This chapter outlines the methods used for evaluating the current body of research knowledge specific to the accuracy of death certificate data with a focus on suicide as a cause of death. A conceptual framework is established including the variables of interest and the methods used to analyze the accuracy of those variables. Potential data sources for evaluation and comparison of death certificate data are presented. The chapter concludes with a summary of the known issues surrounding the ascertainment, tracking, and reporting of suicide data.

Search Methods

Google Scholar, Ebsco Host, and PubMed were used to search for literature related to the accuracy of death certificates, the accuracy of suicide reporting, variables important to suicide surveillance, as well as vital records data quality. A record of search terms and the number of articles returned by each search can be found in Table A1 in the appendix. Many searches returned thousands of articles. Results were limited to publication dates between 2013 and 2020 and sorted by relevance. Articles were selected for review based on location of study, relevance of title, and inclusion of related concepts in the abstract. A limited number of international articles were included for comparison of findings and methods used to quantify the accuracy of vital records. In addition to the database searches described above, additional sources include the reference lists from relevant articles, suicide prevention websites such as Hope 4 Utah, and governmental reports from the Utah Department of Health and CDC. A total of 259 articles were selected for review out of which 159 were found to be relevant to this work.

Important Variables in the Assessment of Suicide

The first step in identifying the variables important to evaluating the accuracy of death certificates in reporting suicide, is to understand the variables that are important to tracking, analyzing, and understanding suicide as a public health problem. Suicide has been identified as a multifactorial phenomenon (Sarchiapone & D'Aulerio, 2015). A comprehensive review of the literature has resulted in this list of pertinent variables that are collected on death certificates: sex, age, race, geography, occupation, veteran status, education, marital status, and cause of death. There is a subset of variables not currently being collected on the death certificate that are associated with suicide including sexual orientation, religion, family and social support, experience of violence, income, and mental illness. Many of the variables that are not captured on death certificates are captured in other databases such as NVDRS and the Behavioral Risk Factor Surveillance System (BRFSS) (CDC, 2016; National Center for Injury Prevention and Control, 2016). The variables important to tracking and studying suicide that are not on the death certificate, but that are included in the NVDRS will be discussed below. The scope of this study is limited to evaluating the accuracy of the death certificate in reporting each of these variables. It is important to understand the relationship between each variable and suicide along with the strengths and weaknesses of how each variable is reported or recorded. Data collection methods used by researchers to identify these variables as being related to suicide will be used to compare and contrast the methods used to collect the data for death certificates. Because not all of the variables are collected on death certificates or included in the NVDRS dataset being used in this study it will not be

possible to include them all as variables in this study. A subset of variables will be defined in Chapter 3 for use in this study. Because they are important in understanding suicide and the accurate reporting of suicide each variable will be discussed in detail here.

Sex and Gender

Disparities in suicide rate and risk have been documented related to sex (Curtin, Warner, & Hedegaard, 2016b; Ivey-Stephenson et al., 2017; E. M. Sullivan et al., 2015; Turecki & Brent, 2016). Males, in the United States from 1999 through 2014, complete suicide at a rate greater than females (20.7 deaths per 100,000 in males; 5.8 deaths per 100,000 in females), this trend has held true over time with the gap becoming smaller in recent years (Curtin et al., 2016b; E. M. Sullivan et al., 2015). Suicide-related gender differences exist but are different in sub-populations like sexual minorities, veterans, and those with mental illness (Bostwick et al., 2014; Hoffmire, Kemp, & Thompson, 2015; Matarazzo et al., 2014; Rogers et al., 2017; Stone, Luo, Lippy, & McIntosh, 2015; Tucker et al., 2018; Williams, Langhinrichsen-Rohling, Wornell, & Finnegan, 2017).

Sexual minorities, those who do not identify as heterosexual, experience health disparities related to suicide, mental health, and access to healthcare (Blosnich, Farmer, Lee, Silenzio, & Bowen, 2014). Sexual minority women were three times more likely to have experienced serious suicidal ideation or attempt compared to heterosexual (Blosnich, Nasuti, Mays, & Cochran, 2016). Homosexual men have a seven-fold increase in lifetime suicide attempts compared to heterosexual men (Blosnich et al., 2016).

Several gender related disparities have been identified in veterans that have served in the U.S. military. Transgender veterans are four times more likely than male or female veterans to experience suicide ideation and suicide attempt (Tucker et al., 2018). Gender disparity related to mental health has also been observed in the younger population. Based on data from the NVDRS from 2005-2008 including youth aged 10-17 years from 16 states, female youth who died by suicide experienced mental illness at a higher rate compared to males (depression: females = 72.8%, males = 60.5%; bipolar disorder: females = 16.7% males = 12.1%; anxiety disorder: females = 4.4% males = 1.8%; eating disorder: females = 3.5%, males = 3.5% (Karch, Logan, McDaniel, Floyd, & Vagi, 2013). The gender disparities from these different subpopulations support the importance of including gender as a variable in the model for this study.

According to the instructions for completing the U.S. death certificate, sex should come from the classifying physician or the medical record of the decedent (National Center for Health Statistics, 2005). Sex is recorded as male, female, or unknown. Transgender individuals experience multiple health disparities including increased risk for anxiety, depression, and suicide that cannot fully be understood or studied without an accurate way to identify a person as transgender either in the medical record, vital records, or other sources of data (Bosse, Leblanc, Jackman, & Bjarnadottir, 2018; Haas & Lane, 2015). Transgendered individuals are 19 times more likely to experience death by suicide when compared to matched nontransgender controls in Sweden (Dhejne et al., 2011). The national guidelines for completing the death certificate do not allow a place to record transgendered status (Ikeda et al., 2014; National Center for Health Statistics,

2005). This makes assessing mortality disparities among transgendered persons difficult (Haas & Lane, 2015). Recognizing this important disparity some national data sets such as the NVDRS have begun collecting transgender status. The NVDRS began collecting transgender status in 2013 (National Center for Injury Prevention and Control, 2016). The NVDRS coding manual indicates that sex should be recorded as the biological or legal sex at time of death; additionally, there is a data variable to capture transgender status (National Center for Injury Prevention and Control, 2016). NVDRS data abstractors determine transgender status using family or physician report, in addition to any medical record documentation of gender reassignment therapy (National Center for Injury Prevention and Control, 2016).

The studies cited above have used several methods for identifying sex including transgender status. Studies based on survey data collect sex and transgender status with specific self-report demographic style questions (Blosnich et al., 2014; Bostwick et al., 2014; Stone et al., 2015; Tucker et al., 2018; Williams et al., 2017). The survey questions used to ascertain sex vary among the different studies. Some of the surveys ask about and record transgender status while others only allow male or female answers. Many of the studies use data from vital records which, as documented above, only records male, female, and unknown (Curtin et al., 2016b; Ivey-Stephenson et al., 2017; Sullivan et al., 2015; Turecki & Brent, 2016). One study used international classification of disease 9th revision (ICD-9) codes to identify those with gender identity disorder as potentially transgender (Blosnich et al., 2013). Each of these data collection methods has strengths and weaknesses.

The accuracy of sex as recorded on the death certificate in the United States has not been reported. A study from a large hospital in India found inaccuracies in the sex recorded on four of the 151 (2.65%) death certificates filed by the hospital in 2012 (Dash, Behera, & Patro, 2014). One major known weakness with the sex variable as recorded on death certificates in the U.S. is the absence of a transgender classification (Bosse et al., 2018). The accuracy of capturing sex using survey questions has also not been reported. Capturing transgender status using ICD-9 codes does have some documented weaknesses. These weaknesses include excluding those who have not been officially diagnosed with gender identity disorder, including those who have been diagnosed but who do not identify as transgender, and including those who may have been inaccurately coded as having gender identity disorder (Blosnich et al., 2013). The inability to record transgender status or gender identity or the misclassification of sex limits the ability of researchers to identify and understand any disparities in these sub-populations (Bosse et al., 2018; Ikeda et al., 2014).

Age

Age is recorded on the death certificate as years at the decedent's last birthday (National Center for Health Statistics, 2005). Date of birth is also captured and verified with a copy of the decedent's birth certificate. The NVDRS captures age in the same way with verification of additional documents including birth certificate or medical records (National Center for Injury Prevention and Control, 2016).

Suicide rates vary by age (Curtin, Warner, & Hedegaard, 2016a; Ivey-Stephenson et al., 2017; Jiang, Mitran, Minino, & Ni, 2015; Turecki & Brent, 2016; Wang et al.,

2016). Suicide has become a leading cause of death among young people ages 10-34 in the United States (National Center for Injury Prevention and Control, 2020). Suicide rates vary by age group, but there is also variation within the age groups by race and gender. The age group with the highest suicide rate among females is 45-54 while it is 75-79 among males (Wang et al., 2016). Risk factors for suicide also vary by age (Blosnich et al., 2016; Canetto, 2017; Dilillo et al., 2015). Sexual minority women reported first suicide attempt at a mean age of 15.9 years compared to heterosexual women who reported first attempt at a mean age of 19.6 years of age (Blosnich et al., 2016). Youth who are treated with antidepressants as well as older American men of European descent are examples of age-related risk groups that differ by specific risk factors (Canetto, 2017; Dilillo et al., 2015).

As with the sex variable, the accuracy of age as captured on the death certificate in the U.S. has not been reported. A small number of death certificates (8/151, 5.3%) filed by large hospital in India had the age field completed inaccurately (Dash et al., 2014). A copy of the birth certificate is required to complete a death certificate so that the date of birth and other demographics can be verified (National Center for Health Statistics, 2005). The electronic system used to capture and record death certificate data will verify that the age entered agrees with the date of birth and date of death entered (National Center for Health Statistics, 2005). This electronic validation reduces the chances for a data entry or verbal reporting error.

Race and Ethnicity

The race categories included on the death certificate are White, Black or African American, American Indian or Alaskan Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, Other Asian, Native Hawaiian, Guamanian or Chamorro, Samoan, Other Pacific Islander, Other, Unknown, Not obtainable, and refused (National Center for Health Statistics, 2005). Hispanic, Spanish, or Latino ethnicity is captured as yes/no with a follow up questions to identify the country of origin (Utah Department of Health, 2017). This is collected from a family member or informant that gives the information to the physician, death certificate clerk, or funeral director (Arias, Heron, & Hakes, 2016; Utah Department of Health, 2017). The NVDRS race variable has different categories including: White, Black or African American, Asian, Native Hawaiian or other Pacific Islander, American Indian or Alaska Native, and unspecified (National Center for Injury Prevention and Control, 2016). Both systems document ethnicity in a separate field.

Nationally suicide rates vary by race with non-Hispanic White females experiencing an 80% increase from 1999 to 2014 ending with a rate about four times higher than other female races (Curtin et al., 2016a). Non-Hispanic American Indian or Alaskan Native males experienced the highest suicide rate in 2014 (48.0 per 100,000), which was a 60% increase from 1999 to 2014 (Curtin et al., 2016a). Sub-populations like sexual minorities and veterans also experience disparities in race-specific suicide rates (Reger et al., 2015; Stone et al., 2015). Veterans who were non-Hispanic Native American (30.36 per 100,000), non-Hispanic White (20.17 per 100,000), or Other (27.50

per 100,000) had higher rates of suicide compared to veterans of other races using data from 2001 to 2009 (Reger et al., 2015). Among sexually active youth in Milwaukee, 40% of sexual minority white youth reported attempting suicide compared to 7.06% of heterosexual white youth (Stone et al., 2015).

The accuracy of recording Native Alaskan or American Indian on the death certificate was assessed using medical record data from Indian Health Services (Espey et al., 2014). Native Alaskan or Native American race was misclassified in 17.7% of the 176,137 death records that were analyzed (Espey et al., 2014). Misclassification was identified by matching death records to records from Indian Health Services, case where individuals verified to be Native Alaskan or Native American were classified in some other race (Espey et al., 2014). Classification errors related to Native Alaskans or Native Americans varied by geographical region with the highest error rate, 35.6%, in the Southern Plains (Espey et al., 2014). These errors resulted in underreporting of deaths in the Native Alaskan or Native Americans by 20.9% nationally and 40.9% in the Southern Plains region (Espey et al., 2014). These reporting errors could mask disparities that need attention from public health authorities. Another study using census survey data from 1979-2011 as a comparison, Native Alaskan and Native American race was accurately identified only 54% of the time (Arias et al., 2016).

Ethnicity is related to race and further complicates accurately recording and reporting race. Ethnicity refers to nativity or country of origin, with Hispanics being the largest immigrant group in the United States (Van Hook, Bean, Bachmeier, & Tucker, 2014). The death certificate allows multiple races to be selected along with ethnicity, for

example, someone can be White and Hispanic (Arias, Heron, & Hakes, 2016). Legal immigration status affects self-report of ethnicity (Van Hook et al., 2014). Funeral directors and physicians completing the death certificate data are encouraged to obtain race from next of kin but have the ability to record race and ethnicity based on observation (Arias et al., 2016). Accurate classification of Hispanic origin has improved over time but 3% of Hispanic deaths are still ethnically misclassified as non-Hispanic (Arias et al., 2016). This underreporting could negatively affect the accuracy of any research done on Hispanic deaths.

Classification of race and ethnicity based on observation of physical appearance is used in general healthcare and in data collection for death certificates (Arias et al., 2016; Gomez, Le, West, Satariano, & O'Connor, 2003). While this is not the only method used, it was found to be the method used to classify race in almost half of hospitals in a study conducted in the San Francisco Bay area (Gomez et al., 2003). Efforts have been made to standardize and improve data collection policies and procedures (Zingmond et al., 2015). Overall accuracy of classifying race and ethnicity has improved significantly over time, with correct classification of Hispanics approaching the accuracy of Black and White races, the misclassification of American Indian and Alaska Native continue to be a problem (Arias, Eschbach, Schauman, Backlund, & Sorlie, 2010; Arias et al., 2016; Espey et al., 2014; Zingmond et al., 2015).

Geography

Variables such as state, county, urbanicity, and altitude are geographic features that are related to suicide (Huber, Coon, Kim, Renshaw, & Kondo, 2014; Ivey-

Stephenson et al., 2017; Mann & Michel, 2016; Turecki & Brent, 2016). According to U.S. vital records data from 2001 to 2015, those in rural areas experience a higher rate of suicide (17.32 per 100,000) when compared to those in urban communities (11.92 per 100,000) (Ivey-Stephenson et al., 2017). There are interesting variations in urbanicity at the state level. Utah, as an example, follows the national trend with rural areas having the highest rate. However, this does not hold true when accounting for age, for youth ages 11-24 the medium metro areas have the highest rate (Annor et al., 2017; CDC, 2017b; Utah Department of Health, 2016)

Additionally, variation in accuracy of race classification on death certificates, specifically among Native American and Native Alaskan races, varies by geographic region with an error rate of 6.3% in the Southwest compared to 35.6% in the Southern Plains region of the country (Espey et al., 2014). The experience and skills of personnel and resources available to collect death certificate information and classify cause of death may vary geographically. This geographic variation in accuracy could cause a drastic underreporting of suicide or other causes of death among Native American or Native Alaskan racial groups in the Southern Plains region of the United States.

Marital status

Marital status is captured on the death certificate as married, married but separated, widowed, divorced, never married, and unknown (National Center for Health Statistics, 2005). The preferred source for this variable is the informant or family member who is providing information to the individual completing the death certificate (National Center for Health Statistics, 2005). Social and familial support is an important

protective factor for suicide (Matarazzo et al., 2014; Miller, Esposito-Smythers, & Leichtweis, 2015; Mustanski & Liu, 2013; Younes et al., 2015). In contrast, relationship issues such as divorce, intimate partner violence, and separation have been found to increase risk for suicide (Evans, Scourfield, & Moore, 2016; Goldblum et al., 2012; Kaplan, McFarland, Huguet, & Valenstein, 2012; Kazan, Calear, & Batterham, 2016; Stack & Scourfield, 2015). No conclusive evidence has been found of suicide risk differences based on gender after separation or divorce (Evans et al., 2016). According to a study of male veterans using data from the NVDRS, 2003 to 2008, half of younger male veterans age 18-34 who died by suicide were reported to have relationship problems shortly prior to suicide (Kaplan et al., 2012). The same was not true of older veterans (Kaplan et al., 2012). Given the demonstrated association between relationship or marital status and suicide, it is an important variable to track and assess. Additionally, given the potential for age to modify the effect of marital status it will be important this as an interaction term in the statistical analysis model.

Beyond the preferred informant report on death certificates, NVDRS data collection guidelines suggest that there are several other sources for these data including medical records, police reports, and reports from the medical examiner (National Center for Injury Prevention and Control, 2016). A weakness of marital status on death certificate is that it comes from one self-report source and is not generally validated using multiple source documents.

