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GEOGRAPHIC DISTRIBUTION OF U.S. ACTIVE DUTY AND CIVILIAN SUICIDALITY AND CO-VARIATES: A QUANTITATIVE ANALYSIS

Schneider, Lincoln J.

Monterey, CA; Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

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by

Lincoln J. Schneider

June 2018

Co-Advisors: Yu-Chu Shen
Marigee Bacolod

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This quantitative study examines the geographic distribution of suicide rates within the United States among civilian and active duty military populations and seeks to identify significant covariate relationships that point to relevant public health, environmental, and economic factors that civilian and military leaders should consider in planning, preparation, training, and deployment of health system resources. Multivariate regression analysis techniques specify associations between rates of civilian suicide and rates of relevant co-morbidities, analyzed across U.S. counties. ArcGIS mapping and advanced statistical techniques visualize variation in rates of national military and civilian populations in ways that are more complete and informative than has previously been made available to public health practitioners, prevention planners, and policymakers. Significant outcomes include identification of localities indicating clusters of significantly increased localized mainland U.S. military suicide rates, enhanced visualization of U.S. civilian suicide rates, including low frequency counties, and significantly correlated environmental and public health sources of county-level morbidity.

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GEOGRAPHIC DISTRIBUTION OF U.S. ACTIVE DUTY AND CIVILIAN SUICIDALITY AND CO-VARIATES: A QUANTITATIVE ANALYSIS

Lincoln J. Schneider
Lieutenant, United States Navy
BA, Tulane University of Louisiana, 2003
JD, University of Florida, 2010
MPH, University of Florida, 2014

Submitted in partial fulfillment of the
requirements for the degree of

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June 2018

Approved by: Yu-Chu Shen
Co-Advisor

Marigee Bacolod
Co-Advisor

Yu-Chu Shen
Academic Associate
Graduate School of Business and Public Policy

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This quantitative study examines the geographic distribution of suicide rates within the United States among civilian and active duty military populations and seeks to identify significant covariate relationships that point to relevant public health, environmental, and economic factors that civilian and military leaders should consider in planning, preparation, training, and deployment of health system resources. Multivariate regression analysis techniques specify associations between rates of civilian suicide and rates of relevant co-morbidities, analyzed across U.S. counties. ArcGIS mapping and advanced statistical techniques visualize variation in rates of national military and civilian populations in ways that are more complete and informative than has previously been made available to public health practitioners, prevention planners, and policymakers. Significant outcomes include identification of localities indicating clusters of significantly increased localized mainland U.S. military suicide rates, enhanced visualization of U.S. civilian suicide rates, including low frequency counties, and significantly correlated environmental and public health sources of county-level morbidity.

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LIST OF ACRONYMS AND ABBREVIATIONS

AD	US Active Duty Military Forces
AMFES	Armed Forces Medical Examiner System
CDC	US Centers for Disease Control and Prevention
CONUS	Military term describing inside the continental United States, not Alaska, Hawaii, territories, or overseas bases.
CY	Calendar Year
DoD	US Department of Defense
DoDSER	DoD Suicide Event Report
MTF	Military Treatment Facility
NG	National Guard
OCONUS	Military term describing locations in Alaska, Hawaii, U.S. Territories, or locations not in the continental US.
SMR	Standardized Mortality Ratio
SPAN	VA Suicide Prevention Application Network
SUD	Substance Abuse Disorder
US	United States of America
VA	US Department of Veterans Affairs
VHA	US Veterans Health Agency
WISQARS	CDC's Web-Based Injury Statistics Query and Reporting System

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Lastly, I would like to dedicate this work to my father, Gary Schneider, and Captain Gordon Nakagawa, both Vietnam Navy Veterans who survived and flourished in spite of the immense adversity they faced.

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I. GEOGRAPHIC DISTRIBUTION OF MILITARY SUICIDE

A. SUICIDE AND THE MILITARY

Suicide in the military is a costly and destabilizing progression of events that happens with unfortunate frequency. In recent years, suicide has become the top non-combat cause of loss of life, and accounted for almost 20 percent of all active duty deaths (Shen, Cunha, & Williams, 2016). Suicide can be as destabilizing to a military unit as a homicide, a fatal accident, or the loss of a comrade due to violence or disease. Unfortunately, for military populations, suicide happens with far more frequency than many other fatal events. This thesis aims to quantify where suicide happens throughout the United States and to survey suicide reporting in order to inform prevention efforts across U.S. populations.

1. Research Questions

The primary research questions for this study seek to address what is the overall geographic distribution of suicides in the United States population. Additionally, how does the geographic distribution of suicides vary with local demographics and geospatial information, including localized populations of U.S. Active Duty Military and Veterans? As a secondary research question, asks, to what extent can a qualitative analysis of suicide co-variates at the county-level provide significant associations that help explain these geographic patterns in suicide rates?

2. Scope of this Thesis

This thesis analyzes suicide rates for all U.S. counties based on best available for military and civilian data between 2003 and 2008. The scope of this thesis is to provide a characterization of the extent of suicides across different geographic areas in the United States, with a particular eye towards suicides among the military or former military populations. The study will also examine environmental, economic, and other public health data at local geographic units to see how they correlate with suicides. The analysis is intended to evaluate whether the geographic distribution of suicides within subsets of U.S.

populations, primarily at the county-level, can better inform current U.S. agency reporting on suicide and ongoing awareness, prevention, and intervention of suicidal behaviors in the US. This research is quantitative in nature.

3. Findings

The geographic distribution and analysis of military and civilian suicide can and should drive suicide reporting for prospective prevention, education, and intervention efforts in the United States. Through the use of multivariate regression analysis and geoinformatic visualization, this study explores the geographic distribution of U.S. suicide and makes several conclusions of importance for institutional suicide prevention, intervention, reporting, and response. First, it shows that the "where" of suicide matters, especially with respect to the importance of useful policymaking and system responses based on indications at the county-level. Larger aggregations are informative of national trends only, and much of the variation in where suicide mortality occurs is in the local and county "tails" of the overall statistical distribution of suicide mortality. This variation can inform analysis and provide health practitioners and policymakers with sound analysis with which to design future prevention, intervention, and response measures. Second, multivariate regression analysis and other advanced statistical techniques can and should be utilized in the reporting and public education of suicidality in the United States, especially applying information pertinent at the more-localized community levels, such as U.S. counties or municipal aggregations. Fourth, geographic isolation, economic and demographic factors, environmental measures, and measures of several other causes of mortality matter to civilian rates of suicide and its geographic distribution.

For military populations, during the cross-section of years 2003–2008, patterns of geographic distribution of military suicide mostly differed from those of civilian counties. This pattern of variation is represents what might be expected for the military population, which tends to train and distribute personnel in very different ways than civilian communities. Despite these apparent differences, important conclusions can be drawn from this portion of the research. *Chief of these is that patterns of uneven distribution of suicidality exist in military populations, based on the large-cohort, large-cross section*

data that serve as foundation for this study. These uneven patterns represent massive opportunities for DoD and VA health professionals and policymakers to lead in the area of suicide research, prevention, and response. Very significantly, some of these uneven patterns of distribution actually show evidence of regional areas of suicide "clusters," in which multiple counties seem to be alerting to dramatically increased need for suicide intervention and "post-vention." This is not simply a normative conclusion; this area represents positive findings for geographic locales in which suicide intervention efforts can align to clusters of areas of demonstrably higher rate of suicide, and where policymakers can make a huge difference.

B. STRUCTURE OF THESIS REPORT

The following sections of this report identify factors relevant to the geographic distribution of suicide. Section II discusses relevant civilian suicide reporting through the U.S. Centers for Disease Control (CDC) statistics and graphics for fatal injury mortality, and military suicide reporting through the suicide reports of the U.S. Veterans Administration (VA) and U.S. Department of Defense (DoD). These resources often report certain circumstances and co-morbidities of suicide, but neglect to identify the geographic distribution of suicide below the national- or state-level. Section III discusses the data and quantitative methods used by this study to help identify the geographic distribution of U.S. Military and Civilian suicides. Section IV provides findings and results of the quantitative analysis of the geographic distribution of U.S. suicides. Section V provides conclusions and recommendations for future research and tailored suicide prevention efforts with respect to incorporation of concepts related to the geographic distribution of U.S. Military and Civilian suicide mortality.

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II. BACKGROUND AND LITERATURE REVIEW

Reporting of mortality factors associated with Military and Civilian suicide influences important areas of public health research and policy. In fact, the stated goal of the CDC's Web-based Injury Statistic Query And Reporting System (WISQARS) is to provide relevant information on all forms of premature mortality to public health professionals, researchers, and the public (U.S. Centers for Disease Control, 2018). These resources can be used to inform and focus Department of Defense (DoD) suicide prevention efforts.

A. NEED FOR IMPROVED U.S. AGENCY SUICIDE REPORTING

National suicide reporting efforts in the United States are woefully inadequate to the task of providing information that is directly useful to policymakers and leaders, who control resources for suicide prevention and response. Current suicide reporting in the U.S., both from military and civilian agencies, essentially publishes descriptive statistics and trends based on aggregated detail subcategories. Each of these observations represents an event that has already taken place. The trends identified often provide little context for leaders to be able to gauge the relative problem at sub-levels within their organization that can provide prospective intervention tailored to specific needs areas. This is especially true for intervention efforts tailored to organizational levels below national-level and state-level initiatives across large organizations.

While this approach provides a reassuring sense to stakeholders that agencies are tracking the phenomenon, it does not aid efforts in helping a person in crisis (or someone who is trying to help that person). National prevention efforts, including those of the U.S. Department of Defense (DoD), can improve suicide prevention efforts by utilizing reporting techniques that employ advanced statistical analysis and mapping to inform prospective prevention policy decisions.

1. Importance: Suicide Loss and Military Professionalism

From the perspective of the military, the impact of a suicide within its ranks cannot be overstated. In addition to the personal, familial, and social pain that a suicide causes, a military suicide erodes the perception of the military in the minds of the civilian public and their representatives; namely, those citizens whom the military proposes to defend. There is a substantial and direct cost to the United States and its People each time a Servicemember takes his or her own life.

A military suicide is a Sentinel Event, one that carries required reporting to the highest levels of military leadership—including offices at the Pentagon—within 59 minutes of notification of the event. The reasons for this may require some elaboration for those unfamiliar with military affairs. Samuel P. Huntington, in his seminal 1957 work, *The Soldier and the State*¸ compellingly made the case that officers of the American military deserves the recognition due its status as a profession (Huntington, 1956). There, he posited that members of the U.S. military belong to the "profession of arms." Using Harold Lasswell's (one of America's greatest social scientists, nonetheless) definition, Huntington identified "the management of violence" as the military officer profession's key attribute (p.11).

Thus, when it comes to instances of suicide in the military, the destabilizing effect becomes clear. The *undisciplined* use of violence by a Servicemember against himself or herself trebly violates the code of military professionalism. First, it exemplifies an *improper use of violence*, the key attribute of the military, over which it must maintain a sober and disciplined monopoly. Second, the *loss of the service due to society* from the Servicemember itself represents a violation of the code. Third, it denotes *loss of unit effectiveness* caused by the losses to a variety of tangible and intangible unit resources (not the least of which is unit cohesiveness and *esprit de corps*), independent of those losses represented directly by the fallen member. A case of suicide in the military comes with extreme pain and cost to many individuals; it also erodes public faith in military professionalism. Thus, military suicides taken together represent an internal and external threat to confidence in the U.S. Military profession; and, by extension, to National Security.