Occupation and Veteran Status

Occupation has been proposed as a significant factor influencing suicide risk (Germain, 2014; Stallones, Doenges, Dik, & Valley, 2013). The occupations with the highest risk for suicide are farmers, fishing industry workers, and forestry workers (Germain, 2014; Stallones et al., 2013). The relationship between occupation and suicide is complicated and may be influenced by other factors such as gender and socioeconomic status (Milner, Spittal, Pirkis, & LaMontagne, 2016; Pan, Stewart, & Chang, 2013). Occupation is collected on the death certificate as reported by the informant or family member and is not verified using any additional documentation (National Center for Health Statistics, 2005). An evaluation of the accuracy of occupation on death certificates in North Carolina from 1987-2001 found low levels of agreement between death certificate and self-report occupation, however when classified into job categories the agreement reached 67% (Bidulescu, Rose, Wolf, & Rosamond, 2007).

Suicide rates for specific occupations, such as firefighters, police officers, physicians, nurses, and veterinarians , have been reported along with elevated suicide risk and differing risk factors which range from stress to access to lethal means (Alderson, Parent-Rocheleau, & Mishara, 2015; Gold, Sen, & Schwenk, 2013; Goldman, Shah, & Bernstein, 2015; Nett et al., 2015; Stanley, Hom, & Joiner, 2016; Violanti et al., 2016). Another well-studied group in relation to suicide is veterans. Veterans are another high-risk occupation group (Kirsch, 2014). Veteran status is specifically collected on the death certificate and is obtained by report from a family member or informant (National Center for Health Statistics, 2005). Between the years 2000 and 2010 a 40% increase

was observed in suicide rates of all female veterans as compared to a 13% increase in the non-veteran female population (Hoffmire et al., 2015). When compared to nonveteran males, 6% more veteran males used a firearm to complete suicide (Hoffmire & Bossarte, 2014). Death certificate data from Colorado, years 2004 - 2008, was used to evaluate the accuracy of veteran status reported on the death certificate as compared to Colorado Violent Death Reporting System as well as linkage to Veteran Benefits Administration data (Bahraini et al., 2012). Agreement between the other sources and death certificate were high, suggesting veteran status was generally accurate in Colorado from 2004 to 2008 (Bahraini et al., 2012).

Education

Education is captured on the death certificate as eighth grade or less, ninth through 12th grade no diploma, high school or GED completed, some college credit but no degree, associate degree, bachelor's degree, master's degree, doctorate, and unknown (National Center for Health Statistics, 2005). Rates of suicide vary by level of education, those with higher levels of education have lower rates of suicide (Phillips & Hempstead, 2017). Education has also been used as an indicator of socioeconomic status (Casey et al., 2018; Darin-Mattsson, Fors, & Kåreholt, 2017). Education will be included in this study as an indicator of socioeconomic status. It is important to understand if there are differences in the accuracy of suicide reports on the death certificate among different levels of socioeconomic status.

Cause of Death

Cause of death is one of the most important variables on the death certificate. The attending physician or medical examiner signing the death certificate assigns the cause of death, underlying causes of death, and contributing diseases (National Center for Health Statistics, 2005). The death certificate allows for an unlimited number of causes to be assigned, the electronic data set only stores the first 5 listed (National Center for Health Statistics, 2005). If recorded appropriately, suicide will be reported as the manner of death. It is also possible for suicide related codes to be reported in the cause of death fields. Since suicide can be reported in either place on the death certificate it is possible for there to be suicide related cause of death codes assigned and the manner of death to be recorded as something different; this would be an error. If there are suicide related cause of death codes, then the manner of death should be classified as suicide. The major focus of this study was to assess the accuracy of manner of death related to the reporting of suicide deaths.

The accuracy of assigning suicide as a cause of death in the U.S. has not been reported. The accuracy of several other specific causes of death have been reported for the U.S. as well as other countries (Bakst et al., 2015; German et al., 2011; Mieno et al., 2016; Perera et al., 2016). Each of these studies uses a different source for validation of the cause of death, these range from diagnosis codes to medical record review. Misclassification of suicide as cause of death was assessed in Israel where suicide rates would be 42% higher if suicide was accurately recorded as cause of death (Bakst et al., 2015). Method of suicide was found to be related to misclassification (Bakst et al.,

2015). Previous cause of death studies from the U.S. have focused on cancer, hypertension, poisonings, and infections (Cheng et al., 2012; Donaldson et al., 2006; German et al., 2011; Govindan, Shapiro, Langa, & Iwashyna, 2014). Variations in accuracy have been attributed to training of the certifying official, order of cause of death codes, missing information, and exclusion of proximal or contributing causes of death (Cheng et al., 2012; Donaldson et al., 2006; German et al., 2011; Govindan et al., 2014).

Studies focused on cancer related cause of death found errors related to proper sequencing of cause of death codes, the amount of detail documented in the cause of death fields on the death certificate, and inconsistencies in site and type of cancer compared to validation data (Falci et al., 2018; German et al., 2011; Massa et al., 2017; Mieno et al., 2016). These studies used a variety of methods to assess the accuracy of cancer as reported on the death certificate including medical record review, re-coding of the cause of death by expert reviewers, and evaluation using secondary data sources such as Surveillance, Epidemiology, and End Results (SEER) cancer registry data. Differences in how cancer statistics would have changed based on the errors was not reported, the general focus was on how many records accurately recorded cancer related cause of death (Falci et al., 2018; German et al., 2011; Massa et al., 2017; Mieno et al., 2016).

The evaluation of dementia as recorded on the death certificate provides interesting insights into potential sources of error and misclassification of cause of death on the death certificate (Perera et al., 2016). Secondary data sources that included case registry and electronic medical record data were used to identify individuals who were

diagnosed with dementia and are now deceased. Errors in reporting dementia on the death certificate varied by place of death, age of decedent, and type of dementia (Perera et al., 2016).

The order in which cause of death codes are recorded on the death certificate is important and documents the sequence of events or disease that caused the death (Centers for Disease Control and Prevention, 2003). Errors in sequencing can lead to errors in surveillance and reporting (Cheng, Lin, et al., 2012). Inappropriate sequencing can lead to counting deaths in the wrong category leading to under or over reporting of specific causes of death like hypertension, pneumonia, or diabetes (Cheng et al., 2012; Falci et al., 2018; Gjertsen et al., 2013).

Missing information, and exclusion of proximal or contributing causes of death is another significant source of death certificate error (Donaldson et al., 2006; Govindan et al., 2014; Trinidad, Warner, Bastian, Minino, & Hedegaard, 2016). Missing information or errors of exclusion were identified using medical record review and secondary data such as Medicare Diagnosis-related Group (DRG) codes as a reference. The missing information can make it difficult or impossible to accurately classify the death, resulting in the underreporting of conditions such as suicide and infection (Donaldson et al., 2006; Govindan et al., 2014; Trinidad et al., 2016).

Several potential sources of inaccuracy or error in cause of death reporting on the death certificate have been detailed. Additionally, multiple methods for evaluating the accuracy of cause of death as recorded on the death certificate have been identified. The methods identified here could be used to evaluate the accuracy of suicide data captured

on the death certificate in Utah. It is also important to understand the limitations of the data collected on the death certificate.

Important Variables not Collected on Death Certificate

This section of the chapter covers variables that are important to the assessment of suicide, specifically evaluating the accuracy of suicide as reported on the death certificate. There is a subset of variables, not collected on the death certificate, that are important in understanding the epidemiology of suicide. Some of the important missing variables are sexual orientation, religion, family or social support, experience of violence, income, and mental illness. The suggested inclusion or exclusion of these variables as a part of the death certificate will be discussed in chapter 5.

Many of these variables such as sexual orientation, religion, family or social support, experience of violence, and income have been identified as protective or risk factors (Bannink, Broeren, Jansen, Waart, & Raat, 2014; Blosnich et al., 2016; Hilton et al., 2002; Kazan et al., 2016; Miller et al., 2015; Pan et al., 2013). Sexual orientation, experience of violence, and lower income have been found to be associated with increased risk of suicide or suicide attempt. Sexual minority individuals experienced a six to seven-fold increased risk of suicide attempt compared to heterosexual individuals (Blosnich et al., 2016). Women who experience intimate partnership violence are at between three and seven times increased odds for a subsequent suicide attempt (Devries et al., 2013). Adolescents who experience bullying (OR = 1.22-2.53), intimate partnership violence and intimate partnership separation are also at increased risk for suicidal ideation, attempt, and completion (Bannink et al., 2014; Kazan et al., 2016).

Lower income has also been found to be associated with increased incidence of mental illness and suicide attempts, those with lower income and mental illness are 16 times more likely to experience a suicide attempt (Pan et al., 2013). Lower perceived parental, school, and close friend support among adolescents is also negatively related to history of suicide attempt (b = -1.06 - -1.60) (Miller et al., 2015). Active participation in religion has been found to be protective against suicide (OR = 0.38) (Hilton et al., 2002; Wu, Wang, & Jia, 2015).

Mental illness is a key component in understanding suicide. It may be better described as a comorbidity, contributing factor, or underlying cause for suicide (Bostwick et al., 2014; Gold et al., 2013; Huber et al., 2014; Schaffer et al., 2017; Taliaferro & Muehlenkamp, 2015). Those with mental disorders experience suicide and death at a higher rate than those without, additionally mental illness is suspected to be significantly underreported (Chesney, Goodwin, & Fazel, 2014; Landes & Peek, 2013; Vigo, Thornicroft, & Atun, 2016; Walker, McGee, & Druss, 2015). It would be difficult to understand the true etiology of suicide without considering mental illness. This study, however, was limited to the variables collected on the death certificate and therefore does not include mental illness as a specific variable. Some mental illness could be captured in the cause of death, however that is suspected to be underreported (Landes & Peek, 2013; Vigo et al., 2016; Walker et al., 2015). Mental illness is captured in NVDRS data and is collected through medical record abstraction (National Center for Injury Prevention and Control, 2016). This would allow for the comparison of mental illness in

any of the cause of death codes from the death certificate and data captured by NVDRS data abstraction.

Methods Used in the Assessment of Accuracy of Vital Records

Several previous studies have evaluated the accuracy vital records, particularly death certificates. A common emphasis of these studies is the correct classification of cancer deaths, cardiac related deaths, or other specific diseases (Ceelen et al., 2015; German et al., 2011; Govindan et al., 2014; Mieno et al., 2016; Minelli & Marchetti, 2013). There are, however, few studies that have evaluated the accuracy of death certificates in reporting suicide in Utah or in the United States.

Potential Data Sources

There have been several different types of data sources used to evaluate and assess the accuracy of vital records, particularly death certificates. Clinical autopsy has historically been regarded as a valid reference standard and major source of clinical information used in assigning cause of death (Ceelen et al., 2015; Kircher, Nelson, & Burdo, 1985; Porucznik, Johnson, Rolfs, & Sauer, 2014; Xaverius et al., 2018). However, not every death is subject to autopsy. Medical records are another source that can be used to inform or assess the accuracy of cause of death assignment (Minelli & Marchetti, 2013; Tripp, Duncan, Finch, & Huff, 2015). Psychological autopsy is another method that can be used to ascertain information critical to the correct assignment of suicide as the cause of death. Psychological autopsy, in combination with clinical autopsy, uses additional information such as police reports, prior mental health history, along with other information to establish intent and state of mind at the time of death

(Botello et al., 2013). Every visit to a hospital, emergency room, or clinic that is paid by Medicare or private insurance has a set of billing codes associated. Some states, such as Utah, collect this billing information into one large database (Peters, Sachs, Porter, Love, & Costello, 2014). Each of these potential sources will be further defined, including the strengths and limitations for using each of them to evaluate the accuracy of death certificate data. Other national data sets such as the NVDRS have also been used to validate or evaluate the accuracy of death certificates. The NVDRS uses data abstractors that follow specific guidelines to collect information about each violent or accidental death in participating states (Paulozzi et al., 2004).

Clinical Autopsy. A clinical or forensic autopsy is the physical, surgical, microscopic, and toxicologic examination of the body to determine exact cause of death (Kuijpers et al., 2014). Clinical autopsy has been referred to as the gold standard for cause of death and has been used in many studies to evaluate cause of death assigned on the death certificate (Kuijpers et al., 2014). Studies using clinical autopsy to evaluate the accuracy of cause of death on death certificates have found both under-reporting and over-reporting of specific conditions (Basu, Fletcher, Shale, & Adisesh, 2015; Churruca et al., 2018; McCleskey, Davis, & Dye, 2017; Mieno et al., 2016; Minelli & Marchetti, 2013; Xaverius et al., 2018). Many of the studies that used autopsy as a method to evaluate the accuracy of cause of death as recorded on the death certificate also used medical records and administrative data such as death or disease registries as additional sources of information (Churruca et al., 2018; McCleskey et al., 2017; Minelli & Marchetti, 2013). The studies that used autopsy data with supplemental data, used expert

reviewers to classify or validate the classification of cause of death based on all available information (Churruca et al., 2018; McCleskey et al., 2017; Minelli & Marchetti, 2013, 2013). Clinical autopsy allows additional physical, biological, and toxicological information to be used in classification of the death. This information would not be available in the absence of a clinical autopsy. One important limitation to clinical autopsy is the type of data available (Kuijpers et al., 2014). Clinical autopsy generally only includes information that the pathologist can obtain from the body of the deceased, providing a snapshot of what physically caused the death (Kuijpers et al., 2014). Additionally, a clinical autopsy is not conducted on every death, but is generally reserved for deaths that occur outside of a licensed medical facility or cases that include suspicious or illegal circumstances (Xaverius et al., 2018).

Psychological Autopsy. A psychological autopsy is usually conducted in addition to a clinical autopsy and collects information that cannot be collected from the body itself (Botello et al., 2013). The examiner conducting the psychological autopsy will dig deeper into the social and psychological history of the deceased individual using interviews with family, legal records, medical records, and psychological records if available. The purpose of the psychological autopsy is to identify potential non-medical factors that may have influenced the death (Botello et al., 2013; Moskos, Olson, Halbern, Keller, & Gray, 2005). Psychological autopsies have been used to study suicide in Utah but have not historically be conducted on a routine basis (Moskos et al., 2005). The Utah Legislature enacted Utah Code 26-4-28.5 Psychological autopsy examiner, which went into effect on May 9, 2017 (Utah Medical Examiner Act, 2017). This legislation

mandates the position of a psychological autopsy examiner and requires a psychological autopsy for every suicide that occurs in the state of Utah. The resulting data are collected and stored in a database to be made available for research on suicide in Utah. This may be a viable source of data in the future.

Medical Records. Clinical providers document patient diagnosis and treatment information in medical records. Medical records are kept in both the acute care (in-patient hospital) and ambulatory care (outpatient clinic) settings. Important information such as past medical history and family medical history are also included in this documentation. The data included in medical records can provide background, context, and details that can enhance the accurate assignment of underlying cause of death (Bohnert et al., 2013; Klijs, Nusselder, & Mackenbach, 2014). Using medical records as a data source to evaluate the accuracy of death certificates is possible, but would be labor intensive and cost prohibitive as records for each death to be included in the study would need to be obtained and manually abstracted.

Administrative data. Administrative data is data collected or generated for administrative purposes. This would include coded data like ICD codes used for billing and reimbursement. This would also include data collected for registries such as the cancer registry, birth defects registry or any other registry that collects clinical data on individuals with a specific disease. Cancer registry data have been used extensively to validate cancer related cause of death recorded on death certificates (Falci et al., 2018; German et al., 2011; Govindan et al., 2014; Massa et al., 2017). There is not a specific registry for suicide. Suicide is included as a part of the NVDRS which will be discussed

in detail next. Utah, as well as several other states, maintains a database of all ICD codes submitted by acute care hospitals for reimbursement from either Medicaid, Medicare, or private insurance (Peters et al., 2014). Coded data can be used to identify patients with specific diseases including suicide or self-harm. The limitation of using this type of data a source for evaluating the accuracy of cause of death, is that it would require the evaluation of patient records to ascertain the reason for the assignment of the suicide code. This is a rich source of data but would require extensive time and resources to be used as a source for this study.

National Violent Death Reporting System. The NVDRS is a national data collection system focused on deaths due to intentional and unintentional violent injury, it is supported by the National Center for Injury Prevention and control at the CDC (Crosby et al., 2016). Suicide is considered a violent cause of death and meets the criteria for inclusion in the NVDRS (National Center for Injury Prevention and Control, 2016). The NVDRS uses several data sources including medical records, death certificates, medical examiner reports, interviews with informants who knew the decedent, and law enforcement records to gain an accurate picture of the circumstances surrounding each violent death that occurs in participating states (Crosby et al., 2016). The NVDRS dataset includes the original source data from the death certificate as well as fields to capture any updates to cause of death, underlying cause of death, or manner of death (National Center for Injury Prevention and Control, 2016). Having both the original death certificate data along with updated cause of death in the same file makes this dataset ideal for analyzing the accuracy of death certificate in reporting suicide in Utah.

Several studies have used NVDRS data to analyze death certificate data (Anna E. Austin et al., 2016; Bahraini et al., 2012; Donaldson et al., 2006; Gold et al., 2013; Huber et al., 2014; Karch et al., 2013; Rockett, Lian, Stack, Ducatman, & Wang, 2009). Several of the studies used NVDRS data to enhance death certificate data to establish intent for poisonings, validate veteran status, and identify additional circumstances surrounding youth suicide (Bahraini et al., 2012; Donaldson et al., 2006; Karch et al., 2013). The limitation of this data source is that it is a secondary data source, meaning that the data has already been collected and changes cannot be made to the variables that are collected or the methods used to collect them. Another limitation is timeliness of the data, the most recent year of data available is two to three years old (Centers for Disease Control and Prevention, 2017a).

Conceptual Framework

The conceptual framework for this study was created based on previous studies with similar research questions. The framework is graphically represented in Figure 1.

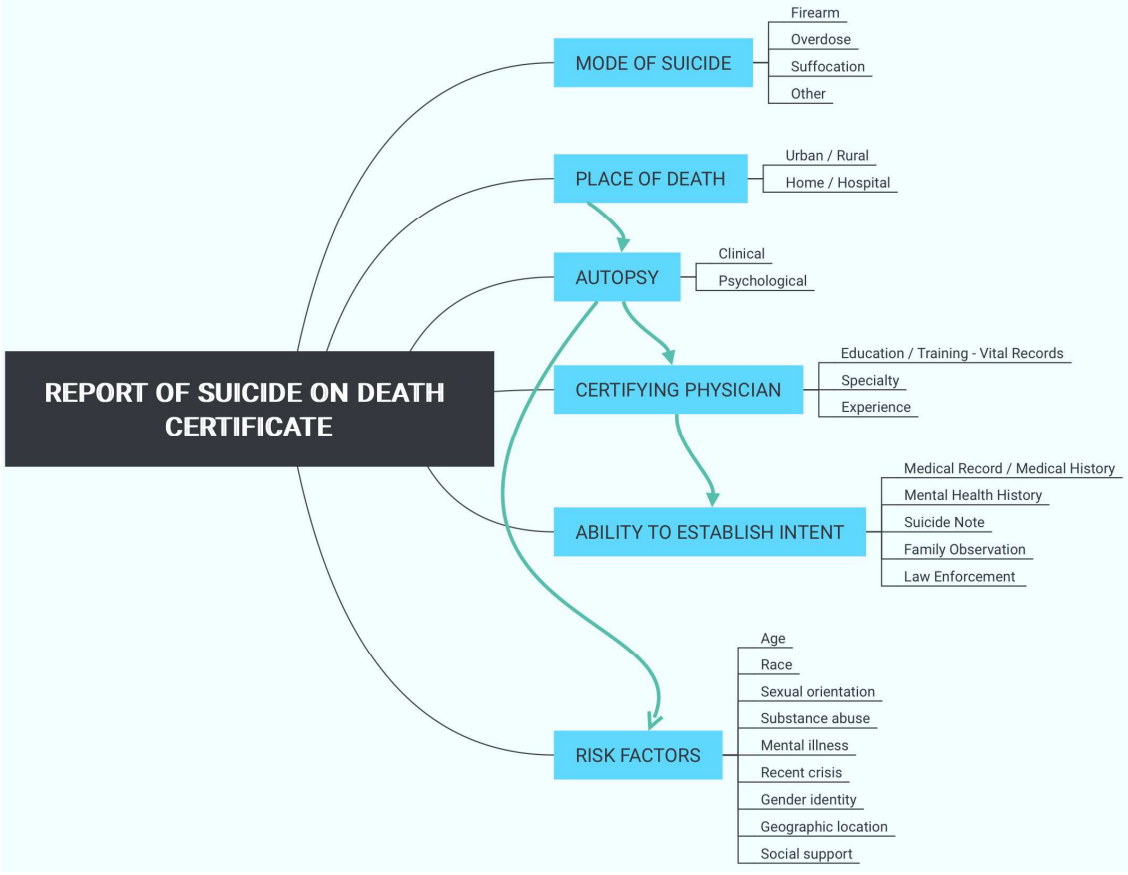

Figure 1. Graphical representation of conceptual framework.

As previously described, suicide is multifactorial requiring many different variables for accurate tracking and analysis. Previous suicide studies have been used to identify each of the important variables in the framework that need to be validated or analyzed for accuracy. Previous studies evaluating the accuracy of vital records and death certificates have been used to identify important variables and potential sources for error. The important variables related to suicide combined with the potential sources of error and methods for evaluation have been used to create the following conceptual logic model.

Several elements factor into an accurate report of suicide on the death certificate. One of the most challenging is the ability of the person classifying the death to establish intent (Rockett et al., 2014). Medical history including previous suicide attempts, mental health history, interactions with law enforcement, presence of a suicide note, witnesses, and statements from the family can all be used to help establish intent (CDC, 2003; National Center for Injury Prevention and Control, 2016). If any of these are missing the chance for a misclassification increases.

Other factors that may affect the ability to establish intent include method of suicide, place of suicide, presence of an autopsy report, and training of the classifier. Suicides completed by firearm or suffocation are more obvious than other methods of suicide like overdose, electrocution, or falling/jumping that may be harder to differentiate between accidental and suicidal intent (Tøllefsen et al., 2015). The location and circumstances of the suicide can also influence the ability to establish intent, for example if a person jumps from a bridge that had fences and safety equipment would be easier to rule a suicide than a person who jumps from a cliff alongside a hiking trail (Abel & Ramsey, 2013; Advenier, Guillard, Alvarez, Martrille, & Grandmaison, 2016; Amy E. Austin, Heuvel, & Byard, 2013; Todt, Ast, Wolff-Maras, Roesler, & Germerott, 2014).

Location of the death can also factor into whether an autopsy is performed. If a person dies while under the care of a physician who is willing to sign the death certificate, then an autopsy will not be performed (Utah Medical Examiner Act, 2017). An example of this may be a terminally ill patient on hospice that purposefully overdoses with suicidal intent. In the absence of a letter or information from witnesses, this death

may erroneously be classified as natural. If the death is unattended, meaning that the decedent was not under the care of a physician or the physician is unwilling to sign the death certificate, then an autopsy is required. A clinical autopsy can provide additional physiological information that may help in establishing intent and may provide other important information related to risk factors (Advenier et al., 2016). This information may be enhanced if the jurisdiction where the autopsy is performed also conducts psychological autopsies. Psychological autopsies go beyond the physical, medical, and histological examination to include an examination of the psychological and social circumstances preceding the death (Botello et al., 2013)

Finally, training of the person classifying the death can also influence accuracy (Al-Samarrai et al., 2013; Cheng et al., 2012; Madsen & Begier, 2013). A clinician who has training in how to conduct psychological autopsies will have the knowledge and skills to seek additional information beyond the clinical autopsy to help establish intent and accurately classify the death. Alternatively, a physician in a rural hospital, who is not experienced with suicide may have a higher chance of error and misclassification.

Many of these factors may not be independent. For example, location of death may be directly related to whether there is an autopsy performed. The presence of substance abuse, a risk factor, may also make it harder to accurately determine intent. The decedent may be concealing important risk factors such as sexual orientation or mental illness from family, which may not only make it more difficult to establish intent, but also to accurately capture those risk factors (Cohen, Blasey, Barr Taylor, Weiss, & Newman, 2016).

Now that the important variables and potential sources of error have been outlined, it is important to establish an appropriate data source and method for evaluating the accuracy of these variables as recorded on the death certificate. This study was focused on the accuracy of suicide recorded as manner of death. Other secondary, but related variables were also evaluated for accuracy. Several previous studies have used alternative sources of data such as the NVDRS to validate and analyze the accuracy of death certificate data (Austin et al., 2016; Donaldson et al., 2006; Karch et al., 2013). NVDRS data are collected by abstractors in each state that review administrative, medical, psychological, and legal records to verify and enhance the information collected on death certificate (Crosby et al., 2016). This data abstraction process used in collecting the NVDRS data decreases the chance for misclassification. Additionally, the NVDRS ascertains cases to abstract not only from death certificate data, but also from hospital coding and law enforcement reports (National Center for Injury Prevention and Control, 2016). These additional sources of ascertainment increase the chance of accurately capturing cause of death and validating demographic and risk factor data collected on the death certificate. In addition to the variables collected on the death certificate, NVDRS collects other variables and information that has been identified as important in evaluating violent deaths (National Center for Injury Prevention and Control, 2016). This rich data can be used to not only evaluate the accuracy of death certificate data but may also help to point to important data elements that may need to be included on the death certificate in the future.

There are limitations to using the NVDRS for evaluating the accuracy of suicide as recorded on the Utah death certificate. NVDRS data collection methods rely heavily on medical records and review of other documentation. The data collected by NVDRS is only as accurate as the records that are evaluated during data collection. Additionally, NVDRS does not collect every data element that has been identified as a risk factor for suicide. Therefore, this study was limited by the union of the data that were collected both by the NVDRS and by the death certificate. Additionally, the timeliness of the data for this study will be limited by the timeliness of NVDRS data.

Previous studies have evaluated the accuracy of different elements of the death certificate. Some have evaluated specific causes of death, others have evaluated the order of cause of death codes and the resulting errors when using death certificate data for surveillance and disease research (Falci et al., 2018; Foreman et al., 2016; Tøllefsen et al., 2015). The evaluation methods from these studies are relevant to this study. Variables important to the study of suicide have been identified using previous research and known associations. The NVDRS has been identified as an appropriate source for evaluating the accuracy of suicide as reported on the death certificate. Several other studies have used NVDRS data to research suicide and to evaluate the accuracy of death certificate data, but none have evaluated the accuracy of suicide as recorded on death certificates. The method and findings from the previous studies will be used to guide this study as detailed in the methods section that follows.

Summary

Suicide is a critical public health challenge in the United States. There is a gap in the literature concerning the accuracy of the death certificate in reporting suicide in the US. Errors in cause of death reporting in other countries has led to significant under-reporting of suicide (Bakst et al., 2015). It is important to assess the accuracy of suicide data reported by the death certificate. The true scope of this public health problem could be misunderstood if there are errors in the data being used to measure the problem.

Previous studies have identified several methods for evaluating the accuracy of cause of death as recorded on the death certificate. National studies based on data from the United States have focused on several different conditions like cancer and dementia. International studies have also covered these conditions as well as suicide. The methods used range from medical records abstraction to the use of secondary administrative data. A conceptual framework was proposed based on the methods used in these previous studies. This framework can be applied to assess the accuracy of suicide related cause of death as reported on the death certificate in the US. The operationalization of this framework is presented in chapter 3.

Chapter 3: Research Method

Introduction

Suicide has been identified as one of the leading causes of death in the United States (Safe States Alliance, 2017). The purpose of this study was to evaluate how accurate the death certificate is at reporting suicide as a cause of death. Additional contributing factors such as method of suicide, location of death, age, and race were also evaluated. A conceptual framework based on previous research focused on suicide and the evaluation of the accuracy of vital records was used to guide this study. The methods presented here are grounded in theory and have been proven effective as demonstrated by prior research outlined in Chapter 2. This chapter will detail the research design, methodology, threats to validity, and ethical procedures specific to this study.

Research Design and Rationale

The assessment or quantification of the accuracy of suicide related manner of death as recorded on death certificates requires the use of quantitative methods. Quantitative methods are appropriate for testing theories and assessing the relationship between different variables (Creswell & Creswell, 2018b). In contrast, qualitative research is focused on understanding the experience of a problem or phenomena at an individual level (Creswell & Creswell, 2018b). The secondary data used in this study are structured and derived from official documents such as death certificates, medical records, police reports, and medical examiner reports. While the data that were used for this study have individual level records, they do not contain the level of experiential information necessary to conduct qualitative research. The research questions outlined in

chapter 1 and discussed later in this chapter are focused around quantifying or measuring the accuracy of data recorded on death certificates. The methods used to answer these questions include descriptive and inferential statistics to measure the differences between death certificate data and NVDRS data. These quantitative methods are presented in detail below.

Variables

The dependent variable in this study was based on the manner of death as recorded by the death certificate. More specifically, the dependent variable represents the accuracy of the manner of death recorded on the death certificate as compared to NVDRS data. This was a calculated dichotomous variable indicating the agreement or discordance of manner of death recorded on death certificate as compared to NVDRS. The abstractors who collect the NVDRS data may have access to more data than the physician or clinician who originally classified the manner of death on death certificate. For this reason, the NVRDS will be considered the standard. The details of the calculation and coding of this calculated variable are provided in the operationalization section below.

The independent variables were method of suicide, sex, age, race, geography, marital status, education, state of suicide and year of suicide. The variables outlined here were key in quantifying the accuracy of suicide reported on death certificates. Additionally, these variables were used to identify and understand any relationships between the dependent and independent variables. This information helped to identify factors that influence the accuracy of suicide reporting.

Methodology

A conceptual framework based on the methods and theories used in previous studies was presented in Chapter 2. This conceptual framework was used to guide the methodology for the study and is described below. Secondary data analysis using NVDRS data was used to quantify the accuracy of death certificates in reporting suicide.

Population

The population for this study includes all suicide deaths included in the NVDRS from 2003-2017. The number of states contributing data to the NVDRS increased during this time from seven in 2003 to 38 in 2017 (CDC, 2017). There were 203,216 suicide deaths recorded by the NVDRS during this time period (National Center for Injury Prevention and Control, 2020).

Sampling and Sampling Procedures

The population level sample for this study included all deaths identified as suicide by NVDRS that occurred in states contributing data to the NVDRS 2003 through 2017. Data for all suicide related deaths were available, therefore no sampling techniques were used. All cases identified as suicide by NVDRS during the specified time period were included in this study. Specific case inclusion criteria were the report of suicide as manner of death recorded by NVDRS abstractors.

Sample size estimations were calculated using G*Power 3.1.9.3 (Faul, Erdfelder, Buchner, & Lang, 2017). A detailed justification for selection of multiple logistic regression as a statistical test is provided later in this chapter. The parameters to calculate an a priori sample size estimation for logistic regression were set using instructions

published in the G*Power users guide (Faul, Erdfelder, Buchner, & Lang, 2009). The options and parameters used to complete the calculations in G*Power are displayed in Table 1. A two-tailed test was selected and the values of alpha (0.05) and power (0.8) were set to standard levels (Creswell & Creswell, 2018a). Based on previous studies, the odds for misclassification of suicide on death certificate are 0.41; using a conservative 0.5 event rate for the null hypothesis G*Power calculates an odds ratio of 0.69 (Bakst et al., 2015). According to the calculations performed in G*Power a sample size of 324 is required to achieve a power of 0.8. The 203,216 suicide deaths that occurred in from 2003 through 2017 provide a sample large enough to meet this sample size requirement. However, because of this large sample size it will be important to consider the size of effect in addition to any reported p-values (Cumming & Calin-Jageman, 2017; Field, 2017a).

Table 1

*G*Power Settings and Parameters.*

G*Power Parameter	Value Selected
Test Family	Z tests
Statistical Test	Logistic Regression
Type of Power Analysis	A priori
Tails	Two
Odds Ratio	0.69
Pr(Y=1|X=1) Ho	0.5
A err prob	0.05
Power (1-ß err prob)	0.8
R^2 other X	0.25
X distribution	Normal
X parm μ	0
X parm σ	0

All deaths classified as homicide, suicide, unintentional firearm accidents, violent deaths including legal interventions such as officer involved shootings, and deaths of undetermined intent are included in the NVDRS dataset (National Center for Injury Prevention and Control, 2016). If the clinician assigning manner of death is unable to determine the intent the death is classified as undetermined or unknown intent (National Center for Injury Prevention and Control, 2016). The NVDRS ascertains cases through healthcare provider reports, medical billing ICD-10 coding reports from hospitals, medical examiner cases, and police reports (National Center for Injury Prevention and Control, 2016). Table 2 provides a list of manner of death along with the associated ICD-10 codes that meet the case inclusion criteria for the NVDRS. All deaths classified by NVDRS abstractors as suicide were included in the data used for this study.

Table 2

NVDRS Manners of Death and Associated ICD-10 Codes.

Manner of Death	ICD-10 Code
Suicide	X60-X84, X87.0
Homicide	X85-X99, Y00-Y09, Y87.1
Unintentional Firearm Accident	W32-W34, Y86
Legal Intervention	Y35.0-Y35.4, Y35.6-Y35.7, Y89.0
Terrorism	U01-U03

Note. Adapted from *National violent death reporting system web coding manual version 5.2*, by National Center for Injury Prevention and Control, 2016, p. 18.