In this light, the importance of understanding how the military deals with its suicides becomes very apparent. How does the military report its suicides, and what are the rates with which it happens? Are major geographic differences indicated, which can guide prevention efforts and prevent deeply impactful event such as suicides over time? This information can be impactful to policymakers and planners of prevention efforts both for military and civilian deaths due to suicide.

2. DoD Suicide Prevention Efforts

Suicide prevention in the DoD is a patchwork-quilt of cross-referencing websites, prevention offices, contact numbers, and links to multi-media materials. A variety of offices provide sincere efforts in making a trained professional available to help someone in crisis on a round-the-clock basis, or to help someone trying to help the individual in crisis. Generally, this prevention method is the most time-intensive on the part of the intervener, providing an anonymous crisis-line for someone in crisis to call, or in contemporary times to text or chat. A major shortfall of this prevention approach is that it many people in crisis, or those who are trying to help someone in crisis, do not call. They do not reach out. In many cases known to the author, they seek isolation before and during the event. While there is no question that these prevention resources are important components of an overall prevention strategy for the DoD, this thesis seeks to provide additional information for prospective prevention and intervention efforts.

Individual treatment facilities, including Military Treatment Facilities (MTFs), have detailed procedures with regard to suicide referral, screening, and treatment. Having personally administered portions of these treatment algorithms, the author acknowledges that localized facility suicide referral and treatment procedures represent a sincere and unwavering effort from DoD military healthcare professionals, literally spanning the globe. These efforts often catch suicidal ideations and indications, and refer at-risk individuals to treatment. Unfortunately, all too often the suicide *response* mode of these procedures activate, with no prior notice of an individual being in crisis.

Between the national-level and healthcare facility/network area efforts, there exist tens of thousands of people in crisis at any given time. The question is: what can be done to engage those who are not likely to call the suicide prevention lines or directly seek treatment, but who also are not identified by their social and military network as a suicide risk/referral? An empirically-driven study of "where" suicides are happening can help focus DoD suicide research and prevention efforts, which have generally tended to focus on the event demographics ("who"), individual co-morbidities ("what"), year/month/day-of-week ("when"), and method ("how"), as well as the psychosocial/physiological/socio-economic factors ("why") that the academic literature tends to emphasize. A targeted, population-centered approach to suicide prevention provides a better course of action for future healthcare and organizational leadership.

B. UNITED STATES DEPARTMENT OF DEFENSE (DOD) REPORTING

1. DoD Suicide Reporting, 2008-Present

Since 2008, the U.S. Department of Defense has issued detailed reports on suicide within its ranks using the annual Department of Defense Suicide Event Report (U.S. Department of Defense [DoD], 2018). Each DoDSER is the result of a collective effort of researchers at the National Center for Telehealth & Technology (T2), part of the Defense Centers of Excellence for Psychological Health & Traumatic Brain Injury. Over time, the form and content of the individual DoDSER reports have evolved, providing a growing array of information about suicide, while using changing metrics and associations. Table 1 summarizes the DoDSER reporting, extrapolating information from each DoDSER in one centralized graphic.

Table 1. Summary of U.S. military components, in raw counts and rates per 100,000 person-years. Compiled from DoDSER Reports, 2008–2016.

CY	Suicides Active Duty (AD)	Suicide Rate AD	Suicides Reserves	Suicide Rate Reserves	Suicides National Guard (NG)	Suicide Rate (NG)	Attempts Reported (AFMES)
2015	266	20.2	90	24.7	123	27.1	1199
2014	276	20.4	179	-	91	-	1126
2013	259	18.7	222	23.4	134[a]	28.9	1034
2012	321[a]	22.7	203	19.3	132[a]	28.1	841
2011	301	18.03	-	-	-	-	915
2010	295	17.52	-	-	-	-	863[b]
2009	309	18.5	-	-	-	-	502[c]
2008	268	16.1	-	-	-	-	570[c]

[a] Data updated utilizing Defense Suicide Prevention Office 2016 Quarterly Suicide Report. Previous DoDSER reports show 319 Active Duty Suicide Deaths for 2012.

[b] Attempted Suicides for 2010 extrapolated from DoDSER data using algebraic method.

[c] 2008 and 2009 DoDSER reporting reports Attempted Suicides for U.S. Army only.

In addition to the data points consolidated into Table 1, the hyphens denote the intersection of times and groups in which suicide data is neither directly available, nor are values able to be extrapolated from related information. Where possible, the author interpolated missing data intersections, compiling information from other DoD reports or using an algebraic method for extrapolation from related data.

During this period, DoDSER reporting shows Active Duty suicides reached an apex in 2012, representing a rate exceeding 22 per 100,000 Person-Years. 2012 was also the first year in which enough data is available across the DoDSERs to include rates for Reserve Component (Reserves) suicides, as well as for the National Guard Branches (National Guard). Direct reporting of suicide attempts within the Active Duty DoD began in 2011, with values for 2010 calculated for this study using algebraic method. For 2008 and 2009, suicide attempts are available for U.S. Army Active Duty only. Utilizing what data is available, and making comparison of within-population rates only, it appears that U.S.

Active Duty suicides peaked in 2012, while suicide attempts (or reporting of attempts) continues to grow significantly and steadily. For Reserves, the very limited data contained across DoDSER years shows a consistent rate increase, despite general trends of military downsizing and receding deployment levels.

2. DoDSER Strength: Consistent Input

These reports represent intensive efforts on behalf of the healthcare statistics reporting community within the DoD. Additionally, they illustrate the evolving nature with which DoDSER reporting utilizes statistics, categories, rates, and associations in suicide reporting. Input for DoDSER suicide event counts and rates consists of the case information entered by credentialed Medical Examiners and associated staff into the Armed Forces Medical Examiner System (AFMES), providing consistent and professionally-trained input into the system. Perhaps the greatest strength of this system is that it is professionally staffed, worldwide, clearly defined, and consistent in its input forms and terminology. Additionally, it is non-branch specific, providing consistent reporting across military branches, components, communities, *etc*.

3. DoDSER Weakness: Inconsistent Reporting

As its evolving nature indicates, DoDSER reporting has several weaknesses. First, it is sometimes inconsistent, providing new trends, denominations, subcategories, *etc*., with each iteration. Second, past examples of the DoDSER indicate that the reporting is incomplete, adding new reporting dimensions as it progresses. For example, raw counts of National Guard suicides are available in only the two most recent DoDSERs, those of CY2014 and CY2015.

This presents two policy problems from the prevention and intervention-minded leader. First, it leaves out vital information from years before 2014, during which military deployments of the National Guard were far more widespread and impactful. Second, this knowledge gap could lead to leaders looking to outside sources for suicide prevention data, steering them away from the consistency in medical training that goes into the DoDSER library. It is possible that someone in this predicament will resort to dubious sources of

information, or that they might make their managerial decisions without reliable information at all.

In addition to the above issues, DoDSER statistics and information report primarily on raw counts and trends of subcategories based on information entered into AFMES. This is a worldwide system, providing mortality-related statistics for the DoD. These categories adequately describe information recorded into the system as well as the DoD-appointed Medical Examiner's opinion of the cases. Nevertheless, these statistics, or the systems that reproduce them as healthcare outcomes, represent only aggregated raw counts by category and subcategory. Such data provide little usable information to Commanders, prevention specialists, and healthcare professionals, aside from retrospective information and aggregated personal details. In other words, information on military suicides may be very well organized *going into* the system, but often the information *coming out of the system* is noisy or incomplete. One large-scale example of this issue will be discussed in detail in Chapter III of this report.

4. DoDSER Opportunities

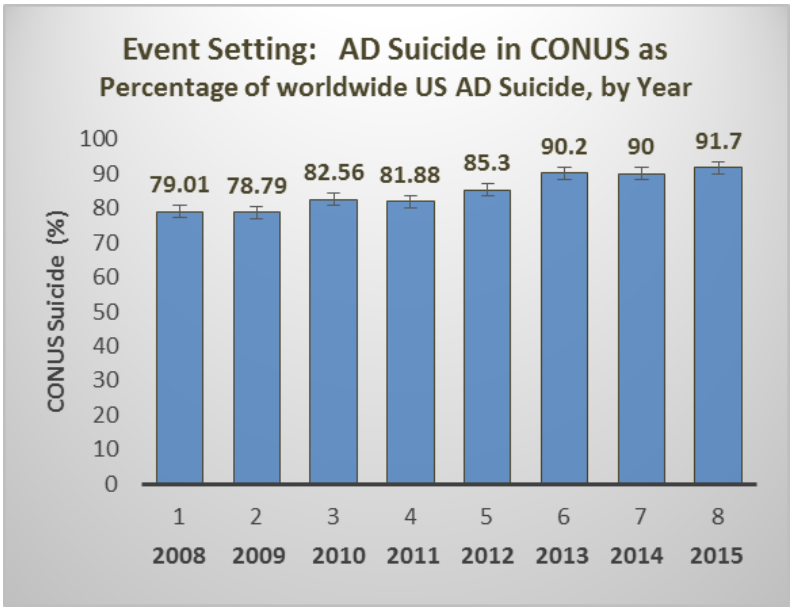
Because of both its strengths and weaknesses, future DoDSER releases represent an evolving opportunity for the DoD Suicide research and prevention community to get the most out of its very capable DoDSER/AFMES system. It is likely that, at times, the community is barely scratching the surface of the useful information contained in their system, let alone providing advanced statistical analytics. This is true both in terms of the opportunity for advanced statistical tools, but also for identification of viable information (variables) for prevention/intervention efforts, such as the geographic distribution of suicide mortality.

In order to become useful information, the DoD Suicide statistics reporting board(s) should consider using a statistical analysis approach to control for changing demographics, unit and localized community effects, peer effects, geolocation, rank and seniority, rate and subspecialty, location and method of event, *etc*. One example of this follows in Chapter IV of this thesis. A standard methodology may be useful for the analysis of suicide statistics, to complement the efforts embodied by the DoDSER process. This will complete the

information cycle and complement the standard Medical Examiner and Decedent Affairs methodology in the clinical environment, which processes the individual cases. Ultimately, this will provide a complete, consistent, and timely dataset to DoD leadership tasked with preventing suicide in the ranks.

5. Active Duty Suicide Reporting Conclusions

One important factor in all of the DoDSER reports to date is the need for observers to account for, and properly weight, the impact of the worldwide catchment area for the DoDSER reporting. This varies greatly from other government agencies, which report on CONUS suicide almost exclusively. The sheer percentage of suicides occurring overseas has changed significantly over the years that the DoDSERs program has been in effect. Figure 1 depicts the percentage of U.S. Active Duty suicides occurring in the Continental United States (CONUS), with the remainder representing DoD overseas suicide mortality, and has been compiled from information contained deep within each yearly DoDSER report.



Source: Data compiled by author for this Figure from individual 2008–2015 DoDSER reports.

Figure 1. Percentage of active duty suicides reported in the continental United States (CONUS) by Armed Forces Medical Examiner System (AFMES), 2008–2015.

Clearly, the there is a strong upward trend in the percentage of yearly U.S. Active Duty suicides occurring in CONUS, while the percentage of U.S. DoD suicides occurring overseas has correspondingly decreased. This directly and dramatically correlates with the general direction of movement of DoD personnel, as well as force-shaping movements during the relevant years.