Procedures for Data Collection

The data source for this study was the NVDRS. The data were collected by each participating state. Each state employs data abstractors who are trained to collect data using NVDRS approved procedures. States generally have state level health code and

laws that allow for the collection of this data under the public health authority (Crosby et al., 2016). This and other portions of the administrative code allow states to collect identifiable personal health information for the purpose of protecting and improving the health of the general public. NVDRS abstractors use information from death certificates, medical billing, physician reports, medical examiner reports and law enforcement to identify cases for inclusion in the NVDRS data (National Center for Injury Prevention and Control, 2016).

Once cases are identified, abstractors use the NVDRS guidelines and forms published by the CDC to collect the data. Abstractors use records from hospitals, physicians, law enforcement, the office of the medical examiner, and the family of the decedent to collect information about the injury and the circumstances leading up to the event (National Center for Injury Prevention and Control, 2016).

NVDRS has two datasets available for research. The first is publicly available data through an internet query tool called WISQARS (Web-based Injury Statistics Query and Reporting System). These data are aggregated to the state and county level to protect privacy. Additionally, only a small subset of the variables collected by the NVDRS are available on this public portal. The NVDRS also has a second Restricted Access Dataset (RAD) which contains individual level data with all of the variables collected by NVDRS (Centers for Disease Control and Prevention, 2017). The individual level more detailed RAD dataset was used for this study. Use of the RAD is governed by a panel of CDC staff. There is no charge for accessing the data, however there are restrictions on who can access it and for what purpose.

Access to the RAD is granted to doctorate level investigators with appropriately documented research protocols to address public health related issues. A detailed proposal including the purpose of the study, research questions, and analysis methods must be submitted to the panel for approval. Upon approval the RAD is delivered along with documentation to the approved research team (Centers for Disease Control and Prevention, 2017) Because the dataset is generally de-identified, NVDRS does not require IRB approval, however they do state if IRB approval is required by the investigator's institution, the approval must accompany the application for access. The review and approval process takes approximately 2-3 weeks (Centers for Disease Control and Prevention, 2017).

Instrumentation and Operationalization of Constructs

The forms and instruments used to collect NVDRS data have been validated (Crosby et al., 2016; Paulozzi et al., 2004). Quality control procedures such as re-abstraction and data validation queries are used to ensure the quality of the collected data. This study was strictly archival in nature, with no additional or new data collected. The paragraphs that follow provide specific details about each variable including how it was collected and stored by NVDRS, and how it was used in this study.

The dependent variable in this study was a calculated dichotomous variable that was created by the researcher, reflecting the accuracy of manner of death as recorded on the death certificate. Manner of death is a classification of the death into a category based on the events and conditions that lead to the death. This categorical variable should not be confused with the cause of death variable which lists the specific ICD-10

codes for the specific medical conditions and circumstances that led up to the death. Manner of death from both the death certificate and NVDRS datasets are recorded as natural, accident, suicide, homicide, pending investigation, and undetermined. The NVDRS includes an additional classification in manner of death to reflect cases where death occurred as a result of a legal intervention such as an officer involved shooting (National Center for Injury Prevention and Control, 2016). The manner of death recorded on death certificate was compared to the manner of death assigned by the NVDRS abstractor. The classification from the NVDRS abstractor was used as the standard. The dichotomous accuracy variable was calculated by the researcher and was based on a comparison of the manner of death reported on death certificate and manner of death assigned by the NVDRS abstractor, the variable was recorded as: 0 (NVDRS = Suicide & Death Certificate = Suicide); 1 (NVDRS = Suicide, Death Certificate = Other Classification). Recording a one for this variable indicates an error in the manner of death classification on the death certificate. The primary research question regarding the accuracy of death certificates in reporting suicide was answered using this variable.

There are several independent variables that may affect the accurate reporting of suicide on the death certificate. These variables include sex, transgender status, age, race, geography or geographic region, marital status, sexual orientation, method of suicide, history of mental illness, and substance abuse. Each of these variables and how they are represented in NVDRS dataset will outlined.

Sex is captured as a coded variable with the available values of 1 (male), 2 (female), 9 (unknown).

Transgender status is collected by the NVDRS but is not recorded on the death certificate. Transgender status is recorded as 0 (not transgender), 1 (transgender). This variable, while not recorded on death certificate, was used both in descriptive analysis and as a predictor of accuracy in the inferential analysis. Transgender status has only been collected by NVDRS since 2013.

Age is captured in units of years, months, weeks, days, hours, or minutes. These categorizations, used on the death certificate, are intended to improve the accuracy of data related to infant mortality (National Center for Injury Prevention and Control, 2016). For the purpose of this study years was the appropriate unit of measure. Age in years is recorded as the raw age in years with 999 indicating unknown age. For the purpose of this study the raw age was categorized into 5 year age groups (except for the youngest and oldest groups): 14 and under, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80 years of age and older.

In addition to age, the year that the death occurred will also be included. Inclusion of the year of death will allow for time trend analysis; specifically. Specifically, quantifying if there are any significant differences in classification error rates over time. There have been some changes to the methods used to collect and classify data on the death certificate (National Center for Health Statistics (U.S.), 2018). It is important to evaluate what effect these changes may have had on the accuracy of death certificates in reporting suicide.

Race and ethnicity are captured in two separate variables. Ethnicity is a coded variable and has the options of 0 (not Hispanic or Latino), 1 (Hispanic or Latino), and 9

(unknown). Race is recorded using the standard census categories of White, Black or African American, Asian or Pacific Islander, American Indian or Alaska Native, Two or More Races, or Unspecified.

Geography is captured by both NVDRS and the death certificate as county of residence. The National Center for Health Statistics (NCHS) has published a six-level urban to rural classification system (Ingram & Franco, 2014). The six levels include large central metro, large fringe metro, medium metro, small metro, micropolitan, and noncore (Ingram & Franco, 2014). These were coded as one through six respectively with missing observations coded as 99. Due to low cell counts it was necessary to further collapse this variable down to three classifications, 0 (nonrural), 1(rural), and 9(missing). State where the incident occurred was also included as a geographic variable.

Marital status captures the marital status of the decedent at the time of death. It is a coded variable with the following options: 1 (married / civil union / domestic partnership), 2 (never married), 3 (widowed), 4 (divorced), 5 (married / civil union / domestic partnership, but separated), 6 (single, not otherwise specified), 9 (unknown).

Sexual orientation is only captured by NVDRS data and is recorded as: 0 (Heterosexual); 1 (Gay); 2 (Lesbian); 3 (Bisexual); 9 (Unknown).

Education is recorded as education level. Education level is coded as: 0 (eight grade or less); 1 (ninth to 12^{th} grade, no diploma); 2 (high school graduate or GED); 3 (some college credit but no degree); 4 (associates degree); 5 (bachelor's degree); 6 (master's degree); 7 (doctorate or professional degree); 9 (unknown or missing). Method

of suicide is recorded as weapon type in the NVDRS data. Weapon type is a coded variable using the following values: 1 (firearm); 5 (non-powder gun); 6 (sharp instrument); 7 (blunt instrument); 8 (poisoning); 9 (hanging, strangulation, suffocation); 10 (personal weapons); 11 (fall); 12 (explosive); 13 (drowning); 14 (Fire or burns); 15 (shaking); 16 (motor vehicle); 17 (other transport vehicle); 18 (intentional neglect); 19 (biological weapons); 66 (other); 99 (unknown). Because of small cell counts these classifications were further collapsed. Non-powder gun, personal weapons, explosive, intentional neglect, biological weapons, blunt instrument, and fire or burns all had small counts and were combined and collapsed into a category labeled other or unknown.

History of mental illness captures if the decedent was identified as having a mental health problem at the time of suicide. This is recorded as 0 (no or unknown); 1 (yes).

Substance abuse indicates if the decedent was identified as having a non-alcohol substance abuse problem at the time of suicide. This is recorded as 0 (no or unknown); 1 (yes).

Year of incident records the year the suicide occurred. This is an important variable to consider when analyzing for accuracy as there have been changes to data collection and methodology over time that could affect accuracy. For example, in 2011 the National Center for Healthcare Statistics centralized all cause of death coding (National Center for Health Statistics (U.S.), 2018).

State of incident records where the suicide occurred. This variable is important to include as there may be variations in accuracy by state, as the data are collected at the

state level. State is a coded variable numbered 1-38 corresponding to the 38 states that contributed data to the NVDRS during the study period.

Data Analysis Plan

IBM SPSS version 25 used to perform the data cleaning and statistical analysis for this study. To ensure the data were clean and ready for analysis, frequency tables including descriptive statistics were created for each variable. Outliers and invalid data points were investigated. Outliers were evaluated for their influence on the model fit, where possible valid outliers were not removed from the data (Sarkar, Midi, & Rana, 2011). Prior to conducting logistic regression, bivariate analysis was performed to evaluate relationships between the variables. The output from this analysis guided the selection of variables for the logistic regression model (Zhang, 2016). This process is discussed in more detail below. Assumptions for logistic regression include linearity and independence of errors (Field, 2017b). Because all of the variables that were included in the model are categorical, the best way to test for violation of the linearity assumption was to evaluate the variance of the residuals from the model for homogeneity (Field, 2017b). The second assumption is independence of errors, if violated this will produce overdispersion, this was tested for using the Chi-Square goodness of fit statistic included in the SPSS output for logistic regression (Field, 2017). Logistic regression is also sensitive to multicollinearity, which was evaluated by producing tolerance and VIF statistics (Field, 2017).

This study has been designed to answer the following questions:

RQ: Using the NVDRS as the standard, what is the accuracy of death certificates in reporting suicide in the United States?

RQ1: What is the level of agreement between manner of death reported as suicide in the NVDRS and manner of death reported as suicide on the death certificate?

$H_0$1: The proportion of suicide cases misclassified by the death certificate is equal to or less than 0.01%.

H_a1: The proportion of suicide cases misclassified by the death certificate is greater than 0.01%.

RQ2: How does the accuracy of U.S. death certificate data in reporting suicide vary by method of suicide, age group, sex, transgender status, sexual orientation, race, marital status, geographic region, history of mental illness, substance abuse, year of suicide, state of suicide, or education?

$H_0$2: The accuracy of death certificate data in reporting suicide does not vary by method of suicide, age group, sex, transgender status, sexual orientation, race, marital status, geographic region, history of mental illness, substance abuse, year of suicide, state of suicide, or education.

H_a2: The accuracy of death certificate data in reporting suicide does vary by method of suicide, age group, sex, transgender status, sexual orientation, race, marital status, geographic region, history of mental illness, substance abuse, year of suicide, state of suicide, or education.

Individual sub-hypotheses for each variable:

$H_02_1 - H_02_{13}$: The accuracy of death certificate data in reporting suicide does not vary by [method of suicide (H_02_1), age group (H_02_2), sex (H_02_3), transgender status (H_02_4), sexual orientation (H_02_5), race (H_02_6), marital status (H_02_7), geographic region (H_02_8), history of mental illness (H_02_9), substance abuse (H_02_{10}), year of suicide (H_02_{11}), state of suicide (H_02_{12}), or education (H_02_{13})].

$H_a2_1 - H_a2_{13}$: The accuracy of Utah death certificate data in reporting suicide does vary by [method of suicide (H_a2_1), age group (H_a2_2), sex (H_a2_3), transgender status (H_a2_4), sexual orientation (H_a2_5), race (H_a2_6), marital status (H_a2_7), geographic region (H_a2_8), history of mental illness (H_a2_9), substance abuse (H_a2_{10}), year of suicide (H_a2_{11}), state of suicide (H_a2_{12}), or education (H_a2_{13})].

RQ3: How does the accuracy rate with regard to suicide related manner of death assigned on the death certificate, change by year from 2005-2017?

H_o3: The accuracy of suicide related manner of death assigned by death certificate does not vary by year from 2005 - 2017.

H_a3: The accuracy of suicide related manner of death assigned by death certificate does vary by year from 2005-2017.

Statistical Methods. Several statistical procedures were used to answer the questions listed above. Research question 1 was answered using a z-test. A z-test is used to evaluate differences in population level proportions (Cumming & Calin-Jageman, 2017). Reference values for proportions when using the z-test are usually selected using prior research or in exploratory research the values such as .5 or 50% can be used (L. M. Sullivan, 2018). For the purpose of this study a reference value of .0001 was selected.

This would reflect an error rate of .01% or an accuracy rate of 99.99%. This level was selected as it is very close to 100% representing the expectation that vital records data be highly accurate. With the large sample size of this study, even small variations in the error rate would be considered statistically significant; it is therefore more important to evaluate the size of effect and the practical significance of the error rate (Cumming & Calin-Jageman, 2017; Ellis, 2010).

Research question 2 and all subhypotheses were answered using logistic regression. Multiple logistic regression can be used to evaluate the relationship between a categorical outcome variable and categorical predictor variables (Merrill, 2016). Multiple logistic regression was used to identify which of the independent variables may be a predictor of accurately or inaccurately reporting suicide as manner of death on death certificate. Variables were included in the multiple logistic regression model using purposeful selection. Bivariate analysis was conducted on each variable, those variables with a p-value less than 0.05 were included in the initial model (Field, 2017). Variables with insignificant p-values that did not contribute to the model were removed. Each new model was compared to ensure no contributing variables were excluded from the final model (Zhang, 2016). Based on the literature two potential confounders have been included in this analysis, history of mental illness and substance abuse. One advantage of using logistic regression is if any of the included variables have a confounding effect the model inherently handles this by creating adjusted odds ratios (Field, 2017).

There may be an interaction between sex and method of suicide. Prior studies have found errors in reporting suicide when the method of suicide was poisoning or

overdose (Donaldson et al., 2006). Previous studies have also found that there are known differences between preferred method of suicide used by men and women (Curtin et al., 2016b). This interaction was included in the final logistic regression model to test how it influenced the model.

Research question 3 was answered by conducting a time trend analysis using a one-way ANOVA test to determine if there was a significant trend in accuracy over time (Field, 2017). Because the ANOVA test indicated a statistically significant time trend in accuracy over time a Tukey post-hoc test was used to determine which years contributed to the significance (Field, 2017).

Threats to Validity

External Validity

Common threats to external validity come from improper sampling or small sample size (Frankfort-Nachmias, Nachmias, & DeWaard, 2015b). This study will utilize all suicide related deaths that occurred in the states contributing data to the NVDRS during the study period. While this does not extend external validity or generalizability beyond the population of these states, it does strengthen the external validity within these states. Generalizations will not be made beyond the scope of the study.

Internal Validity

History, maturation, and experimental mortality are not factors based on the data source and design of the study. The instrumentation for the study has been validated and has been consistent over time (Paulozzi et al., 2004). Changes to the data collection

instrument over time are well documented with, re-validation and data translation employed to ensure all years of data are comparable (Crosby et al., 2016). Both data sources being used for this study employ classifications of cause of death that are assigned by either a clinician or an abstractor. The activity of appropriately classifying cause of death is prone to error (Falci et al., 2018; German et al., 2011; Govindan et al., 2014). One of the objectives of this study is to evaluate the accuracy of assigning suicide as the manner or cause of death. Because these classifications are assigned by humans there is a chance for error, which would be a threat to internal validity. Additional threats to internal validity can come from improper statistical procedures or errors in data analysis. Documentation and justification for the statistical methods were provided to ensure internal validity.

Construct Validity

Construct validity is maintained by using measures instruments that truly measure what they are intended to measure (Frankfort-Nachmias, Nachmias, & DeWaard, 2015a). The conceptual framework for this study was presented in chapter 2. This framework is based on previous studies using similar data sources measuring outcomes similar to this study. Theoretically grounded measures and statistical analysis techniques were used to ensure construct validity.

Ethical Procedures

IRB

Institutional Review Board (IRB) approval is required any time research is conducted using human subjects. While this study used secondary data, the data were

originally collected about human subjects. IRB approval was sought and obtained from the Walden University IRB. All appropriate forms and documents were completed and submitted prior to accessing any data or conducting any analysis. Approval for this study was received from the Walden University IRB (IRB# 05-20-19-0553617) on August 27, 2019.

Data Access

Access to the NVDRS RAD is governed by CDC staff. All appropriate policies and procedures were followed to request the data. Data were requested in the name of the Dissertation Committee Chair as it is required that the investigator hold a doctoral level degree. The NVDRS RAD Data Access Committee approved the data request for this study on August 23, 2019.All data analysis was conducted by the author under the supervision of the Chair.

Data Privacy and Security

The NVDRS RAD does contain personal level data, however, all data is deidentified. Care was taken to aggregate or summarize reporting of results to a level where reidentification is not possible, for example geographic locations was grouped together until the case count is high enough to preserve anonymity. All study data were stored on an encrypted server or drive in a restricted access, password protected folder. Data will be maintained for the minimum amount of time required by Walden University for the purpose of this dissertation (five years). Data will be destroyed according to NVDRS instructions at the soonest possible date after completion of the study.

Summary

A conceptual framework based on previous research surrounding suicide and the accuracy of vital records has been used in the selection of secondary data analysis methods presented in this chapter. Each research question was presented along with analytical plan to answer the question. The methods are theoretically grounded and justified. The findings from the data analysis presented here are included in the next chapter.