Thus, large-scale trends in troop movements, downsizing, budget considerations (including ongoing Continuing Resolutions during this time period), all have a significant trend effect (bias) on the military suicide rate through the amount of troops in OCONUS during any given month or year. The Troop drawdown overseas, namely in Iraq and Afghanistan, is clearly visible here, while shrinking U.S. military populations and rotation to the Asia-Pacific region are also a potential hidden (omitted) variable. This serves as evidence that indicates the "where" that suicides are happening contains important information and reflections of large-scale trends in the larger population of interest.

Based on a detailed inspection, the current state of DoD Active Duty suicide reporting is inadequate or incomplete to providing sufficient data for the needs of targeted, relevant suicide prevention for this cohort. Improved suicide mortality reporting and analysis, especially containing information using geoinformatic data, could lead directly and affordably to improved suicide prevention measures that are responsive to Active Duty Servicemember demands.

C. UNITED STATES DEPARTMENT OF VETERANS AFFAIRS (VA) REPORTING

1. VA Suicide Reporting, 2001–2014

In 2016, the U.S. Department of Veterans Affairs released "Suicide Among Veterans and Other Americans, 2001–2014," an effort to provide the most comprehensive suicide analysis on U.S. Veterans to date (U.S. Department of Veterans Affairs, Veterans Health Administration [VHA], 2016). Published by the Veterans Health Agency (VHA), Office for Suicide Prevention, the report analyses data from more than 50 million veteran records, including users and non-users of VHA services. Correcting numerous media reports in recent years that 22 Veterans commit suicide each day, this study definitively

establishes the often-discussed average number of daily Veteran deaths in 2014 to 20 each day, and identifies suicide prevention as a top priority for the Veterans Administration and the VHA.

2. VA Suicide Reporting Strengths

The VA's premier report on suicide within the U.S. Veteran population advances healthcare research and reporting, based on a very large national cohort. It first provides descriptive statistics along defined response variables within its health record system, providing insight into the suicide rate among Veterans, primarily those Veterans who utilize the VHA for medical services. Of the 20 Veterans per day who commit suicide in the United states, the VA report estimates 6 were recent VHA users during 2013 or 2014, while the remainder had not used VHA services in the 2 most recent years, or were not enrolled in the VHA at all (VHA, 2016).

Additional visualizations and statistics from the VHA report follow. They are included at length in this thesis report to visually illustrate the strengths are weakness of VA suicide reporting. The 2016 VHA report states the following major findings:

1) Veterans constituted for 18 percent of all U.S. deaths by suicide in 2014 while accounting for 8.5 percent of the U.S. Adult population in 2014;
2) the risk for suicide was 22 percent higher among Veterans compared with U.S. civilian adults, after adjusting for differences in age and sex; and,
3) the risk for suicide was 2.5 times higher among female Veterans compared with U.S. civilian adult women, after adjusting for differences in age (VHA, 2016, p. 4).

For suicides within their enrolled-Veteran population, the authors of the VHA study also find that rates of suicide are highest among younger Veterans (ages 18–29) and lowest among older Veterans (ages 60 and older)(VHA, 2016), confirming the general consensus among researchers that suicide is highly age-related, given that cohort members have each survived given age groups. In other words, the VA Study confirms a customary attribute of the study of suicide, that age controls are appropriate in a variety of settings.

Table 2. Table 2 provides important information with respect to separate age- and sex-adjusted suicide rates for OEF/OIF/OND-deployed Active Duty and Reserve Veterans in its system. Source: VHA (2016, Table 6).

	2007	2008	2009	2010	2011	2012	2013	2014
Active Duty	35.0	43.0	36.2	35.4	48.6	49.2	54.9	54.9
Reserve	25.6	25.8	29.1	24.3	40.9	39.4	43.2	35.6

Active duty veterans of Operation Enduring Freedom, Operation Iraqi Freedom, and Operation New Dawn, when taken together as a class, exhibit a suicide rate that is significantly higher than the same rate for Veterans of the Reserves military components. From the wording of the VA Study, it appears that the Active Duty rates presented in Table 2 represent operational Veterans, whereas Reserve rates do not necessarily reflect whether the Reserve and National Guard Veteran deployed in support of these operations. Thus, it is unclear what proportion of the Reserve group are Veterans of the indicated operations or other military deployments.

It is also unclear if these rates are representative of suicide rates for Reservists in general since many Reservists (and Active Duty Servicemembers as well) do not obtain higher-levels of VHA eligibility unless they receive combat-related injury or service-connected disability ratings. The VA study finds that "compared with rates of suicide among Veterans of the National Guard or Reserve components, rates of suicide were higher among OEF/OIF/OND active duty Veterans" (p. 20). This juxtaposition provides a compelling contrast between the suicide rates amongst some groups of Veterans vis-à-vis others. It especially highlights the differences and diversity in the Veterans groups that the VA serves, especially in the fields of mental health and suicide prevention. However, applicability of this visualization to suicide prevention and actionable reporting of suicide mortality rates, beyond relative rates amongst cohorts and trend analysis, is constrained by its treatment of the data.

3. VA Suicide Reporting Weaknesses

The VA study's key findings indicate the orientation of their analysis; namely, they provide descriptive statistics of those veterans who committed suicide, organized by

background characteristics. These statistics present rates per 100,000 person-years and Standard Mortality Ratios (SMRs) (VHA, p. 5). Figure 2 provides a graphical illustration of this approach.

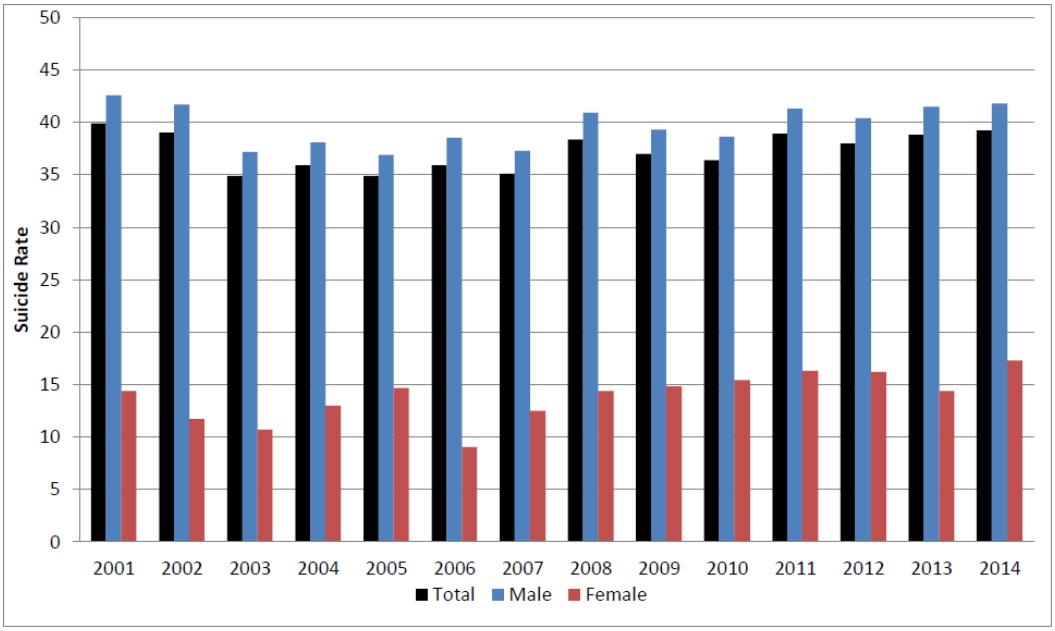


Figure 2. Suicide rates of VHA users by sex per 100,000 person-years, calendar years 2001–2014. Source: VHA (2016, Figure 8).

The VA study organizes much of its analysis by juxtaposition of suicide rates of Veterans by method of mortal injury, year, sex, age group, and enrollment status. The approach embodied by Figure 2 adequately portrays differences in Veteran suicides by sex, but provides very little other context with regard to suicide prevention.

Figure 3 continues this trend by showing a the comparison between male and female Veteran groups' suicide rates as an expression of Standardized Mortality Ratio, another commonly accepted practice in public health statistics reporting. Here, we see both groups' relative trends with regard to the mortality rate of the general U.S. population.

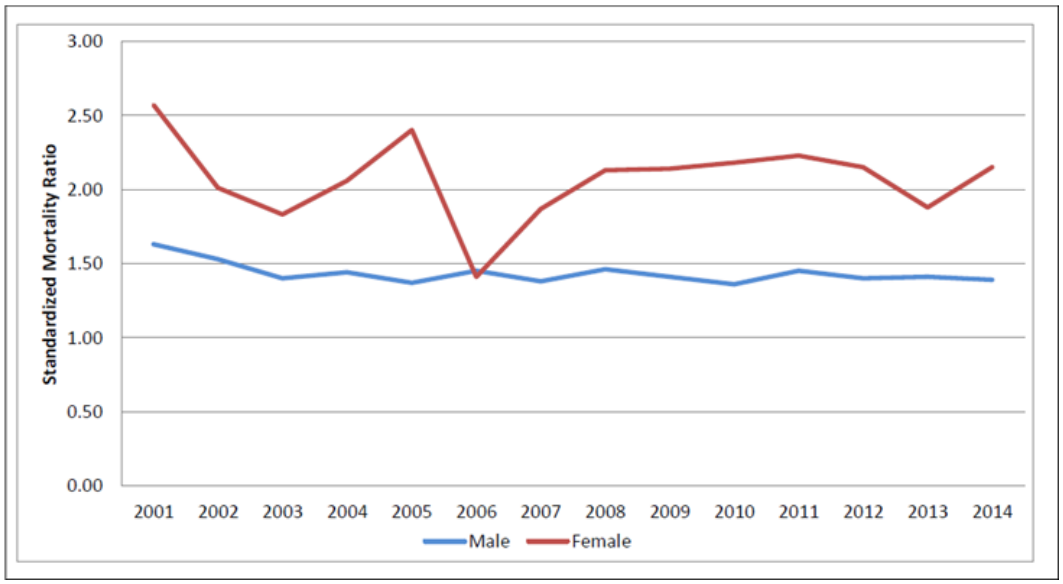


Figure 3. Standard mortality ratios for female and male veterans, 2001–2014, based on VHA system enrollees.
Source: VHA (2016, Figure 9).

An interesting facet of this study identifies the "major finding" of this portion of the VA, saying "compared with the U.S. general population, risk for suicide among users of VHA services has decreased since 2001 among both men and women." (18) While small changes in SMR values on an absolute basis do indicate large changes on a percentage or logarithmic basis, this claim apparently pays attention to only the beginning and ending points of each curve, ignoring the large amounts of variation in between. Additionally, their assessment of "risk" is questionable, if risk denotes more than a cursory term. This finding is questionable, and further underscores the need for more detailed statistical analysis in suicide reporting at the national-agency level.