Chapter 4: Results

Introduction

Suicide is a major public health issue in the United States. Some states, such as Utah, are experiencing upward trends placing suicide as the leading cause of death for younger age groups (Annor et al., 2017; Utah Department of Health, 2016). This study evaluated the accuracy of death certificates in reporting suicide as a cause of death. The methods used in this analysis are described in detail in the previous chapter. This chapter will outline the data collection techniques, including a summary of the records that were included and excluded from the data analysis. General descriptive statistics are presented along with the results from the bivariate analysis. Finally, the results from the inferential, multivariate, and longitudinal analysis are detailed.

Data Collection

This study is a secondary data analysis using data collected by the NVDRS. The data were collected using methods and instruments previously described (Crosby, Mercy, & Houry, 2016). A proposal to request access to the NVDRS Restricted Access Database was submitted following the guidelines set forth by the NVDRS program at the CDC. The proposal was reviewed and approved after some minor clarifications and edits to the proposal. NVDRS staff prepared and delivered a dataset using the parameters specified in the proposal.

The dataset contains records of deaths reported as suicide from 36 states, the District of Columbia, and Puerto Rico. NVDRS collects data at the population level for each participating state, meaning data are inclusive of the population and are not a sample

or sub-population. Data were collected on deaths that occurred from 2003 until 2017. NVDRS began collecting data in seven states in 2003 and expanded to additional states in later years (Crosby, Mercy, & Houry, 2016). The purpose of this study was to evaluate the accuracy of death certificates in reporting suicide; therefore, the unit of measure is the record of death. Person variables were used to help evaluate and describe elements that may influence accuracy, but the frame of reference is the document and the classification of the death. Table A2 in the appendix includes the number of cases contributed from each state by year (total cases = 203,215). There were 930 cases that were missing a manner of death classification from the death certificate or the death certificate was marked as not available. An additional 374 cases had a manner of death classification from the death certificate marked as pending investigation. Both of these groups totaling 1,303 were excluded from the analysis. The limitations of excluding these cases will be discussed in detail in chapter 5. There was agreement between cause of death and manner of death, meaning no cases were identified where the cause of death indicated suicide, but the manner of death did not. A total of 201,912 cases were included in the general analysis. Longitudinal analyses included data from states that contributed data from 2005 to 2017 (n = 141,433). Sixteen states (Alaska, Colorado, Georgia, Kentucky, Maryland, Massachusetts, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, Rhode Island, South Carolina, Utah, Virginia, Wisconsin) contributed data for this 13-year time period. The geographic distribution of states and the years of data contributed are presented in Figure 2.

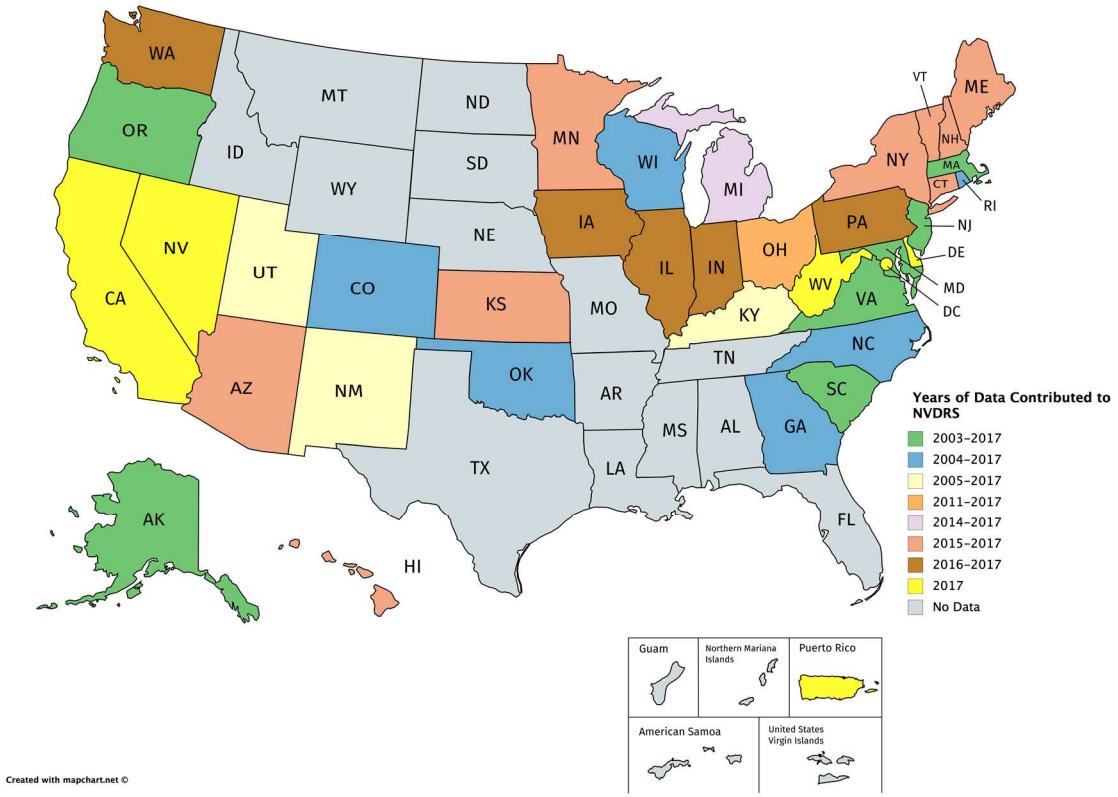

Figure 2. Map of States and Years of Data Contributed to NVDRS. Created using mapchart.net and used under Creative Commons Attribution-ShareAlike 4.0 International.

The data described above have been used to answer the research questions. Data analysis, including both descriptive and inferential analysis, was conducted in accordance with the methods presented in Chapter 3. The results of this analysis are presented below.

Results

The results of both the descriptive and inferential analysis are presented in this section. The dependent variable in this study is the accuracy of the death certificate in

classifying each death as a suicide. The dependent variable Death Certificate (DC) Accuracy is a dichotomous variable classifying each record as accurate or error. Records were classified as accurate if the both the NVDRS abstractor and the death certificate classified the death as a suicide. Records were classified as error if the death certificate classified the death as something other than suicide (all records included in this study dataset have been classified by NVDRS as suicide). Each of the bivariate tables provide counts of each classification within each variable along with the classification of the dependent variable, DC accuracy. Table 3 includes a summary of the number of records and the error rates for each state. The death certificate was very accurate in classifying suicide deaths with an overall error rate of 0.43%. The three states with the highest error rates were Delaware, District of Columbia, and Alaska. Conversely, Hawaii, Maine, Washington, and Puerto Rico had no reported classification errors in this dataset.

Table 3

Death Certificate (DC) Suicide Classification Error Rate by State 2003-2017.

	DC Accuracy			
State	Accurate	Error	Total	Error Rate
Alaska	2404	31	2435	1.27%
Arizona	3881	5	3886	0.13%
California	4367	1	4368	0.02%
Colorado	13346	52	13398	0.39%
Connecticut	1136	8	1144	0.70%
Delaware	116	5	121	4.13%
District of Columbia	46	1	47	2.13%
Georgia	15987	146	16133	0.90%
Hawaii	378	0	378	0.00%
Illinois	2068	5	2073	0.24%
Indiana	2109	19	2128	0.89%

(table continues)

	DC Accuracy			
State	Accurate	Error	Total	Error Rate
Iowa	924	2	926	0.22%
Kansas	1540	13	1553	0.84%
Kentucky	8458	65	8523	0.76%
Maine	731	0	731	0.00%
Maryland	8003	88	8091	1.09%
Massachusetts	8382	13	8395	0.15%
Michigan	5407	12	5419	0.22%
Minnesota	2225	2	2227	0.09%
Nevada	665	1	666	0.15%
New Hampshire	728	2	730	0.27%
New Jersey	9931	40	9971	0.40%
New Mexico	5514	41	5555	0.74%
New York	4941	12	4953	0.24%
North Carolina	17461	22	17483	0.13%
Ohio	11350	27	11377	0.24%
Oklahoma	8896	82	8978	0.91%
Oregon	10279	50	10329	0.48%
Pennsylvania	3321	3	3324	0.09%
Rhode Island	1558	8	1566	0.51%
South Carolina	9498	74	9572	0.77%
Utah	6634	8	6642	0.12%
Vermont	349	1	350	0.29%
Virginia	14947	3	14950	0.02%
Washington	2150	0	2150	0.00%
West Virginia	395	3	398	0.75%
Wisconsin	10665	28	10693	0.26%
Puerto Rico	249	0	249	0.00%
Total	201039	873	201912	0.43%

The descriptive frequencies for each of the independent variables are found in Table 4. Frequency distributions within each variable were unremarkable and consistent with general population distributions reported in previous suicide research in the United States (Curtin et al., 2016a; Lyons, 2016; Safe States Alliance, 2017). These variables are

included in the study to analyze the potential relationship between each of the variables and an error in classification of suicide on the death certificate. The focus is not on the distribution of suicide among the different groups.

Table 4

Descriptive Frequencies for All Independent Study Variables 2003-2017.

Category	n (%)
Biological Sex	
Male	156999 (77.8)
Female	44861 (22.2)
Unknown	52 (0)
Transgender Status [a]	
No	201732 (99.9)
Yes	180 (0.1)
Age	
14 and Under	1799 (0.9)
15-19	9500 (4.7)
20-24	16193 (8)
25-29	16304 (8.1)
30-34	15997 (7.9)
35-39	16436 (8.1)
40-44	18396 (9.1)
45-49	20662 (10.2)
50-54	21426 (10.6)
55-59	18830 (9.3)
60-64	13630 (6.8)
65-69	9660 (4.8)
70-74	7475 (3.7)
75-79	5941 (2.9)
80 and Older	9663 (4.8)

(table continues)

Category	n (%)
Race	
White	177072 (87.7)
Black or African American	12778 (6.3)
American Indian/Alaska Native	2649 (1.3)
Asian/Pacific Islander	4110 (2)
Two or more races	3222 (1.6)
Unknown	2081 (1)
Rural Suicide	
No	194098 (96.1)
Yes	4827 (2.4)
Missing	2987 (1.5)
Marital Status	
Married/Civil Union/Domestic Partnership	68014 (33.7)
Never Married	68494 (33.9)
Widowed	12016 (6)
Divorced	43455 (21.5)
Married/Civil Union/Domestic Partnership, but separated	4620 (2.3)
Single, not otherwise specified	2676 (1.3)
Unknown	2637 (1.3)
Sexual Orientation [a]	
Straight/Heterosexual	19417 (9.6)
Lesbian, Gay, or Bisexual	1077 (0.5)
Unknown	85170 (42.2)
Missing	96248 (47.7)
Method of Suicide	
Firearm	101703 (50.4)
Sharp instrument	3829 (1.9)
Blunt instrument	115 (0.1)
Poisoning	31944 (15.8)
Hanging, strangulation, suffocation	53196 (26.3)
Fall	4290 (2.1)
Drowning	2114 (1)
Fire or burns	862 (0.4)
Motor vehicle including buses, motorcycles	1330 (0.7)

(table continues)

Category	n (%)
Other transport vehicle, e.g., trains, planes, boats	1653 (0.8)
Other (e.g. taser, electrocution, nail gun)	386 (0.2)
Unknown	490 (0.2)
History of Mental Health	
No, Not Available, Unknown	118333 (58.6)
Yes	83579 (41.4)
History of Substance Abuse	
No, Not Available, Unknown	173496 (85.9)
Yes	28416 (14.1)
Education Level	
8th grade or less	6323 (3.1)
9th to 12th grade, no diploma	20636 (10.2)
High school graduate or GED	58760 (29.1)
Some college credit, but no degree	23696 (11.7)
Associates degree	10765 (5.3)
Bachelor's degree	16625 (8.2)
Master's degree	5744 (2.8)
Doctorate or professional degree	2651 (1.3)
Unknown or Missing	56712 (28.1)
Total	201912 (100)

Note: [a] Transgender status and sexual orientation were collected beginning in 2013.

Table 5 through Table 15 provide the bivariate analysis results for each of the independent variables (sex, transgender status, age, race, geography, marital status, method of suicide, history of mental illness, history of substance abuse, and year of suicide). The bivariate analysis results for biological sex are displayed in Table 4. While females have a lower overall rate of suicide there is a slightly elevated error rate in the classification of female suicide on the death certificate.

Table 5

Biological sex by Death Certificate (DC) Accuracy 2003-2017.

	DC Error			
Biological Sex	Accurate	Error	Total	Error Rate
Male	156416	583	156999	0.37%
Female	44571	290	44861	0.65%
Unknown	52	0	52	0.00%
Total	201039	873	201912	0.43%

Transgender status has only been collected by NVDRS since 2013. The error rate among suicide decedents identified as transgender is presented in Table 6. The error rate is slightly higher those identified as transgender than those who were not.

Table 6

Transgender Status by Death Certificate (DC) Accuracy 2013-2017.

	DC Accuracy			
Transgender	Accurate	Error	Total	Error Rate
Yes	179	1	180	0.56%
No	200860	872	201732	0.43%
Total	201039	873	201912	0.43%

The bivariate analysis for age is presented in Table 7. Error rates are relatively consistent with those in the younger age groups having slightly higher error rates.

Table 7

Age Group by Death Certificate (DC) Accuracy 2003-2017.

Age Group	DC Accuracy		Total	
	Accurate	Error		Error Rate
14 and Under	1786	13	1799	0.72%
15-19	9453	47	9500	0.49%
20-24	16108	85	16193	0.52%
25-29	16223	81	16304	0.50%
30-34	15919	78	15997	0.49%
35-39	16355	81	16436	0.49%
40-44	18303	93	18396	0.51%
45-49	20572	90	20662	0.44%
50-54	21337	89	21426	0.42%
55-59	18749	81	18830	0.43%
60-64	13584	46	13630	0.34%
65-69	9634	26	9660	0.27%
70-74	7455	20	7475	0.27%
75-79	5924	17	5941	0.29%
80 and Older	9637	26	9663	0.27%
Total	201039	873	201912	0.43%

The bivariate analysis for race is displayed in Table 8. The error rate is lowest among Asian/Pacific Islander's and highest among Black or African American's.

Table 8

Race by Death Certificate (DC) Accuracy 2003-2017.

	DC Accuracy			
Race	Accurate	Error	Total	Error Rate
White	176360	712	177072	0.40%
Black or African American	12673	105	12778	0.82%
American Indian/Alaska Native	2628	21	2649	0.79%
Asian/Pacific Islander	4101	9	4110	0.22%
Two or more races	3201	21	3222	0.65%
Other/Unspecified/Unknown	2076	5	2081	0.24%
Total	201039	873	201912	0.43%

Table 9 includes the bivariate analysis results for geographic region, specifically if the suicide occurred in a rural area. The error rate is slightly elevated in suicides that occurred in rural areas, but interestingly the highest error rate is among suicides that were missing the urban/rural classification. This may indicate higher error rates among death certificates that are incomplete or missing information in multiple fields (National Center for Health Statistics (U.S.), 2018).

Table 9

Suicide Occurred in Rural Area by Death Certificate (DC) Accuracy 2003-2017.

	DC Error			
Rural Suicide	Accurate	Error	Total	Error Rate
Yes	4798	29	4827	0.60%
No	193275	823	194098	0.43%
Missing	2966	21	2987	0.70%
Total	201039	873	201912	0.43%

The bivariate analysis results for marital status are presented in table 10. The highest error rate is observed among decedents who were classified as single, not otherwise specified. The lowest error rate is among those who were classified as being married, civil union, or partnership but separated.

Table 10

Marital status by Death Certificate (DC) Accuracy 2003-2017.

Marital Status	DC Error		Total	
	Accurate	Error		Error Rate
Married/Civil Union/ Domestic Partnership	67750	264	68014	0.39%
Never Married	68183	311	68494	0.45%
Widowed	11979	37	12016	0.31%
Divorced	43247	208	43455	0.48%
Married/Civil Union/ Partnership, but separated	4610	10	4620	0.22%
Single, not otherwise specified	2645	31	2676	1.16%
Unknown	2625	12	2637	0.46%
Total	201039	873	201912	0.43%

The results from the bivariate analysis of sexual orientation are presented in Table 11. Sexual orientation was only collected by NVDRS beginning in 2013, therefore only cases from 2013-2017 are included in its analysis. The error rate is slightly elevated among decedents reported to be non-heterosexual (gay, lesbian, or bisexual).

Table 11

Sexual Orientation by Death Certificate (DC) Accuracy from 2013-2017.

	DC Error			
Sexual Orientation	Accurate	Error	Total	Error Rate
Straight/Heterosexual	19362	55	19417	0.28%
Gay, Lesbian or Bisexual	1073	4	1077	0.37%
Unknown	84936	234	85170	0.27%
Total	105371	293	105664	0.28%

The bivariate analysis of method of suicide is included in Table 12. This variable has the most variation in death certificate reporting accuracy. The highest error rate is among

method suicide classified as other/unknown (2.91%). Of note, error rates among poisonings, drownings, and suicides involving motor vehicles were all above 1%. Classification error rates were lowest among hanging classification.

Table 12

Method of Suicide by Death Certificate (DC) Accuracy 2003-2017.

Method of Suicide	DC Accuracy		Total	
	Accurate	Error		Error Rate
Firearm	101417	286	101703	0.28%
Sharp instrument	3814	15	3829	0.39%
Poisoning	31593	351	31944	1.10%
Hanging, strangulation, suffocation	53109	87	53196	0.16%
Fall	4264	26	4290	0.61%
Drowning	2087	27	2114	1.28%
Motor vehicle including buses, motorcycles	1316	14	1330	1.05%
Other transport vehicle including trains, planes, boats	1640	13	1653	0.79%
Other/unknown	1799	54	1853	2.91
Total	201039	874	201912	0.43%

The bivariate analysis results for mental health history are presented in Table 13. The error rate among those with a history of mental health issues are the same as the overall error rate.

Table 13

History of Mental Health Issues by Death Certificate (DC) Accuracy 2003-2017.

	DC Accuracy			
History of Mental Illness	Accurate	Error	Total	Error Rate
Yes	83220	359	83579	0.43%
No, Not Available, Unknown	117819	514	118333	0.43%
Total	201039	873	201912	0.43%

The bivariate analysis results for history of substance abuse is displayed in Table 14. Decedents identified as having a substance abuse problem have a slightly elevated error rate.

Table 14

History of Substance Abuse Problem by Death Certificate (DC) Accuracy 2003-2017.

	DC Error			
Substance Abuse Problem	Accurate	Error	Total	Error Rate
Yes	28222	194	28416	0.68%
No, Not Available, Unknown	172817	679	173496	0.39%
Total	201039	873	201912	0.43%

The NVDRS has been collecting data for over ten years. As previously stated, new states have been added to the system over time. Table 15 includes the error rates by year of suicide. There is a consistent pattern of declining error rates over time.

Table 15

Year of Suicide by Death Certificate (DC) Accuracy 2003-2017.

	DC Error			
Year	Accurate	Error	Total	Error Rate
2003	3564	30	3594	0.83%
2004	7625	62	7687	0.81%
2005	8732	68	8800	0.77%
2006	9096	81	9177	0.88%
2007	9511	82	9593	0.85%
2008	9495	56	9551	0.59%
2009	10206	67	10273	0.65%
2010	10449	74	10523	0.70%
2011	12382	36	12418	0.29%
2012	12814	32	12846	0.25%
2013	13039	43	13082	0.33%
2014	14773	35	14808	0.24%
2015	20442	60	20502	0.29%
2016	25814	68	25882	0.26%
2017	33097	79	33176	0.24%
Total	201039	873	201912	0.43%

The bivariate analysis for education level is displayed in Table 16. The highest error rate is among those with some high school but no diploma (0.59%). The lowest error rate is among those with a bachelor's degree (0.29%). Using education as a proxy for socioeconomic status, these data indicate a higher error rate among the lowest levels of socioeconomic status.

Table 16

Education Level by Death Certificate (DC) Accuracy 2003-2017.

Education Level	DC Error		Total	
	Accurate	Error		Error Rate
8th grade or less	6287	36	6323	0.57%
9th to 12th grade, no diploma	20515	121	20636	0.59%
High school graduate or GED	58541	219	58760	0.37%
Some college credit, but no degree	23600	96	23696	0.41%
Associates degree	10728	37	10765	0.34%
Bachelor's degree	16576	49	16625	0.29%
Master's degree	5724	20	5744	0.35%
Doctorate or professional degree	2641	10	2651	0.38%
Unknown or Missing	56427	285	56712	0.50%
Total	201039	873	201912	0.43%

Research Questions

The first research question (RQ1) was: What is the level of agreement between the manner of death reported as suicide in the NVDRS and manner of death reported as suicide on the death certificate? The best measure to answer this question is using the proportion of cases that were classified incorrectly by death certificate, or error rate. Because there are no previous studies establishing a known error rate for death certificates in reporting suicide, an accuracy rate of 99.99% corresponding to an error rate of 0.01% is assumed. The new null and research hypothesis were:

- $H_0 1$: The proportion of suicide cases misclassified by the death certificate is equal to or less than 0.01%.
- $H_a 1$: The proportion of suicide cases misclassified by the death certificate is greater than 0.01%.

A z-test for proportions was used to test this new hypothesis. Based on the analysis the null hypothesis is rejected ($z = 188.74$, $p < 0.001$, two-tailed). Even though the error or misclassification rate is small, 0.43% 95% CI [0.40%, 0.46%], it is significant. It should be noted that with the large sample size, even small differences would be considered significant. The size of effect and practical significance of this error rate are as important as the p-value (Cumming & Calin-Jageman, 2017; Ellis, 2010). An error rate of 0.43% means that the death certificate is accurate at classifying a death as suicide 99.57% of the time when compared to the NVDRS.

Research question 2 was: How does the accuracy of U.S. death certificate data in reporting suicide vary by method of suicide, age group, sex, transgender status, sexual orientation, race, marital status, geographic region, history of mental illness, substance abuse, year of suicide, state of suicide or education? With the following null and research hypotheses:

- $H_0$2: The accuracy of death certificate data in reporting suicide does not vary by method of suicide, age group, sex, transgender status, sexual orientation, race, marital status, geographic region, history of mental illness, substance abuse, year of suicide, state of suicide, or education.
- H_a2: The accuracy of death certificate data in reporting suicide does vary by method of suicide, age group, sex, transgender status, sexual orientation, race, marital status, geographic region, history of mental illness, substance abuse, year of suicide, state of suicide, or education.

  - Individual sub-hypotheses for each variable:

- $H_0 2_1$-$H_0 2_{13}$: The accuracy of Utah death certificate data in reporting suicide does not vary by [method of suicide ($H_0 2_1$), age group ($H_0 2_2$), sex ($H_0 2_3$), transgender status ($H_0 2_4$), sexual orientation ($H_0 2_5$), race ($H_0 2_6$), marital status ($H_0 2_7$), geographic region ($H_0 2_8$), history of mental illness ($H_0 2_9$), substance abuse ($H_0 2_{10}$), year of suicide ($H_0 2_{11}$), state of suicide ($H_0 2_{12}$), or education ($H_0 2_{13}$)].
- $H_a 2_1$-$H_a 2_{13}$: The accuracy of Utah death certificate data in reporting suicide does vary by [method of suicide ($H_a 2_1$), age group ($H_a 2_2$), sex ($H_a 2_3$), transgender status ($H_a 2_4$), sexual orientation ($H_a 2_5$), race ($H_a 2_6$), marital status ($H_a 2_7$), geographic region ($H_a 2_8$), history of mental illness ($H_a 2_9$), substance abuse ($H_a 2_{10}$), year of suicide ($H_a 2_{11}$), state of suicide ($H_a 2_{12}$), or education ($H_a 2_{13}$)].

Two methods were used to test hypotheses $H2$ and $H2_1$-$H2_{13}$. Bivariate analysis was conducted using each of the independent variables to determine which variables would be appropriate for inclusion in a logistic regression model. All of the variables in the analysis were categorical variables, therefore the Pearson Chi-Square test was used to evaluate the relationship between the independent variables and the dependent variable. The results from the bivariate analysis are presented in Table 16.

Table 17

Results of Pearson Chi-Square Bivariate Analysis of Each Independent Variable by DC Error.

Independent Variable	Chi-Square	p value
Biological Sex	61.564	<0.001
Transgender Status	0.064	0.801
Sexual Orientation	0.390	0.823
Age	36.622	0.001
Race	66.492	<0.001
Geography	8.579	0.014
Marital Status	48.127	<0.001
Education Level	36.290	<0.001
Method of Suicide	792.856	<0.001
History of Mental Illness	0.027	0.870
History of Substance Abuse	48.145	<0.001
Year of Death	267.935	<0.001
State of Death	589.183	<0.001

The results from the bivariate analysis were used to build the initial binary logistic regression model. Independent variables with significant Chi-Square were entered into a binary logistic regression model, transgender status, sexual orientation, and history of mental illness were excluded based on non-significance. The results from the first model were used to create a refined model by removing variables that were non-significant. Sex, geography (urban vs rural), and the interaction between sex and method of suicide were removed from the model based on the initial model. Although non-significant, marital status and education were included in the final model as each variable improved the model fit using the Hosmer and Lemeshow test X^2 (8, N = 201,912) = 3.658 p = 0.887 (p = 0.216 with these variables excluded) (Lai & Liu, 2018). The final model is

presented in Table 17. and accounts for approximately 13.4% of the variation in accuracy (Nagelkerke R^2 = .134).

Table 18

Binary Logistic Regression Model for Death Certificate Accuracy.

Variables in the Equation (Reference Value)	p value	Exp(B) Odds Ratio	95% CI Exp(B) Lower	Upper
Age Group (14 and Under)	0.064			
15-19	0.069	0.535	0.273	1.049
20-24	0.053	0.527	0.275	1.008
25-29	0.035	0.496	0.258	0.952
30-34	0.014	0.438	0.227	0.847
35-39	0.006	0.399	0.206	0.772
40-44	0.005	0.390	0.202	0.754
45-49	0.001	0.327	0.169	0.634
50-54	0.001	0.340	0.175	0.661
55-59	0.005	0.383	0.197	0.746
60-64	0.002	0.340	0.170	0.680
65-69	0.001	0.299	0.143	0.627
70-74	0.004	0.328	0.152	0.708
75-79	0.009	0.347	0.157	0.766
80 and Older	0.007	0.360	0.171	0.758
Marital Status (Married/Civil Union/Domestic Partnership)	0.123			
Never Married	0.833	1.021	0.840	1.242
Widowed	0.182	0.778	0.538	1.125
Divorced	0.360	1.091	0.905	1.314
Married/Civil Union/Partnership, but separated	0.647	0.861	0.453	1.636
Single, not otherwise specified	0.025	1.590	1.060	2.386
Unknown	0.318	0.737	0.405	1.342
Race (White)	0.000			
Black or African American	<0.001	1.708	1.370	2.130
American Indian / Alaska Native	0.494	1.183	0.731	1.915
Asian / Pacific Islander	0.416	0.758	0.389	1.478
Two or More Races	0.874	1.037	0.664	1.620
Unknown	0.101	0.472	0.192	1.158
Method of Suicide (Firearm)	<0.001			
Sharp Instrument	0.049	1.695	1.003	2.863
Poisoning	<0.001	4.588	3.878	5.428
Hanging, strangulation, suffocation	<0.001	0.582	0.454	0.745
Fall	<0.001	2.676	1.771	4.043
Drowning	<0.001	5.254	3.499	7.891
Motor vehicle including buses, motorcycles	<0.001	4.459	2.582	7.699
Other transport vehicle including trains, planes, boats	<0.001	3.469	1.966	6.122
Other/Unknown	<0.001	10.619	7.843	14.378

(table continues)

Variables in the Equation (Reference Value)	p value	Exp(B) Odds Ratio	95% CI Exp(B) Lower	Upper
Education Level (8th grade or less)	0.383			
9th - 12th grade, no diploma	0.902	0.975	0.649	1.464
Highschool graduate or GED	0.190	0.769	0.519	1.139
Some college, but no degree	0.254	0.782	0.511	1.194
Associate's degree	0.190	0.718	0.438	1.179
Bachelor's degree	0.089	0.666	0.417	1.063
Master's degree	0.417	0.787	0.441	1.403
Doctorate or professional degree	0.749	0.888	0.429	1.838
Unknown/Missing	0.643	0.907	0.602	1.368
State (Alaska)	<0.001			
Arizona	0.001	0.203	0.077	0.536
California	0.001	0.037	0.005	0.274
Colorado	<0.001	0.270	0.168	0.434
Connecticut	0.677	0.837	0.362	1.933
Delaware	<0.001	6.781	2.458	18.709
District of Columbia	0.435	2.275	0.289	17.934
Georgia	0.131	0.721	0.472	1.102
Hawaii	0.994	0.000	0.000	
Illinois	0.031	0.342	0.129	0.904
Indiana	0.183	1.525	0.819	2.838
Iowa	0.147	0.341	0.080	1.457
Kansas	0.435	1.316	0.661	2.620
Kentucky	0.109	0.673	0.415	1.092
Maine	0.991	0.000	0.000	
Maryland	0.168	0.731	0.468	1.141
Massachusetts	<0.001	0.095	0.048	0.186
Michigan	0.001	0.317	0.157	0.641
Minnesota	0.006	0.132	0.031	0.561
Nevada	0.167	0.243	0.033	1.811
New Hampshire	0.203	0.388	0.090	1.665
New Jersey	<0.001	0.280	0.166	0.472
New Mexico	0.041	0.593	0.360	0.978
New York	0.003	0.338	0.166	0.687
North Carolina	<0.001	0.087	0.049	0.155
Ohio	<0.001	0.294	0.168	0.515
Oklahoma	0.257	0.764	0.480	1.217
Oregon	<0.001	0.348	0.214	0.566
Pennsylvania	0.002	0.144	0.043	0.481
Rhode Island	0.005	0.319	0.143	0.711
South Carolina	0.044	0.621	0.390	0.988
Utah	<0.001	0.099	0.044	0.221
Vermont	0.439	0.453	0.061	3.377
Virginia	<0.001	0.013	0.004	0.044
Washington	0.985	0.000	0.000	
West Virginia	0.530	1.476	0.438	4.976
Wisconsin	<0.001	0.195	0.112	0.341
Puerto Rico	0.995	0.000	0.000	
Substance Abuse	<0.001	1.560	1.317	1.849
Year of Suicide	<0.001	0.905	0.886	0.923
Constant	<0.001	8.355E+85		

These results indicate that accuracy does vary by at least one of the independent variables. Therefore, I reject the null hypothesis $H2_0$. Not all of the independent variables contributed significantly to the variation in accuracy. The following null sub-hypotheses were accepted: H_02_3 (sex), H_02_4 (transgender status), H_02_5 (sexual orientation), H_02_8 (geographic region), and H_02_9 (history of mental illness). The following null sub-hypotheses were rejected: H_02_1 (method of suicide), H_02_2 (age group), H_02_3 (sex), H_02_6 (race), H_02_7 (marital status), H_02_{10} (substance abuse), H_02_{11} (year of suicide), H_02_{12} (state of suicide), and H_02_{13} (education).

Method of suicide had several categories with the largest odds ratios: other/unknown (OR = 10.619); drowning (OR = 5.254); and poisoning (OR = 4.588). These data indicate those records with a method of suicide classified as other/unknown were 10.691 times more likely to have manner of death classified as something other than suicide. Among those with a method of suicide classified as other/unknown (n = 1853) 54 (2.9%) had a misclassified manner of death with undetermined as the most common misclassified category 79.6% (n = 43). Those classified with a method of suicide as drowning (n = 2114) 27 (1.3%) had a misclassified manner of death with undetermined as the most common misclassified category 70.4% (n = 19). Of the 194 deaths that were misclassified among those with a method of suicide classified as poisoning 67.5% (n = 131) were classified as undetermined manner of death, and 25.8% (n = 50) were classified as an accident, the remainder were classified as natural or a homicide (6.7%, n

= 13). Among all deaths in the study that had an error in manner of death classification, 40.2% (n = 351) were overdose/poisoning deaths.

The state of Delaware also had a high odds ratio (OR = 6.781; 95% CI 2.458, 18.709). There were only 121 cases included in the dataset from Delaware, so this should be interpreted with caution. Some other factors were protective or less likely to have manner of death classification errors such as the 65-69 age group (OR = 0.299) and deaths occurring in Virginia (OR = 0.013).

The final research question was RQ3: How does the accuracy rate with regard to suicide related manner of death assigned on death certificate change by year from 2005-2017? This question was answered using a one-way Analysis of Variance (ANOVA) followed by post-hoc Tukey test to identify which years were significantly different. The results from the one-way ANOVA test indicate that there is a significant time trend [F (12, 141,420) = 14.625, $p < 0.0001$]. The results from the one-way ANOVA and the post-hoc Tukey test can be found in Table 17 and Table 18. Based on these results, the null hypothesis, $H_0$3: The accuracy of suicide related manner of death assigned by death certificate does not vary by year from 2005-2017, was rejected. There is a significant difference in the accuracy of death certificates in reporting suicide over time. According to the results from the post-hoc Tukey test, the earlier years 2005-2010 have a significantly (p <0.001) increased error rate when compared to error rate from the later years 2011-2017. There were more errors observed in the early years with a drop in the error rate around 2011. Significant changes were made by the National Center for Health Statistics to death certificate data collection and coding methods between 2003 and

2011(National Center for Health Statistics (U.S.), 2018). These changes likely explain this significant drop and are discussed in detail in chapter 5.