4. VA Suicide Reporting Opportunities

In perhaps its most elucidating treatment, the VA study provides some analysis of the relationship between completed suicides and patient prior medical history within the VA Suicide Prevention Application Network (SPAN). Using data gathered from patient histories, important findings are also summarized by in figures 4–6, based on data from years, 2001–2014, unless otherwise noted:

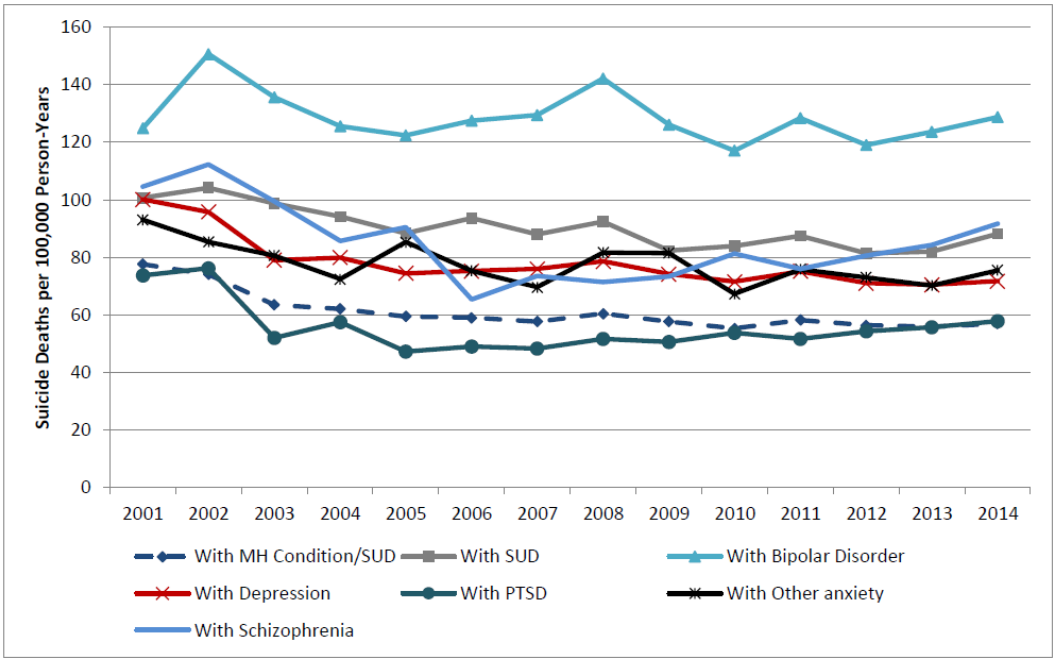


Figure 4. Suicide rate per 100,000 person-years for VHA users who received a prior mental health (MH) or substance use disorder (SUD) diagnosis, by condition, calendar years 2001–2014.
Source: VHA (2016, Figure 3).

This approach reveals a very powerful tool at the VHA's disposal for the reporting and prevention of suicide: the ability to track and provide data on suicide co-morbidities, co-variates, and prior patient medical histories that may correlate with healthcare outcomes. Curiously, the VA study concludes this section of its analysis with the "main finding" that "compared to 2001, rates of suicide have decreased among VHA patients diagnosed with a mental health condition or a Substance Use Disorder (SUD)." This statement seems to ignore macro-trends that are clearly identifiable in the visualization of the data (Figure 4). One of these is that the combined Mental Health/SUD curve drops dramatically from the start of the reported data to around 2005, and then appears to have a moderate but consistent upward trend through the end of the reporting period. The variation and subcategories represented by this visualization indicate rich data and analysis opportunities inherent to this data, which could enhance future reporting and intervention opportunities. The approach embodied by this analysis and others like it in the VA study illustrates a huge opportunity for suicide prevention and reporting, in terms of being one

of the few known agency studies that has reported with relative detail on underlying co-morbidities of suicide.

Figure 5 illustrates this concept in detail. Here, the suicide rate per 100,000 Person-Years illustrates an extremely elevated incidence for the class of patients that had received an Opioid Use Disorder diagnosis during calendar years 2001–2014.

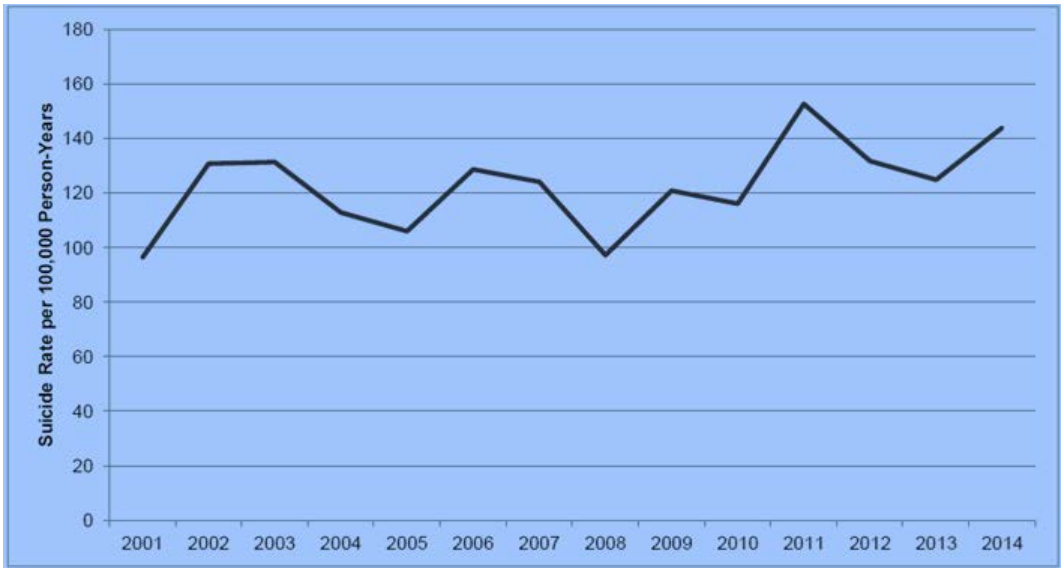
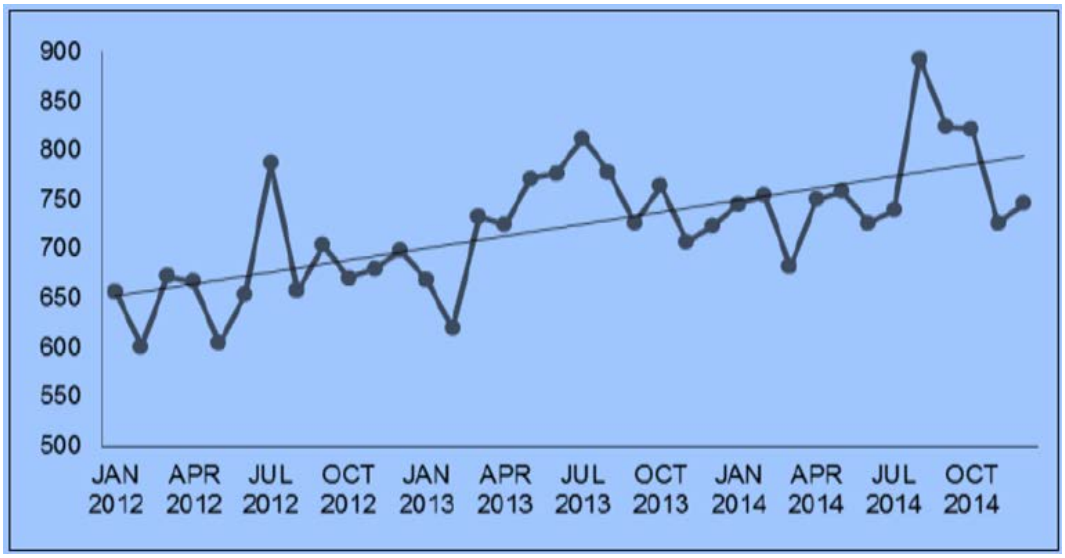


Figure 5. Suicide rate per 100,000 person-years for VHA users who received an opioid use disorder diagnosis, calendar years 2001–2014. Source: VHA (2016, Figure 4).

This visualization of the study data shows a strong overall increase in the national-level suicide rate among veterans who are opioid dependent, or at a minimum, those identified with unauthorized or inappropriate opioid use. Here, the VA study's "main finding" indicates that "Rates of suicide were elevated among VHA patients diagnosed with an Opioid Use Disorder (OUD) and have increased since 2001." It is also worth noting that, according to the VA reporting, the suicide rate for this subset of their patients is more than nine times the national rate for each of the years of the study, irrespective of variation in either rate.

Figure 6 also illustrates an opportunity for future reporting of suicide mortality to inform prevention efforts and policymaking. Here, the VA study describes a noticeable seasonal pattern of suicide rates for its population.



Note the pronounced seasonal pattern, reaching monthly maximums around July of each Calendar year.

Figure 6. Suicide attempts reported the VA's suicide prevention (SNAP) network, by month 2012–2014. Source: VHA (2016, Figure 5).

Here, there appears to be a strong downward trend and seasonal minimum between January and April of each of the relevant years. This trend accompanies a strong seasonal trend with annual maximum between June and September of each year. This data is very promising, both in terms of prevention importance for the VA population, as well as for analysis if this pattern follows for other cohorts and prevention opportunities. It is worth noting here that according to DoDSER reporting, the same seasonal trends do not follow for members currently serving on Active Duty. Access to this data (as well as to rich Active Duty Servicemember suicide data) would help researchers confirm both patterns, and analyze if seasonality is indeed signification to both groups individually and jointly.

5. VA Suicide Reporting Conclusions

VHA suicide reporting, as evidenced by the long-term, large-cohort 2016 "VA Report on Suicide among Veterans and Other Americans" represents a major advance in government agency reporting on suicide mortality in that it clearly presents evidence of the co-variates and co-morbidities of suicide among U.S. Veteran populations, including separate visualizations of suicide rates among important sub-populations of veterans. Particularly promising in the VA data are prevention-oriented reporting of factors associated with suicide mortality such as seasonal associations, mental health histories, and substance abuse co-morbidities. These efforts represent a real advance for government agency reporting, which rarely reports on co-morbidities/co-variates, instead choosing to focus on categories of background attributes and trend reporting.

However, that no controls for geographic variation, socio-economic functions, or access to care are included in the analysis means that 1) any conclusions drawn from inadequately localized statistics are of questionable prevention value, and 2) omitted variables and self-selection are sure to have biased the isolated informational value that these types of statistics provide. The value of data reported in this manner is generally that of an efficient depiction of past events and natural variation among a large cohort, by the organization that tracks it. However, these types of statistics are so general as to be mostly irrelevant from the perspective of suicide prevention and policy planning in the short- to medium-term.

Based on a detailed inspection, the current state of VA suicide reporting is assessed to be inadequate or incomplete to providing sufficient data for the needs of targeted, relevant suicide prevention for relevant cohorts. Improved suicide mortality reporting and analysis could lead directly and affordably to improved suicide prevention measures; ones tailored to Veteran demands, as well as improved criteria for generalizability to the public.

D. CDC DATA REPORTING AND MAPPING

The U.S. Centers for Disease Control is one of the leading providers of public health data in the world. Its Center for Injury Control and Prevention operates the CDC Web-Based Injury Query and Statistics Reporting System (WISQARS), which provides

fatal and non-fatal injury data and visualizations for a variety of health conditions and injury. Data from this system will be discussed at length in Chapter III of this study and forms the basis for some of the analysis and conclusions in Chapters IV and V of this study as well.

E. RELEVANT ACADEMIC LITERATURE REVIEW

Studies dealing with the county-level aggregated geographic distribution of suicides are uncommon, especially ones that analyze large, national cohorts consistently across local or county levels. Like DoD and VA reporting, much of the academic literature on suicide tends to relate new understanding of suicide mortality along vectors that can be categorized as describing the "who," "what," "when," and "why" of suicide. These studies are myriad and prolific, often attempting to describe suicide mortality according to a specific causality, associated with a particular environmental, economic, social/political/religious, or pathology-related model. Since this study attempts to explore and identify the geographic distribution of suicide and relevant co-variates based on quantitatively sound, evidence-based analysis, the most relevant studies appear in the following subsections. From the standpoint of this thesis, a multitude of heuristic and analytical functions influence the overall phenomena of suicide and suicide mortality, but the overall goal is information that is relevant to suicide prevention efforts in U.S. military and civilian populations at the sub-national and sub-state level.