Table 19

One-way ANOVA for Time-trend Analysis of Death Certificate (DC) Accuracy and Year of Suicide, Select States 2005-2017.

ANOVA DC Accuracy			df	F	p-value
Between Groups	(Combined)		12	14.625	<.001
	Linear Term	Unweighted	1	134.542	<.001
		Weighted	1	129.686	<.001
		Deviation	11	4.165	<.001
Within Groups			141420		
Total			141432		

Figure 3. displays a histogram of the DC error rate by year of suicide showing a declining trend over the 12-year period. As previously stated, using the post-hoc Tukey test, significant differences ($p < 0.001$) were observed between the early years (2005-2010) and the later years (2011-2017). The detailed results from the Tukey test are included in Table A3 of the appendix.

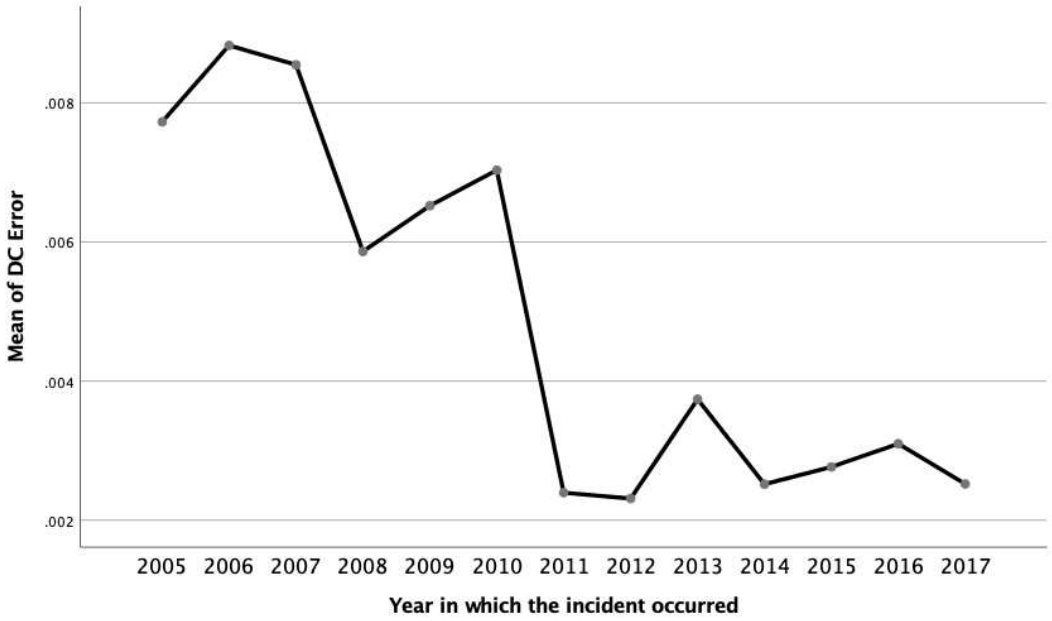

Figure 3. Histogram of Death Certificate (DC) Error Rate by Year of Death, Select States 2005-2017.

Summary

The secondary data obtained for this study from the NVDRS Restricted Accesses Dataset have been described in detail. Results from the descriptive, bivariate, and inferential analyses were presented. Each hypothesis was tested using appropriate statistical methods. Death certificates are accurate in reporting suicide 99.57% of the time. While the error rate of death certificates in misclassifying suicides is small (0.43%), it is significant. Factors that help to explain the variation in the death certificate classification error rate include method of suicide, age group, marital status, race, substance abuse status, level of education, year of death, and state of death. There is a significant time trend in the death certificate error rate, with higher rates in the earlier years (2005-2010) included in the dataset. An interpretation of these results along with

the limitations of this study and suggestions for future research will be discussed in the text chapter.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

Vital records, such as the death certificate, are used by public health professionals and policy makers to inform important policy and public health decisions. It is important to quantify and understand the accuracy of these records in reporting specific diseases and conditions such as suicide. Suicide is a major public health problem in the United States, with some states being affected more than others (Ivey-Stephenson, Crosby, Jack, Haileyesus, & Kresnow-Sedacca, 2017; Olfson et al., 2017; Safe States Alliance, 2017). The accuracy of death certificates in reporting suicide had not been evaluated either at the state or national level. The purpose of this study was to quantify the accuracy of death certificates in reporting suicide. Death certificate reports were evaluated against a second standardized source of mortality data, the NVDRS.

The previous chapter outlined the findings of analysis conducted to quantify the accuracy of death certificates in reporting suicide in the United States using the NVDRS as a reference standard. There was a small, but statistically significant, amount of error observed. Additionally, there was a statistically significant temporal pattern observed with accuracy increasing over time. Overall, death certificates in the United States are very accurate at recording suicide deaths. This chapter will provide a discussion of the meaning of these findings, provide conclusions, and recommendations based on the findings.

Interpretation of the Findings

Previous research described in Chapter 2 presented findings related to the accuracy of vital records in reporting deaths from different conditions such as cancer and pneumonia (Falci et al., 2018; Massa et al., 2017; Mieno et al., 2016). There have been no previous studies evaluating the accuracy of death certificates in reporting suicide in the United States. Research from other countries found a significant amount of underreporting (Bakst et al., 2015; Thomas et al., 2013). Based on the findings from these previous studies it would be expected that there would be some error in reporting suicide related deaths on the death certificate in the United States. Using NVDRS as the standard, this study found the U.S. death certificate to be very accurate in reporting suicide deaths. There is a small but significant amount of error (0.43%) in the accurate reporting and classification of suicide on the U.S. death certificate. Bivariate logistic regression models indicate that a portion of the error in reporting suicide on the death certificate can be explained by a few interesting independent variables.

Decedents who had a history of substance abuse recorded by NVDRS were more likely to have an error in the classification of the death as a suicide on the death certificate (*OR* = 1.56; 95% *CI* 1.317, 1.849), meaning the manner of death was classified as something other than suicide. Additionally, deaths with a method of suicide classified as poisoning were 4.588 (95% *CI* 3.878, 5.428) times more likely to have an error in classifying suicide as the manner of death. This is consistent with previous research indicating an underreporting of suicide among overdose deaths (Johnson et al., 2013; Liu et al., 2019). As described in chapter 4 many of the cases were classified with an

undetermined manner of death. This highlights the potential difficulty in determining suicidal intent in overdose deaths. This phenomenon is described and explored in detail by other studies (Bohnert et al., 2013; Choi, DiNitto, Marti, & Choi, 2019; Oquendo & Volkow, 2018).

The state where the suicide occurred was another significant predictor of errors that would produce an underreporting of suicide deaths on the death certificate. Both NVDRS data and death certificate data are collected and recorded at the state level, meaning the individuals collecting the data are employed and managed at the state level usually at the state department of health (Crosby et al., 2016; National Center for Health Statistics (U.S.), 2018). Data collection methods are standardized and established at the national level but executed by each individual state. This model of state level administration could be a source of variance or error. There are also different medical examiner and coroner systems; some states use a centralized system managed by a chief medical examiner, while other states use a distributed system of county level coroners with a mix of elected and appointed coroners (Martin, Bozlak, & Park, 2018). The education, training, and experience required to be coroner also varies by jurisdiction. Of the five states with the highest error rates, three (Oklahoma, South Carolina, and Kentucky) use a distributed system of coroners while the other two (Maryland and West Virginia) utilize a centralized medical examiner's office model. Previous studies have identified these disparate systems and level of training as a source of error and variation in death classification and reporting particularly related to overdose deaths (Buchanich, Balmert, Williams, & Burke, 2018; Warner, Paulozzi, Nolte, Davis, & Nelson, 2013).

Age of decedent is another significant predictor, with more errors among younger age groups. The older age groups appear to be protective against an error. This means that suicide would be underreported among those in the younger age groups. Accuracy increases as age group increases. This is an unexpected relationship. Classification errors among younger decedents could come from an unwillingness of certifying clinicians to assign suicide as the cause of death among the younger age groups (Tait, Jowett, & Carpenter, 2019). Previous research has also established differences in method of suicide related to age, similar to gender, with younger decedents using poisoning/overdose or suffocation which may be more difficult to determine intent (Ivey-Stephenson et al., 2017; Olfson et al., 2017; E. M. Sullivan et al., 2015).

Method of suicide is another significant predictor of suicide classification error. While significant, this relationship is weak. This relationship was expected with a lower error rate observed among suicide by firearm (0.28%) and higher error rates among other methods such as poisonings (1.10%), drownings (1.28%) and those classified as other/unknown (2.91%). This is consistent with previous research indicating that it may be more difficult to determine intent in cases where the method of suicide is poisoning, drowning, or other methods such as falls (Buchanich, Balmert, Williams, & Burke, 2018; Liu et al., 2019; Rockett, Kapusta, & Coben, 2014).

Year of suicide is another significant predictor of classification error. In addition to the predictive relationship, there is a statistically significant time trend related to the year that the suicide occurred. There are much higher error rates in years before 2011. There is a significant drop in the error rates starting in 2011. In 2003 that National

Center for Health Statistics (NCHS) launched an initiative to improve the accuracy of birth and death certificate data with a new standardized form. States slowly implemented the new form, some taking as 14 years to fully implement the new certificates. Identifying cause of death coding issues as a major source of error, in 2011 NCHS launched centralized cause of death recording (National Center for Health Statistics (U.S.), 2018). This centralized cause of death coding and the adoptions of the standardized form for death certificate data collection likely explain the time trend observed in this study.

While statistically significant, the variables included in the binary logistic regression model only explain a small portion of the classification errors (Nagelkerke R^2 = .134). This indicates that there are other variables not included in the model that contribute to the inaccurate recording of suicide on the death certificate. These variables may include the type of medical examiner/coroner system used, education and training of certifiers, the use of psychological autopsies, or other variations in the collection of NVDRS or death certificate data at the local level (Krywanczyk, Amoresano, Tatsumi, & Mount, 2020; National Center for Health Statistics (U.S.), 2018; Tait et al., 2019; Xaverius et al., 2018).

Limitations of the Study

This study has some important limitations. While this study used national level NVDRS data, NVDRS data have not been collected from every state over time (Crosby et al., 2016). Therefore, the results of this study can only be extrapolated to states that have data included in the dataset as outlined in chapter 4. NVDRS data were used as a

reference standard to evaluate the accuracy of classification of suicide deaths. The NVDRS employs many different techniques to ensure data quality and accuracy; the accuracy of the results for this study are directly linked to the accuracy of the NVDRS data. The NVDRS has well documented, stringent, data collection protocols (National Center for Injury Prevention and Control, 2016). These protocols are executed at the state level. While unlikely, there may be some error in the classification of suicide cases by NVDRS. All NVDRS abstractors are trained using standardized training materials, but they are managed at the local level and they do come from varying backgrounds (Crosby et al., 2016). In addition to variation in background and education of abstractors, there may also be variations in retention and pay as these are not federal employees but are employees of state or local departments of health. This distributed model of data collection is very similar to that used by the NCHS in the collection of vital records data. State level variation in the execution of standardized data collection within the vital records system has been documented (National Center for Health Statistics (U.S.), 2018).

The original design of the study included occupation, as a measure of socioeconomic status. The occupation data received from NVDRS included free text classifications of occupation and a coded variable that could not be accurately mapped to larger standardized occupational classifications. This variable was therefore excluded from the analysis. Level of education was included in the analysis as an alternative measure of socioeconomic status.

The results from this study, specifically the bivariate logistic regression, only explain a small portion of the suicide classification errors. This means that there are

factors and variables not in the current dataset that contribute significantly to the classification errors being made. These factors could range from the training of the individual classifying the death to the type of medical examiner system in each state. States that use a centralized medical examiner's office model, have a chief medical examiner who directly supervises all autopsies and death classification in the state often at a single centralized location. States that use a decentralized coroner system often have county level coroners with varying levels of training and education, this model offers less supervision or standardization (Martin et al., 2018). The sample size for this study is very large. This large sample size might increase the likelihood of making a type I error (Cumming & Calin-Jageman, 2017). It is important to recognize that level of suicide classification error observed in this study is small (0.43%) and some of that error may be random and due to chance.

Recommendations

The results from this study indicate that death certificates are highly accurate at reporting suicide deaths in the United States using NVDRS data as the standard. There is a small amount of unexplained error. Further investigation would be needed to fully understand the factors that contribute to classification errors on the death certificate related to suicide deaths. For example, there are several different medical examiner or coroner models in use across the United States. It would be worth documenting the different types of models and analyzing if there are specific models that are more accurate at recording suicide deaths than others at classifying and recording suicide deaths (Martin et al., 2018; Tait et al., 2019).

Additionally, some states such as Utah are investing significant effort and infrastructure in conducting full psychological autopsies on suicide deaths (Ramseth, 2018; Utah Medical Examiner Act, 2017). While these investigations contribute data and knowledge to the creation and coding of the death certificate, much of the data are stored in secondary databases. It may be meaningful to study states with and without these types of systems, including how the added data collected through a psychological autopsy contribute to completeness and accuracy of data reported on the death certificate.

Using different research methods may yield results with more detailed findings. Studies utilizing machine learning and natural language processing would allow the inclusion of more records while continuing to limit the amount of resources necessary to conduct the research (Liu et al., 2019). If designed correctly, this method could be used to analyze death certificate cause of death classification differences among classifiers based on education, position, or other characteristics. Similar techniques have been used to evaluate or enhance human classification of medical data (Gibbons, Richards, Valderas, & Campbell, 2017; Lakhani et al., 2018). Blinded expert review of medical documentation along with recoding and inter-rater reliability have been used by previous studies to identify sources of death certificate classification error (Bakst et al., 2015; McGivern, Shulman, Carney, Shapiro, & Bundock, 2017). While resource intense, this type of investigation may yield information regarding factors that influence accuracy of suicide reporting that may not be captured otherwise.

Based on the results from this study, the classification of suicide on the death certificate is very accurate. Future studies may focus on the accuracy of other variables

collected and classified by the death certificate, such as method of suicide as well as other variables that record potential suicide risk factors. Additional factors that may influence the accurate reporting of suicide should also be explored such as the fear and stigma associated with assigning suicide as a manner of death as well as socioeconomic factors such as occupation and income.

Implications

Death certificate data have been used locally and nationally to track suicide deaths and establish public health interventions. The quality of these data had not previously been quantified. This study has established that there is a relatively low level of error (0.43%) in the classification of suicide deaths on the death certificate. There were 48,344 (14.78 per 100,000) suicide deaths in the United States in 2018. Using the error rate established by this study there are potentially 208 deaths that would have been misclassified in 2018. This would change the national rate from 14.78 to 14.84 per 100,000. While the error rate is statistically significant it would make relatively little difference in the national rates. Therefore, this study has provided evidence that public health policy and intervention decisions can be based on death certificate data with a relatively high confidence. Suicide related policy and interventions that will bring positive social change must be based on sound science and accurate data. This study provides validation that death certificate data would be an accurate data source upon which to base such decisions.

Conclusion

Suicide is a major public health problem in the United States. Death certificate data are a major source of data for research, policy, and interventions focused on suicide. Prior to this study the accuracy of death certificates in reporting suicide had not been quantified in the United States. This study used NVDRS data as a reference standard to evaluate the accuracy of death certificates in reporting suicide in the US. Based on this study there is a low error rate (0.43%) in reporting suicide on death certificates in the US. A small amount of the error (13.4%) is related to factors on the death certificate including: age group, race, marital status, level of education, method of suicide, history of substance abuse, year of suicide, and state where the suicide took place. These results indicate that there may be other variables, not included in this study, that could predict the accurate classification of suicide on the death certificate. Further investigation would be required to explore what those variables might be. This study establishes that the death certificate is highly accurate (99.57%) at reporting suicide deaths overall. Therefore, death certificate data can be used as an accurate data source upon which to base public health decisions, interventions, and tracking.

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Appendix: Tables

Table A1

Literature Review Search Log.