1. Urbanization and Suicide Rates

Kegler, Stone, and Holland look at suicide rates by urbanization in "Trends in Suicide by Level of Urbanization—United States, 1999–2015" (2017). There, the authors analyze suicide rates by trend, with respect to varying levels of urbanization. Utilizing International Classification of Diseases (ICD) data to define disease conditions along with annual county mortality data from the National Vital Statistics System, they construct a six-level classification system of urbanization. Kegler et al. utilize data from the Center for Disease Control (CDC) WONDER database, which tracks national suicide rates, in their model. This is significant in that the CDC generally reports smoothed rates and suppresses

data values for counties with ≤ 20 reported suicide deaths, regardless of the time-period or geographic subdivision setting chosen, which it states is "unstable data."

To evaluate the rate trends for the period of 1999 to 2015 Kegler et al. use joinpoint regression to apply time-series data oriented to levels of urbanization (2017). The suicide rates indicated by the regression demonstrate that suicide rates increase overall during the time period, and more-urban areas are associated with higher rate increases as compared to less-urban areas, both findings they assessed to be statistically significant. They conduct further research and analysis using demographic variables (e.g., sex, age, race, method of suicide), which are pertinent to traditional reporting of suicide mortality and outside the scope of this study.

The Kegler et al. study reported two significant limitations: the exclusion of data for missing ethnicity and "counties were considered to embody the same level of urbanization throughout the 1999–2015 study period." With this limitation, in conjunction with utilizing the smoothed rates provided by the CDC, these techniques could lead to tautological results. The study does recognize the need for the study of suicide along consistent geographical boundaries at a localized level, but exclusion and smoothing of vast amounts of their data, especially variation from a group of counties/urbanizations that would contribute to the null hypothesis, leads to the need for a better model.

2. Suicide Mapping

Middleton, Sterne, and Gunnell investigate the geographic distribution of suicide as it relates to men aged 15–44 in England and Wales (2006). Built upon previous research indicating that local geographic levels may be significant to suicide rates, the study looks at the spatial patterning of suicides at the ward level (small area). They posit that the estimates produced by previous studies on certain districts and parliamentary constituencies produce unreliable results due the geographic subdivisions chosen and to the use of standardized mortality ratios (SMR). The intent of the research is to find associations or patterns of suicidal behaviors and adopt public policies that may possibly deter or prevent suicide attempts. That is, if areas with higher concentrations of suicides

can be identified, then specific contributing factors for that concentration can be analyzed and lead to preventive measures.

Like the previous study, researchers utilize ICD codes to geocode suicide-event information using the decedent's last known address. Deaths considered to unresolved cases as to principal cause of death are included in the number of suicides in each geographical area since, the authors claim, this coding decision is in keeping with previous analysis (2006, p. 1040). The authors state, consistent with studies conducted in the United States time-series data from 1988 to 1994 (15,821 total suicides in men aged 15–44), that wards with the mean population of 1,221 receive a large, statistically significant distribution of the suicide mortality. The authors apply a Random-effects Poisson regression model to smoothed maps of suicide rates. While common to many studies of healthcare outcomes, smoothing techniques are significant in that they produce an underestimation of variation in both the "donor" and "recipient" districts where data is missing, suppressed, or underreported. Additionally, if other biases exist in the data, the effects of smoothing can also perpetuate false estimates that are material to the research question. Middleton et al. indicate that this modeling allowed for "neighboring areas to have similar rate." (2006, p. 1041) These similar rates, the authors state, were based upon "smoothed rate ratios in each area " and "were calculated as a weighted average of the observed area rate ratio, the global mean rate ratio, and the rate ratio in neighboring areas (understood here to be those areas sharing a border), with weights based on estimated levels of global and local variability."

Often, estimates of rate variation are required to assist in analysis, and this study appears to recognize the need for this as well as the use of mapping techniques and modeling to inform suicide prevention. However, the study also appears to use smoothed rates in all of its imputations, which is logically unsound for two reasons. First, for the same reason as in the previous study, smoothed rates are an estimation in themselves, and are inadequate to mapping in that they "pay" variation from certain subdivisions to others, systematically biasing both. Utilizing better multiple imputation techniques and unsmoothed data would provide a best estimate for missing subdivisions without robbing variation from the subdivisions with values. Secondly, smoothed rates themselves are

disruptive to the authors' primary research question, which is essentially to use geographically "sharp" values to identify important areas for suicide prevention.

The data issues identified above notwithstanding, results that are relevant to the model of the current study include the authors' findings that significant differences exist in suicides as they relate to geography. However, in a footnote, Middleton et al. indicate that "no deaths were recorded in 3,149 wards (34% of all areas)," which indicates that the data is mapped as unsmoothed SMRs (2006, p. 1043). As indicated by issues discussed between U.S. CDC data mapping based on raw and smoothed rates in Chapter IV of this thesis, the raw data in the Middleton et al. study did not provide them with clear evidence of geospatial disparities in suicide rate. To make significant conclusions, Middleton et al. utilize smoothed data account for global and local variability. To them, this provides clear evidence of spatial patterning of suicides, despite relying on smoothed data to share variation between at least 34% of their data by geographic subdivisions. In reality, if 34% percent of subdivisions are missing data, a rule-of-thumb estimate on how many counties "donate" variation would be two-times the number of counties (as a rough minimum estimate), reaching as much as the square of the number of missing counties (as a rough maximum estimate).

3. The "Altitude Effect"

Brenner, Cheng, Clark, and Camargo hypothesize that counties in the United States situated at higher elevations have higher suicide rates due to atmospheric effects (hypoxia) in their research article "Positive Association between Altitude and Suicide in 2,584 U.S. Counties" (2011). The study's authors motivate their article by stating that self-inflicted injuries that result in suicide deaths are a public health issue that needs to be understood and curtailed. As the title of their article suggests, they look at the geography of suicides as it relates to three distinct altitude levels. Building off of the findings of studies by Roth et al. (2002), which find an association between altitude and the enhancement of psychiatric disorders, Brenner et al. seek to evaluate whether there is an "independent relationship between altitude and suicide" (2011, p. 31).

Data for Brenner et al. was collected over a period of 20 years (1979 to 1998) from county mortality statistics utilizing the ICD-9 codes associated with self-inflicted injuries resulting in suicide deaths (2011). As with the previously discussed studies, the data set for Brenner et al. use a large amount of data observations (596,704) over 2,584 U.S. counties. In keeping with previous study methods, suicide rates for counties that reported ≤ 20 suicides ($n = 484$ of 3,068; 15.8%) are considered to have unreliable data and are excluded from the primary analysis. Of note, the threshold for "unstable" and "suppressed" suicide counts as ≤ 20 corresponds, as in other studies, corresponds to the definition provided by the U.S. Centers for Disease Control (CDC). Multivariate regression and logistic models are performed with control variables included as percent of age >50 years, percent male, percent white, median household income, and population density of each county (Brenner *et al.* 2011). Excluding "suppressed" data, the authors find a "strong positive correlation ($r=0.50$, $p<0.001$) between altitude and suicide rate at the county level." (32) Additional research is performed in relation to demographic variables, firearms, and other co-variates. Of note, the study's authors state that a secondary analysis is performed with unreliable data that resulted in a continued positive association between county level suicides and altitude ($r=0.45$, $p<0.001$), but do not discuss if those rates are calculated using smoothed, weighted, or raw data. One reasonable reconciliation of the authors' statements is that their primary (high-significance) model, and therefore their parameter estimates, is based on smoothed data, while their secondary analysis was conducted with raw data with unstable data filled in. Neither of these methods is fully complete, as will be demonstrated in Chapters IV and V of this thesis, such that even when unsmoothed (raw) suicide counts are used with the CDC's dataset, "suppressed" counties still provide data gaps for counties with less than 10 suicide events per subdivision.

This issue results in the lowest-frequency counties being dropped from the raw dataset, often dropping variation from some of the lowest population counties. Significant to the Brenner *et al*. study (and shown in the CDC maps in Chapter IV and ArcGIS outcomes of this study), this would necessarily result in the dropping of numerous counties in the upper Midwest U.S. along with other "plains" counties throughout the United States. Within the study's model, if smoothed rates were used, significant sharing between these

counties would result, significantly pooling their values with other low-altitude counties, on average all else being equal. The same would occur would occur for high-altitude states, magnifying the effect of "altitude." If raw counts were used, as in the secondary analysis, n of the same low-frequency counties would be dropped completely, leading to a similar effect.

This study recognizes the need for county-level suicide statistics, mapping, and other effects and makes a bona fide effort to identify county-level correlates of suicide mortality that would be useful to suicide prevention efforts. Due to its treatment of the data, it most likely contains conclusions based on parameter estimates that are probably overestimated based on data dropped that would strongly contribute to estimates supporting the null hypothesis. Although the authors most likely identify a statistically significant relationship between *counties and suicide*, their attribution that altitude is the controlling factor for rates in these counties is very likely unfounded. Rather, there are almost certainly omitted variables such as isolation, infrastructure, county services and other social support services, health care infrastructure, crime, environmental factors, and related health and lifestyle variables for which "altitude" acts as a proxy in this study.

4. Suicide and Military Population Studies

A few other studies are worth noting for their approaches in estimating parameters associated with suicide and its distribution across various populations. Shen, Cunha, and Williams estimate the time-varying associations between suicide and deployments for current and former military personnel in "Time-Varying Associations of Suicide with Deployments, Mental Health Conditions, and Stressful Life Events Among Current and Former U.S. Military Personnel: A Retrospective Multivariate Analysis," a leading study in military suicide mortality, originally published in the journal *Lancet Psychiatry* (2016). There, they utilize retrospective multivariate analysis to estimate the evolving relationship between military populations and suicide. The authors analyze data on all military members between 2001 and 2011, using Cox proportional hazard model methodology to investigate associations between suicide mortality and factors of deployment, mental health disorders, selected unlawful activity and stressful life transitions and events using the person-quarter

unit of observation (2016, p. 1039). Consistent with the VA in-system findings, Shen et al.'s independent analysis find that the strongest predictors of suicide mortality are "previous incidences of self-inflicted injuries and previously diagnosed mental health disorders" (Shen et al., 2016, p. 1047). Importantly, Shen et al. also find that, all else constant, "...risk of suicide was lower during deployment, increased substantially during the first 7 quarters after deployment, and remained high up to 6 years after deployment" (2016, p. 1047). They find the hazard rate of suicide also increases during the first four quarters (year) from separation from the military, and remains elevated for those who separate for 6 or more years. This study provides important insights regarding the suicide hazard of current and former Servicemembers, including the associated effects of deployment and separation from the military. This study is not motivated by geographic differences in suicide mortality, focusing rather on the time-varying associations that can be analyzed for this population.

Reger et al. (2018) also analyze important associations for military populations using 2002–2007 military population data and 2002–2009 external mortality causes to calculate Standard Mortality Ratios (SMRs) in "Suicides, Homicides, Accidents, and Undetermined Deaths in the U.S. Military: Comparisons to the U.S. Population and by Military Separation Status." There, the authors use negative binomial regression to compare differences in mortality rates before and after separation from military service. The authors find that mortality due to accidents and suicide were highest among members that were under 30 years of age, and that rates exceeded these expected of similar U.S. populations of the same age. Consistent with a vast amount of literature and reporting on military rates, the authors find that suicide rates for their cohort registered below the expected U.S. suicide rate in 2002, but by 2009 had grown dramatically to exceed the U.S. national rate. They find that accident, homicide, and undetermined mortality rates remained below the U.S. rates throughout the study period, and rates associated with all external causes of mortality were significantly higher among separated individuals compared to members currently serving (Reger et al., 2018). Consistent with Shen et al., they find that, although rates of mortality decreased for separated members over longer time periods, the suicide rates remained elevated for those members who remained in uniform. This article

represents important efforts in establishing the relationship between military populations and suicide and other covariates, including other classifications of mortality, including differences before and after separation. While it analyses the data along the aforementioned lines of reasoning, it does not do so with detailed regard to the geographic distribution of suicide rates for either population. Reger et al. reach similar conclusions in their article, "Risk of Suicide Among U.S. Military Service Members Following Operation Enduring Freedom or Operation Iraqi Freedom Deployment and Separation from the U.S. Military," originally published in *JAMA Psychiatry* (2015, separate reference provided). Taken together, the Reger and Shen research groups' studies reveal, among many other insights, that it is very important to take into account recently separated veterans when attempting to measure military suicide rates.

Case and Deaton have two important studies that illustrate the importance of analyzing the associations between suicide and other measures of healthcare outcomes and sources of mortality. In "Suicide, Age, and Wellbeing: an Empirical Investigation" they investigate the relationship between civilian suicides and sex, race and ethnicity, age, differences in nationality and U.S. state residence, time (calendar years and days of the week) as well as measures of individual life evaluation and physical pain (Case & Deaton, 2017a). They find measures of life evaluation and suicide are likely unrelated, while reports of physical pain are strongly predictive of suicide. In light of these findings, they conclude that the question of whether suicide and life evaluation are useful measures of population wellbeing remains unsolved. In "Mortality and Morbidity in the 21st Century," Case and Deaton find that mortality and morbidity both continue to climb from 2000 through 2015. They conclude that increases in drug overdoses, suicides, alcohol-related liver disease—particularly among those with a high school degree or less education—are responsible for an overall increase in all-cause mortality among whites, non-Hispanic Americans (Case & Deaton, 2017b). They find significant differences between white, non-Hispanics (both males and females), that are increasing in disparity by education level. In other words, mortality rates are rising for individuals associated with attainment of a high school or lower level of education, while they are lowering for individuals associated with a college degree or higher levels of education. They find that the data show associations between

mortality and economic variables, and indicate that economic and health-related policies will take many years to reverse increases in observed mortality and morbidity in the United States. They conclude that, despite their dire findings with respect to the relationship between economic and healthcare policy, there are some policy levers available to target improvements in mortality and morbidity trends, including efforts focused on controlling opioid over-prescription, for one example.

The importance of geographic variability has informed recent scholarship into the larger relationship between life expectancy and important economic and demographic correlates of distributed populations. Chetty et al. (2016) study the relationship between factors of income and other economic data, demographics, and public health data as their geographic variation relates to overall life expectancy in "The Association Between Income and Life Expectancy in the United States, 2001–2014." Pertinent to the present study, the authors conclude that geographic differences in life expectancy for lowest-income individuals (by quartile) significantly correlate to other health-related behaviors, e.g., smoking (Chetty et al., 2016). Additionally, the "life expectancy for low-income individuals was positively correlated with the local area fraction of immigrants, . . . fraction of college graduates, . . . and government expenditures" in their data (Chetty et al., 2016, p. 1751). Thus, Chetty et al. conclude that differences in life expectancy (all causes, not just suicide in this case) were correlated with specific health behaviors and local area characteristics (2016, p. 1752). Taken together, these studies provide important and very comprehensive attention on the relationship between suicide mortality, demographic and economic factors, as well as the significances of related health outcomes and sources of mortality. Like the other researchers mentioned in this section, they do not specifically focus on the geographic distribution of suicide.

5. Conclusion

Each of the above studies shows the informative effect that describing the covariates associated with the distribution of suicide can have upon suicide mortality reporting and prevention. Each also uses advanced statistical techniques to do so, further illustrating their potential for U.S. military and civilian agency reporting and prevention policy. While all advanced statistical analysis is ultimately based on data and estimates,

discussion contained in this section identified some potential shortfalls of these approaches. The next sections of this thesis seek to identify the best statistical modeling and estimation techniques to answer the questions: what is the geographic distribution of U.S. military and civilian suicide mortality? Additionally, what co-variates of U.S. suicide mortality can be identified at the sub-national and sub-state level?

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III. DATA AND METHODS

A. DATA SOURCES

This study employs several sources of data from Federal Government agencies, representing U.S. Civilian and Active-Duty suicide mortality and co-variates.

1. Civilian Population Data Sources

The civilian dataset consists of county-level data organized by U.S. Federal Information Processing System (FIPS) code. All FIPS codes contain state- and county-identifying digits such that variables could be matched by county for 3,143 U.S. Counties for the years 2003–2008 and 3,147 U.S. Counties for the years 1999–2015. Geographic boundaries based on the U.S. decennial Census 2000 data apply to assure maximum consistency in data organization. The difference represents four U.S. county geographic consolidations completed before the year 2003, and are thus insignificant to the overall results.

For the civilian multivariate models in this study, the year group 2003–2008 provides maximum congruence across an additional 72 individual variables. The Appendix describes the relevant variables included in the study model. The data set represents 18,882 County-Years (CY), with up to 1,359,504 individual data relationships.

For visualization of the geographic distribution of U.S. Civilian suicides, WISQARS suicide mortality rates are distributed by U.S. county, using 2003–2008 data. This data set provides the maximum available observable data on U.S. county-level suicide rates representing rates covering 53,499 County-Years.

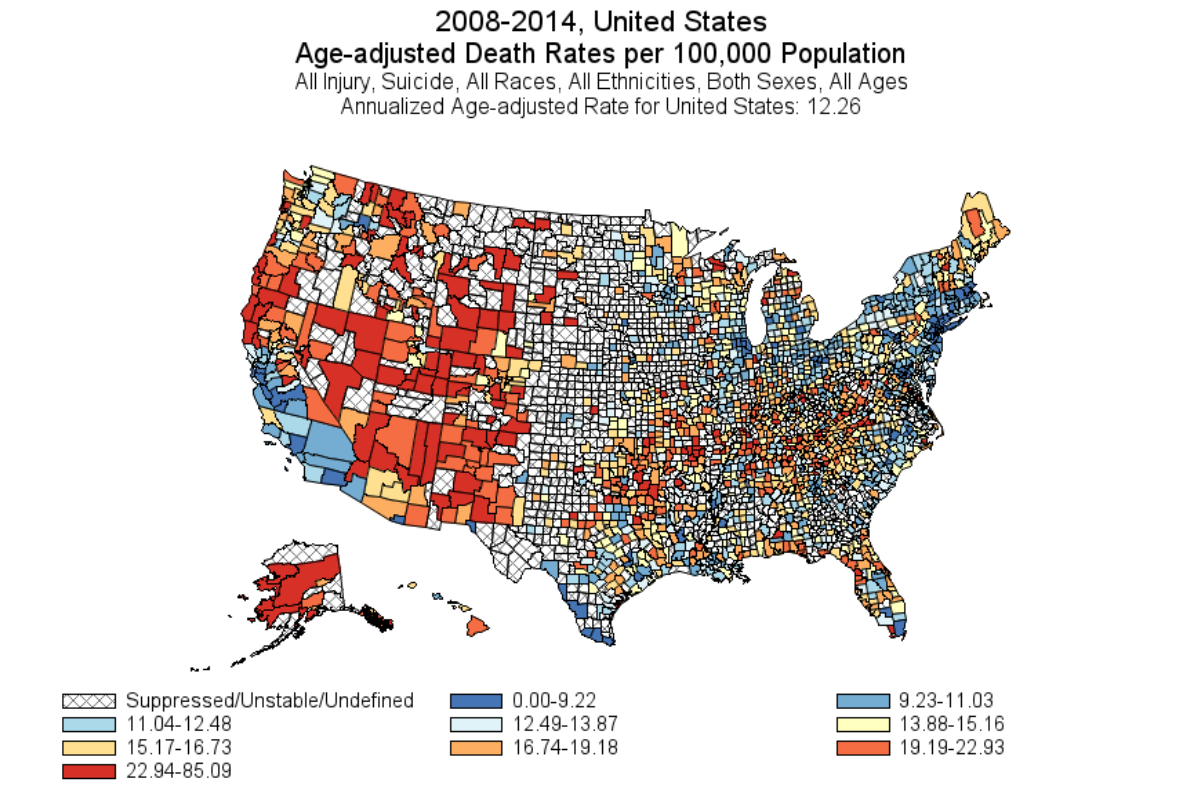
a. CDC Web-Based Injury Statistics and Reporting System (WISQARS)

The primary dataset for U.S. civilian mortality information comes from the U.S. CDC's National Center for Injury Prevention and Control via the Web-based Injury Statistics Query and Reporting System (WISQARS). This system is an interactive, online database that is intended to provide fatal and nonfatal injury and violent death data from a variety of trusted sources to the media, public health professionals, and the public (Centers

for Disease Control and Prevention [CDC], 2018). This system provides age-adjusted and raw-rate mortality data delineated by classification families for the most current International Classification of Diseases (ICD-10), a classification system promulgated by the World Health Organization (WHO).

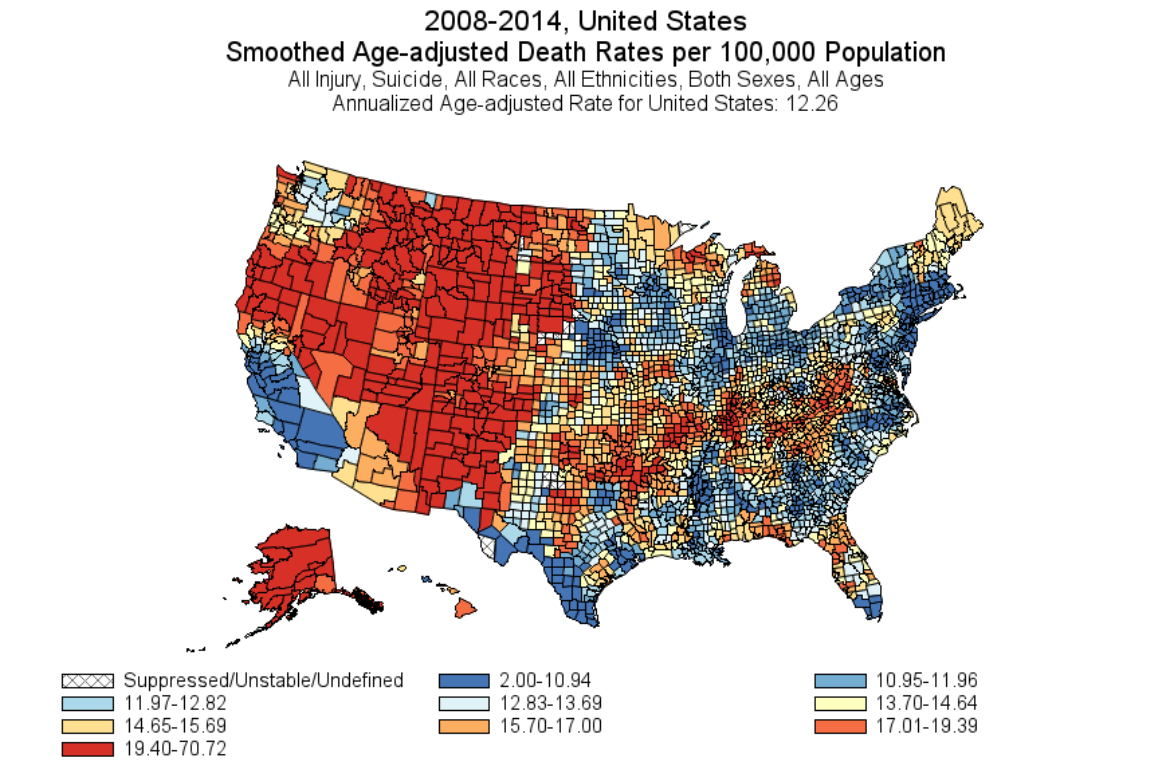
b. Restrictions on Low-Frequency Mortality Events