Date of Search	Database / Search Engine	Years Searched	Search Terms (including limits)	Number of Articles Returned	Number Selected for Review	Notes
10/5/17	Google Scholar	2013-2017	validation of death certificate - sorted by relevance	16,800	15	The first 150 articles were screened for relevance. 15 articles were identified for reading and further review.
10/5/17	Google Scholar	2013-2017	suicide death certificate validation - sorted by relevance	15,000	16	The first 150 articles were screened for relevance. 16 articles were identified for reading and further review.
10/5/17	Google Scholar	2013-2017	quality of death certificate data - sorted by relevance	17,900	0	Most seem unrelated. Picked up mainly on the United States term and death.
10/5/17	Google Scholar	2013-2017	Exact phrase "quality of death certificate data"	0	0	
10/5/17	Google Scholar	2013-2017	Exact phrase "quality of vital records"	6	0	no meaningful results
10/5/17	Google Scholar	2013-2017	Exact phrase "death certificate quality"	3	1	1 article identified for reading and further review
10/5/17	Google Scholar	2013-2017	Exact phrase "cause of death validation"	12	0	No new articles identified - 1 previously identified.
10/5/17	Google Scholar	2013-2017	Exact phrase "accuracy of death certificate"	145	17	17 new articles identified for reading and further review - focused on US studies, but included foreign studies if they seemed highly relevant

(table continues)

Date of Search	Database / Search Engine	Years Searched	Search Terms (including limits)	Number of Articles Returned	Number Selected for Review	Notes
10/6/17	Google Scholar	2013-2017	Clinical autopsy and suicide	15,700	26	26 articles identified for review, focus was put on risk factors and use of clinical autopsy in violent or suspect deaths
10/6/17	Google Scholar	2013-2017	Psychological autopsy and suicide	6,300	19	19 articles identified for review based on suicide and use of psychological autopsy to inform death certificate review
10/6/17	Google Scholar	2013-2017	National Violent Death Reporting System	18,600	29	29 articles identified for review based on NVDRS methods, study of suicide, use of NVDRS data as a standard
2/11/18	Google Scholar	2013-2018	Sex and Suicide	30,300	23	23 new articles identified for reading and further review - focused on US studies, but included foreign studies if they seemed highly relevant, excluded studies on very specific populations like military or patients with specific illnesses
3/25/18	Google Scholar	2013-2018	Suicide among transgender people - sorted by relevance	17,000	18	
3/25/18	Google Scholar	2013-2018	validation of vital records age data	16,800	0	no meaningful results - studies validating outcome measures but not demographics
4/21/18	Google Scholar	2013-2018	gender differences in suicide among the mentally ill	16,700	6	Focused on results that included suicide in the title. Added 6 articles for review.
4/22/18	Google Scholar	2013-2018	validation of age using vital records	215,000	0	no meaningful results - most focused on the accuracy of gestational age as reported by mother

(table continues)

Date of Search	Database / Search Engine	Years Searched	Search Terms (including limits)	Number of Articles Returned	Number Selected for Review	Notes
4/22/18	Google Scholar	no filter	validation of age collected by survey	360,000	0	no meaningful results - validation of age estimation, validation of other information collected by survey such as exposure. No reference to age.
4/22/18	Google Scholar	no filter	best way to collect age	1,170,000	0	no meaningful results - hits where terms like "information age" "age of anxiety" and "best way"
4/22/18	PubMed	no filter	collecting age data	2,161	0	no meaningful results - hits on "data" "age of drones"
4/22/18	PubMed	no filter	self reported age	54,285	0	no meaningful results - hits on adolescents and specific age groups and age related risk factors
4/22/18	PubMed	no filter	accuracy of age collected	2,292	0	no meaningful results - hits on accuracy of diagnosis accuracy of self report family history
4/22/18	PubMed	no filter	validation of age	26,815	0	no meaningful results - validation of different scales and predictive models
4/22/18	PubMed	no filter	collecting date of birth	383	0	no meaningful results - hits on individual words, most results on birth cohort, birth defects, assisted reproductive technology
4/22/18	Google Scholar	2013-2018	accuracy of ethnicity	59,700	3	3 articles identified for review
4/22/18	PubMed	no filter	race and ethnicity on death certificate	617	10	10 articles identified for review other articles were focused on racial and ethnic health disparities no the collection of demographic data
4/22/18	PubMed	no filter	death certification errors	81	15	15 articles identified for review
4/22/18	PubMed	no filter	quality control of death certificate	260	8	

(table continues)

Date of Search	Database / Search Engine	Years Searched	Search Terms (including limits)	Number of Articles Returned	Number Selected for Review	Notes
4/22/18	PubMed	no filter	improving death certificate	171	10	
4/25/18	Ebsco Host	no filter	Mesh Terms - Death certificate, accuracy, validity, reliability	620	5	Many old articles; selected 5 based on significance and relevance
5/13/18	Google Scholar	2013-2018	occupation and suicide	25,600	16	
5/13/18	Google Scholar	2013-2018	mental illness on death certificate	16,900	4	
5/13/18	Google Scholar	2013-2018	violence and suicide	46,500	5	
6/2/20	Google Scholar	2016-2020	education and suicide	77,400	6	Addition of education as a variable
6/2/20	Google Scholar	2016-2020	education as an indicator of SES	43,300	4	
6/2/20	Google Scholar	2016-2020	Death certificates as source for suicide	20,500	3	Update previous search

Table A2

Number of Cases Contributed by Year and State.

State	Year Death Occurred															Total
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Alaska	127	155	138	135	148	167	142	169	146	171	173	163	204	192	205	2435
Maryland	508	489	471	487	502	484	559	513	552	572	573	599	553	588	641	8091
Massachusetts	437	447	491	457	516	513	546	604	588	624	589	619	635	638	694	8395
New Jersey	602	636	538	588	635	401	686	738	739	702	733	770	768	678	757	9971
Oregon	613	572	589	589	623	607	666	718	682	751	733	777	766	786	857	10329
South Carolina	505	498	524	532	540	569	607	627	664	680	702	749	736	819	820	9572
Virginia	802	834	875	892	900	947	972	1001	1065	1059	1063	1138	1094	1151	1157	14950
Colorado	0	818	809	726	837	828	947	879	914	1038	1025	1098	1114	1177	1188	13398
Georgia	0	943	793	968	988	1055	1129	1168	1149	1179	1230	1297	1330	1425	1479	16133
North Carolina	0	1043	1027	1152	1111	1173	1200	1208	1228	1314	1036	1349	1421	1396	1556	17483
Oklahoma	0	515	532	541	535	586	560	569	693	670	663	739	779	836	760	8978
Rhode Island	0	87	75	96	106	111	120	132	102	107	136	118	124	120	132	1566
Wisconsin	0	650	657	660	722	740	737	785	746	729	848	757	867	859	936	10693
Kentucky	0	0	590	623	632	577	552	511	644	643	687	732	782	786	764	8523
New Mexico	0	0	340	365	415	397	391	422	426	441	438	441	496	488	495	5555
Utah	0	0	351	367	383	396	462	479	522	571	603	575	626	649	658	6642
Ohio	0	0	0	0	0	0	0	0	1558	1595	1580	1544	1644	1702	1754	11377
Michigan	0	0	0	0	0	0	0	0	0	0	0	1344	1380	1318	1378	5419
Arizona	0	0	0	0	0	0	0	0	0	0	0	0	1287	1264	1335	3886
Connecticut	0	0	0	0	0	0	0	0	0	0	0	0	369	381	394	1144
Hawaii	0	0	0	0	0	0	0	0	0	0	0	0	201	177	0	378
Kansas	0	0	0	0	0	0	0	0	0	0	0	0	483	522	548	8523
Maine	0	0	0	0	0	0	0	0	0	0	0	0	234	223	274	731
Minnesota	0	0	0	0	0	0	0	0	0	0	0	0	720	724	782	2227
New Hampshire	0	0	0	0	0	0	0	0	0	0	0	0	228	238	264	730
New York	0	0	0	0	0	0	0	0	0	0	0	0	1560	1691	1702	4953
Vermont	0	0	0	0	0	0	0	0	0	0	0	0	101	132	117	350
Illinois	0	0	0	0	0	0	0	0	0	0	0	0	0	996	1077	2073
Indiana	0	0	0	0	0	0	0	0	0	0	0	0	0	1040	1088	2128
Iowa	0	0	0	0	0	0	0	0	0	0	0	0	0	457	469	926
Pennsylvania	0	0	0	0	0	0	0	0	0	0	0	0	0	1469	1855	3324
Washington	0	0	0	0	0	0	0	0	0	0	0	0	0	959	1191	2150
California	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4368	4368
Delaware	0	0	0	0	0	0	0	0	0	0	0	0	0	0	121	121
District of Columbia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	47
Nevada	0	0	0	0	0	0	0	0	0	0	0	0	0	0	666	666
West Virginia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	398	398
Puerto Rico	0	0	0	0	0	0	0	0	0	0	0	0	0	0	249	249
Total	**3594**	**7687**	**8800**	**9177**	**9593**	**9551**	**10273**	**10523**	**12418**	**12846**	**13082**	**14808**	**20502**	**25882**	**33176**	**201912**

Table A3

Cause of Death Classification Error Rate for all Sources of Classification.

Classification Source	Number of Cases	Cases Classified as Not Suicide	Error Rate
NVDRS	203,215		
Death Certificate	201,912	873	0.43%
Office of Medical Examiner	184,522	760	0.41%
Law Enforcement	124,697	2,731	2.19%

Table A4

Tukey Post-hoc Test from One-way ANOVA for Time-trend Analysis of Death Certificate (DC) Accuracy and Year of Suicide, Select States 2005-2017.

(I) Year of Death	(J) Year of Death	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2005	2006	-.001	.001	.997	.00	.00
	2007	-.001	.001	1.000	.00	.00
	2008	.002	.001	.822	.00	.01
	2009	.001	.001	.992	.00	.00
	2010	.001	.001	1.000	.00	.00
	2011	.005*	.001	.000	.00	.01
	2012	.005*	.001	.000	.00	.01
	2013	.004*	.001	.002	.00	.01
	2014	.005*	.001	.000	.00	.01
	2015	.005*	.001	.000	.00	.01
	2016	.005*	.001	.000	.00	.01
	2017	.005*	.001	.000	.00	.01
2006	2005	.001	.001	.997	.00	.00
	2007	.000	.001	1.000	.00	.00
	2008	.003	.001	.130	.00	.01
	2009	.002	.001	.475	.00	.01
	2010	.002	.001	.827	.00	.01
	2011	.006*	.001	.000	.00	.01
	2012	.007*	.001	.000	.00	.01
	2013	.005*	.001	.000	.00	.01
	2014	.006*	.001	.000	.00	.01
	2015	.006*	.001	.000	.00	.01
	2016	.006*	.001	.000	.00	.01
	2017	.006*	.001	.000	.00	.01
2007	2005	.001	.001	1.000	.00	.00
	2006	.000	.001	1.000	.00	.00
	2008	.003	.001	.237	.00	.01
	2009	.002	.001	.667	.00	.01
	2010	.002	.001	.937	.00	.00
	2011	.006*	.001	.000	.00	.01
	2012	.006*	.001	.000	.00	.01
	2013	.005*	.001	.000	.00	.01
	2014	.006*	.001	.000	.00	.01
	2015	.006*	.001	.000	.00	.01
	2016	.005*	.001	.000	.00	.01
	2017	.006*	.001	.000	.00	.01
2008	2005	-.002	.001	.822	-.01	.00
	2006	-.003	.001	.130	-.01	.00
	2007	-.003	.001	.237	-.01	.00
	2009	-.001	.001	1.000	.00	.00
	2010	-.001	.001	.992	.00	.00
	2011	.003*	.001	.017	.00	.01
	2012	.004*	.001	.011	.00	.01
	2013	.002	.001	.550	.00	.01
	2014	.003*	.001	.021	.00	.01
	2015	.003*	.001	.046	.00	.01
	2016	.003	.001	.125	.00	.01
	2017	.003*	.001	.016	.00	.01

(table continues)

2009	2005	-.001	.001	.992	.00	.00
	2006	-.002	.001	.475	-.01	.00
	2007	-.002	.001	.667	-.01	.00
	2008	.001	.001	1.000	.00	.00
	2010	-.001	.001	1.000	.00	.00
	2011	.004*	.001	.001	.00	.01
	2012	.004*	.001	.000	.00	.01
	2013	.003	.001	.119	.00	.01
	2014	.004*	.001	.001	.00	.01
	2015	.004*	.001	.003	.00	.01
	2016	.003*	.001	.010	.00	.01
	2017	.004*	.001	.001	.00	.01
2010	2005	-.001	.001	1.000	.00	.00
	2006	-.002	.001	.827	-.01	.00
	2007	-.002	.001	.937	.00	.00
	2008	.001	.001	.992	.00	.00
	2009	.001	.001	1.000	.00	.00
	2011	.005*	.001	.000	.00	.01
	2012	.005*	.001	.000	.00	.01
	2013	.003*	.001	.020	.00	.01
	2014	.005*	.001	.000	.00	.01
	2015	.004*	.001	.000	.00	.01
	2016	.004*	.001	.001	.00	.01
	2017	.005*	.001	.000	.00	.01
2011	2005	-.005*	.001	.000	-.01	.00
	2006	-.006*	.001	.000	-.01	.00
	2007	-.006*	.001	.000	-.01	.00
	2008	-.003*	.001	.017	-.01	.00
	2009	-.004*	.001	.001	-.01	.00
	2010	-.005*	.001	.000	-.01	.00
	2012	.000	.001	1.000	.00	.00
	2013	-.001	.001	.961	.00	.00
	2014	.000	.001	1.000	.00	.00
	2015	.000	.001	1.000	.00	.00
	2016	-.001	.001	1.000	.00	.00
	2017	.000	.001	1.000	.00	.00
2012	2005	-.005*	.001	.000	-.01	.00
	2006	-.007*	.001	.000	-.01	.00
	2007	-.006*	.001	.000	-.01	.00
	2008	-.004*	.001	.011	-.01	.00
	2009	-.004*	.001	.000	-.01	.00
	2010	-.005*	.001	.000	-.01	.00
	2011	.000	.001	1.000	.00	.00
	2013	-.001	.001	.936	.00	.00
	2014	.000	.001	1.000	.00	.00
	2015	.000	.001	1.000	.00	.00
	2016	-.001	.001	1.000	.00	.00
	2017	.000	.001	1.000	.00	.00
2013	2005	-.004*	.001	.002	-.01	.00
	2006	-.005*	.001	.000	-.01	.00
	2007	-.005*	.001	.000	-.01	.00
	2008	-.002	.001	.550	-.01	.00
	2009	-.003	.001	.119	-.01	.00
	2010	-.003*	.001	.020	-.01	.00
	2011	.001	.001	.961	.00	.00
	2012	.001	.001	.936	.00	.00
	2014	.001	.001	.978	.00	.00
	2015	.001	.001	.997	.00	.00
	2016	.001	.001	1.000	.00	.00
	2017	.001	.001	.974	.00	.00

(table continues)

2014	2005	-.005*	.001	.000	-.01	.00
	2006	-.006*	.001	.000	-.01	.00
	2007	-.006*	.001	.000	-.01	.00
	2008	-.003*	.001	.021	-.01	.00
	2009	-.004*	.001	.001	-.01	.00
	2010	-.005*	.001	.000	-.01	.00
	2011	.000	.001	1.000	.00	.00
	2012	.000	.001	1.000	.00	.00
	2013	-.001	.001	.978	.00	.00
	2015	.000	.001	1.000	.00	.00
	2016	-.001	.001	1.000	.00	.00
	2017	.000	.001	1.000	.00	.00
2015	2005	-.005*	.001	.000	-.01	.00
	2006	-.006*	.001	.000	-.01	.00
	2007	-.006*	.001	.000	-.01	.00
	2008	-.003*	.001	.046	-.01	.00
	2009	-.004*	.001	.003	-.01	.00
	2010	-.004*	.001	.000	-.01	.00
	2011	.000	.001	1.000	.00	.00
	2012	.000	.001	1.000	.00	.00
	2013	-.001	.001	.997	.00	.00
	2014	.000	.001	1.000	.00	.00
	2016	.000	.001	1.000	.00	.00
	2017	.000	.001	1.000	.00	.00
2016	2005	-.005*	.001	.000	-.01	.00
	2006	-.006*	.001	.000	-.01	.00
	2007	-.005*	.001	.000	-.01	.00
	2008	-.003	.001	.125	-.01	.00
	2009	-.003*	.001	.010	-.01	.00
	2010	-.004*	.001	.001	-.01	.00
	2011	.001	.001	1.000	.00	.00
	2012	.001	.001	1.000	.00	.00
	2013	-.001	.001	1.000	.00	.00
	2014	.001	.001	1.000	.00	.00
	2015	.000	.001	1.000	.00	.00
	2017	.001	.001	1.000	.00	.00
2017	2005	-.005*	.001	.000	-.01	.00
	2006	-.006*	.001	.000	-.01	.00
	2007	-.006*	.001	.000	-.01	.00
	2008	-.003*	.001	.016	-.01	.00
	2009	-.004*	.001	.001	-.01	.00
	2010	-.005*	.001	.000	-.01	.00
	2011	.000	.001	1.000	.00	.00
	2012	.000	.001	1.000	.00	.00
	2013	-.001	.001	.974	.00	.00
	2014	.000	.001	1.000	.00	.00
	2015	.000	.001	1.000	.00	.00
	2016	-.001	.001	1.000	.00	.00

* The mean difference is significant at the .05 level.