Due to government restrictions, data for counties with less than ten deaths per any subdivision is "suppressed" by the WISQARS system. This restriction applies to both raw counts as well as to rates-per-100,000. The user agreement for WISQARS prohibits the reporting of actual suicide counts for any subdivision with a raw value of less than ten. Thus, rates for these counties are also suppressed and not reported. Figures 7 and 8 illustrate the limitation on the information value that these restrictions place on suicide mortality data from WISQARS. Given that suicide is a low-frequency event relative to other classifications of mortality, a substantial proportion of the counties on this map are marked as suppressed. This means that WISQARS reporting produces data sets of limited value to public health researchers and professionals, one of the primary intended beneficiaries of the system.



Data and Production notes are included for illustration.

Figure 7. Example of unsmoothed U.S. county suicide mortality data map 2008–2014, illustrating the extent of missing/suppressed U.S. counties. Source: CDC (2018).



Data and Production notes are included for illustration.

Figure 8. Example of smoothed U.S. county suicide mortality data map 2008–2014, illustrating the extent of "borrowing" from non-missing/suppressed counties. Source: (CDC, 2018).

Given the restrictions on reporting of low-frequency mortality, county-level suicide reports tend to attempt to "fill in" the data by using geographic smoothing. This technique borrows from the values of data from adjacent or nearby counties to provide estimates for missing or suppressed counties. While it is unclear exactly what the method of smoothing is, this technique undeniably results in lower estimates for "donor" counties, and unreliable estimates for "recipient" counties.

Alternatively, a researcher or policymaker can resort to using unsmoothed data, resulting in a panel in which the data is highly suppressed, especially in the counties with

lower overall populations (e.g., Figure 7). In statistical terms, this method cuts out the variation from tails of the distribution, and has a high likelihood of throwing off the means and biasing the overall generalizability of the outcomes.

c. Multiple Imputation of Civilian Rates

The statistical gaps in information indicate that the statistical technique of multiple imputation can better inform data associated with the suppression of low-frequency suicide mortality in counties in the 2003–2008 dataset. This technique uses logical branches oriented toward closing a gap in knowledge to identify the best estimator for missing counties. Since known values for suppressed counts of suicides represent values between integers 1 and 9, this value is defined as the range of operation for the multiple imputation. Over this range, branch estimates are produced in a multiple imputation scheme for the relevant set of counties including a set of county value imputations for: minimum-weighted population-based values, maximum-weighted population-based values, random-weighted population-based values, and a criterion-of-realism probability-based imputation.

It is important to note that all individual county-level imputation outcomes represent only an estimate of the county rates for suppressed counties. These are in no way representative of individual events and are in no way an attempt to identify decedents. No actual rates that originate from individual counties in the low-frequency group, nor their specific raw estimates of suicide events, will be published as part of this study, per the WISQARS user agreement.

d. Validation Using CDC Data

Each of these imputations provides estimates of the weighted distribution for low-frequency counties, which range from 11.1 for the minimum-weighted population-based imputation to 11.8 for the maximum-weighted population-based imputation, per 100,000 population. The official or true national mean for this period is can be obtained through the CDC's WISQARS Data Visualization module, which does not suppress low-frequency counties since it is focused on reporting outputs at the national-level only. The CDC thus reports the true national rate as 11.09 per 100,000 for this period (age-adjusted; 11.25 non-age-adjusted per 100,000). As such, any of the imputed county-level rate branches would

place the aggregate national mean within 0.75 points-per-100,000 of the known national rate. Of these, the minimum-weighted, population-based estimator best represents the variation of the suppressed counties in relation to the national mean, providing logically-derived estimates for low-frequency counties while not borrowing variation and magnitude from surrounding counties. This estimator imputation results in a national mean of 11.1 per 100,000, placing it less than 0.01 points-per-100,000 (0.084 on a percentage-point basis) away from the known national mean. For the remainder of this study, this rate will be utilized and as the U.S. county-level civilian suicide rate per 100,000.

Use of this imputation method allows for the combined estimates of the suppressed counties to rejoin the county-level data distribution, bringing the national mean for the study's county-level dataset to nearly the same as the reported national rate. Thus, this method provides a logical methodology for restoring variation from low-frequency counties, reducing dataset bias due to missing counties, and providing valuable estimated rates for visualization of the geographic distribution of U.S. suicide mortality while avoiding biasing the national mean. Use of the county-level data set with restored estimates for the low-frequency counties returns the difference between the known or true national mean and that of the dataset to within 0.01 points-per-100,000, further validating the use of the population-based imputation as the estimator for individual county variation.

2. Military Population Data Sources

Datasets for the visualization of the geographic distribution of military suicide rates match data from the Defense Manpower Data Center for Active Duty Military Units geocoded to counties in the Continental United States (CONUS), Alaska, and Hawaii for the years 2001–2008. The years indicated utilize the largest available data set that can be accurately geocoded.

a. Description of Military Data

Data containing raw counts of suicide events reported to the DoD Health System originate from one of the Co-advisors to this study (Shen et al., 2016). This data contains raw counts of suicide for DoD Active Duty, Reserve, and National Guard, as well as available information on separated personnel who committed suicide during the relevant

years. Wherever possible, this active-duty "ever-served" population mortality is associated with geographic information and other variables outside the scope of this study. This data can be indexed to population data from military Unit Identification Codes (UICs) and U.S. government Area Resource Files. Consolidation by FIPS code forms military ever-served population mortality values associated with U.S. Counties. When a full match occurs, county-level suicide mortality is associated with Active Duty ever-served population and other variables, providing a complete numerator and denominator to form suicide rates by relevant military population.

This data set contains a significant amount of the suicide observations that occurred in this period, but many could not be attributed to a specific military location. The data contain observations for 2,060 suicide events that occurred during this timeframe, associated with 1,788 U.S. counties. For independent comparison, the DoD recognizes 1,609 suicide events for members serving concurrently on Active Duty during the relevant period (RAND 2011). The remainder represent suicide events associated with military service locations linked to suicides from recently separated Servicemembers who served for some length of time on Active-Duty, including Reserve and National Guard personnel. These events in no way represent the total suicide mortality for all eligible Active Duty, Reserve, National Guard, and recently-served veteran populations, but represent a large data set that can be used to inform the geographic distribution of U.S. military suicides.

b. Military Data Limitations

Unfortunately, the best available military suicide data is severely limited, especially when it comes to geoinformation-value. 1,364 of these events either have no geocode or no UIC associated, representing 66 percent of the observations. It is plausible, if not probable, that many of the unassigned suicide events fall within the same geocodes and military units as do the observations for which the data has geoinformatic associations. However, the work necessary to validate that hypothesis is outside the scope and resources of this study.

1,359 U.S. Counties in the data do not report having a significant military population, nor have a military suicide attributed to them, representing about 43 percent of

all U.S. counties. It is plausible that some or most of these missing counties do not have a permanent military presence within their borders.

More than 650 observations exist in the military data that did not contain geocode information, but have UIC information associated with them. These observations are incorporated in the military data set by acquiring individual military unit addresses and cross-referencing to U.S. county FIPS codes. Of these, 465 suicide observations are within the geographical scope of this study (CONUS, Alaska, and Hawaii), and are attributable to Active Duty populations/Units that could be geocoded to a U.S. County. These suicide observations and their corresponding population counts are reflected in the final military data set.

c. Visualization of Military Population Rates

Given the limitations to the military data panel, neither multiple imputation nor multivariate regression techniques are appropriate to further analyze the data. This data set is amenable to visualization via ArcGIS, however. The results of this geoinformatic visual analysis tool is included in the Results chapter of this study (Chapter V).

B. METHODS

Methods to prepare, model, and analyze the data include multivariate regression analysis techniques, paired (dependent) t-tests, and visualization via ArcGIS mapping. The analytical model, Multivariate Regression Analysis constituents, and summary statistics are described in detail below.

1. Multivariate Regression Analysis

Multivariate regression analysis is appropriate to answer the question of what co-variates of suicide mortality are significant to national (civilian) populations.

Here, the response variable is defined as

$$y_i = \textit{suicide mortality by U.S. county (age-adjusted counts \& rates per 100,000 population civilian population)}$$

where suicide mortality can be further described as,

$$\frac{(\text{\# suicides in county}_i\text{, years 2003–2008})}{(\text{Aggregated, age-adjusted population in county}_i\text{, years 2003–2008})}.$$

a. ***Analytical Model***

The above response variable is utilized in the model

$$y_i = \beta_0 + \beta_1 x_i + \beta_2 ln(pop_i) + \beta_3 age_i + \varepsilon_i$$

where,

x_i = families of environmental, economic, mortality classification, and access to care measures,

and,

$_i$ = set of U.S. (CONUS + AK + HI) Counties, years 2003–2008.

Multivariate regressions were estimated for available and congruent sets of variables by family groups to produce estimates of the potential significance and effects of the independent variables. Table 12 in Annex 1 provides a summary of all variables that are relevant to the model.

b. Separation of Related Families

Independent variables are grouped into the following six families: (1) Demographic and economic conditions, (2) environmental measures, (3) healthcare system infrastructure (4) unintentional accidents and events, (5) intentional causes of mortality and neglect, (6) clinical vectors of mortality, (7) pregnancy and childbirth related mortality, (8) and classifications diseases and disorders. Separate multivariate regressions are estimated for each family of independent variables, where the dependent variable is the county level civilian suicide rate per 100K. The separation of groups into variable families is detailed in Table 3.

Table 3. Table diagramming the separation of variables specified as independent variable groups in multivariate regression analysis model.

Demographic and Econonomic conditions:	per capita income, percent white, percent non-white, white population, non-white population, unemployment rates
Environmental Measures:	average daily sunight (KJ/m^2), average daily precipitation (mm), average daily air temperature (deg. F), avearage daily heat index (def F), average daily heat index (deg. F), average day land surface temperature temperature (deg. F/km^2)
Healthcare System Infrastructure:	Federally Qualified Health Centers (FQHCs), federally recognized rural clinics, general physicians, phsyician specialists
Unintentional Accidents and Events:	undetermined causes, accidents including falls, exposure, impacts, vehicle and transport accidents.
Intentional Mortality Factors:	assault (including sexual assault), neglect and maltreatment, and accidents of undetermined intent
Clinical Vectors of Mortality:	clinical findings, and pregnancy-related conditions
Pregancy and Childbirth:	perinatal and neonatal, pregnancy and childbirth, and puerperium
Diseases and Disorders:	congenintal and chromosomal, genitourinary, skin and subcutaneous, musculoskeletal, digestive, respiratory, circulatory, nervous system, endocrine and metabolism, blood and immune systems, neoplasms, infectuous and parasitic diseases

2. Data Validation

Due to the necessarily geographical arrangement and organization of the data and model, as well as the large panel of congruent cross-sectional data, the need for data validation techniques commonly associated with trend analysis, time, and seasonality are eliminated. Standard tests for heteroskedacity and significance tests were performed to check for variables that are tenuously related to county-level suicide. With proper age controls and population-adjusted rates, heteroskedacity was not latent in the model. Insignificant variables are reported in outcome tables to provide context for independent variables of significance.

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IV. FINDINGS AND RESULTS

This chapter discusses the results of analysis of the geographic distribution of U.S. suicide mortality. First, multivariate regression analysis provides parameter estimates for covariates of U.S. civilian suicide rates by U.S. county. The discussion focuses not on the magnitudes of the estimates, but on the statistical significance of the association, if any, between the covariates and suicide rates. Second, geographic distributions of military and civilian suicide rates are provided via ArcGIS visualization. For each of these specifications, population is controlled for by utilizing rates per one hundred thousand population, while age is controlled for by using age-adjusted populations and event observations.

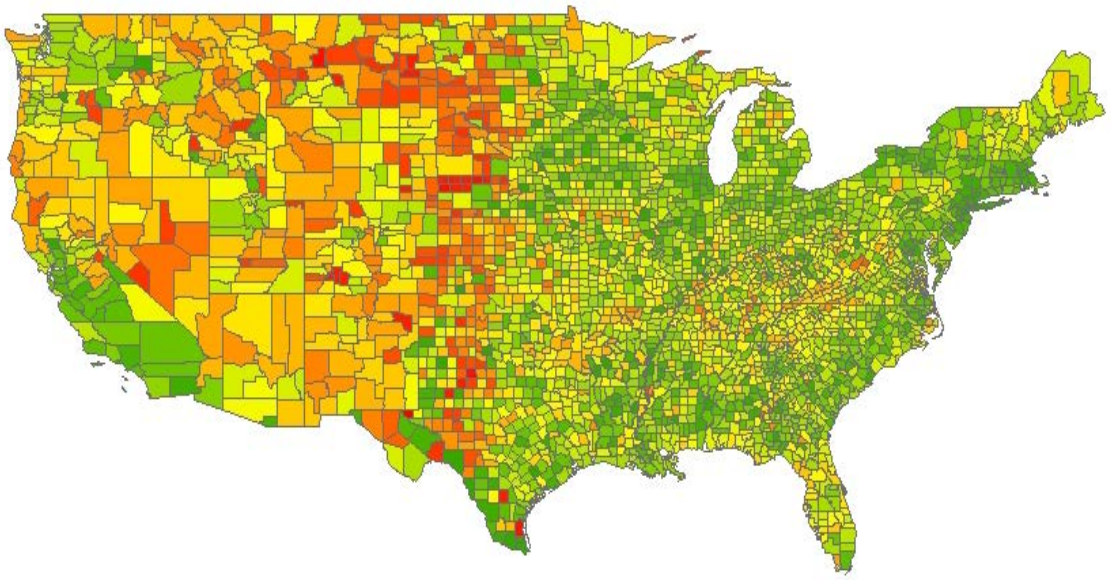
A. VISUALIZATION OF GEOGRAPHIC DISTRIBUTION OF CIVILIAN SUICIDE MORTALITY

ArcGIS is a geoinformation mapping system that is capable of producing very accurate visualizations of data in a format that is accessible to a variety of users. When formatted and mapped in ArcGIS, important factors in raw data can be put back into very useful formats. Variation in the geographic distribution of suicide can be represented in an accessible expression that illustrates the impact of distances between points and populations of interest, access to transportation routes, proximity to geographic features such as coastlines, *etc*. The following sections show the power of combining data analytics utilized in the rest of this study with the geoinformatic power of ArcGIS. Visualization of the geographic distribution of U.S. suicide rates by U.S. county can inform suicide prevention reporting and policymaking, and positively impact clinical and leadership efforts at the leadership level.

1. Visualization

Figure 9 utilizes data and analysis described in previous chapters to visualize the geographic distribution of U.S. county-level suicide rates in an advance in the geoinformatic value of such mapping. This visualization is based off of rates that are

adjusted for age and population, as well as including best estimates for missing and unreliable counties, without resorting to utilizing geographic smoothing. Avoidance of using smoothing techniques means more accurate rates are being reported for what would otherwise be “donor” counties, and population-based estimates for what would otherwise be “recipient” counties in a smoothing scheme. One reason for this is that map-based smoothing assumes contiguous or nearby counties experience the same prevalence of both suicide (numerator) and exhibit similar population profiles (denominator). Since neither of these assumptions is accurate for purposes of suicide prevention and policymaking, the technique represented by the following maps is much more useful and accurate to ultimately inform suicide prevention efforts. Specifically, counties that are usually suppressed in the Mid-Western U.S. visualization show a strong pattern of very high rates of suicide mortality. While it is clear that not all of these will conform to the pattern indicated by this treatment of the data, these counties are precisely the ones that are calling for the most attention from suicide prevention policy. In some settings, suppressing data and visualization outcomes for these counties may be appropriate, but eliminating the variation and geographic distribution of these by either statistical smoothing or suppression from the data means that these counties are not allowed to express the attention that many of them deserve. In addition, not using smoothed rates in visualization means that the relative “heat” or “coolness” for counties with data is more realistic, generally providing better visualization of their actual values. These rate-values generally are higher for “donor” counties in reality than they would be otherwise be in a smoothed scheme, and their values are therefore underrepresented in a visualization based on smoothing of rates.

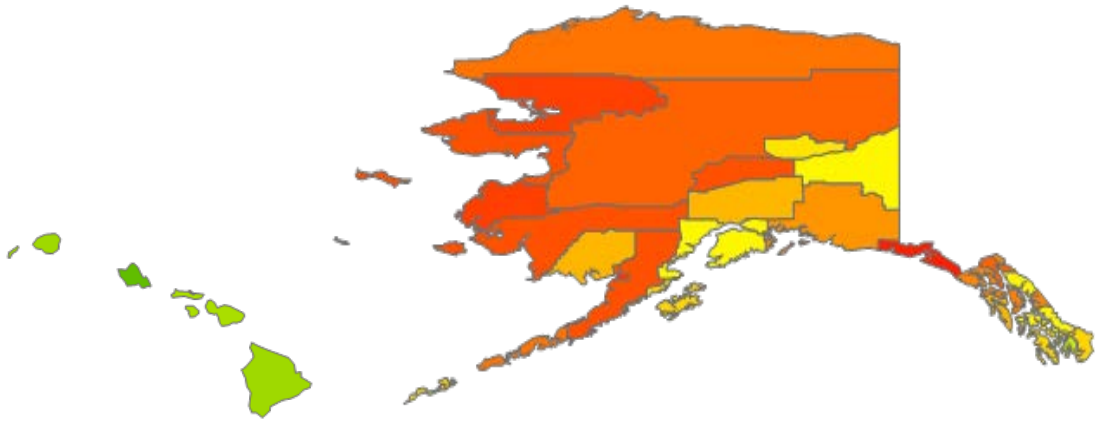


Color Reference…..……Reference rates of Suicide per 100k:
Deepest Green……..……..…….…..…….....3.5-5.7
Midrange Yellow……..……..…….....16.4-18.6
Deepest Red……..……369.9-1577.6

Counties are drawn to scale via ArcGiS, with horizontal reformatting to fit page. Missing rates are based upon minimum imputed, population-based estimates.

Figure 9. Visualization of the geographic distribution of U.S. civilian suicide rates by county, 2003–2008, CONUS (mainland) United States.

This visualization provides clear indications of the large amount of variation across U.S. counties, and patterns that can be connected through statistical analysis to important covariates such as demographic and economic factors, environmental factors, healthcare system infrastructure and access, accidents and intentional causes of mortality, and other health-related vectors of mortality such as disease and disorder classification families (i.e., results from the previous portion of this section).



Color Reference…..…Reference rates of Suicide per 100k:
Deepest Green……..……..…….…….....3.5-5.7
Midrange Yellow……..……..…….....16.4-18.6
Deepest Red……..……369.9-1577.6

Scale is accurate within but not across states within this combined ArcGIS visualization.

Figure 10. Visualization of U.S. civilian suicide rates for the States of Alaska and Hawaii by county, 2003–2008.

Based on the same analysis of civilian suicide rates, Figure 10 provides a context for the suicide rates of Alaska and Hawaii, by county. It is important to note that populations here are not evenly spread over the county geographic boundaries. Like the relationship between sub-national and sub-state aggregations, best estimates of the variation of the county-level suicide rates can help inform the understanding of larger-scale rates and identify counties in need of greater attention and follow-up. In other words, it is best that these rates and their variation target and tailor policymaking and intervention efforts; this analysis is not intended to describe detailed variation within individual counties in itself.

2. Discussion

From the perspective of national suicide prevention and policymaking, the variation of U.S. county-level suicide rates provides important information that can identify "hot spots" that potentially could be targeted for enhanced prevention and intervention efforts. It also supports many of the independent findings of the multivariate regression analysis portion of this study. Namely, the geographic distribution of U.S. Civilian suicide rates,

when properly treated, is highly related to factors such as isolation from population centers, health system access and infrastructure, economic factors, environmental factors, and other healthcare outcomes and sources of mortality. For detailed discussions of these families of covariates, see Chapter IV. , Section C. of this study. This visualization and its underlying analysis underscore that isolation from healthcare system infrastructure and population centers are of deep importance to the rates of civilian suicide across the U.S., and that variation in county-level suicide rates is an important tool of identification of areas in need for deeper analysis for suicide prevention and response.

B. VISUALIZATION OF MILITARY RATES OF SUICIDE

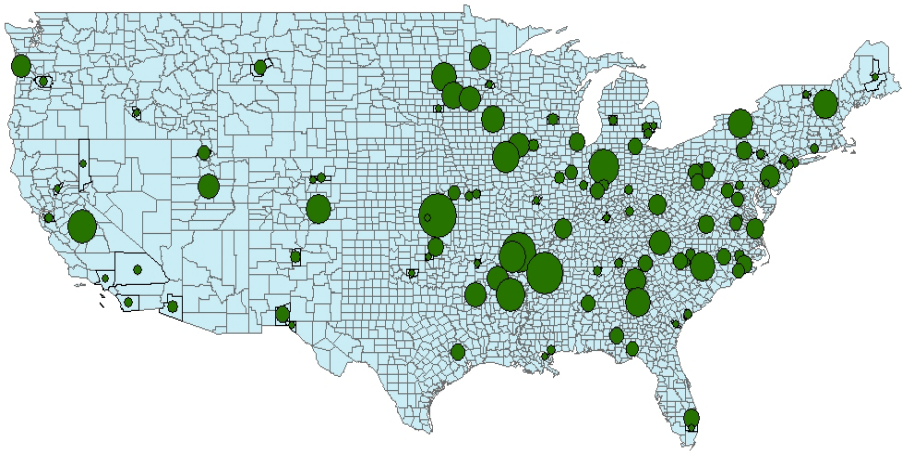
Visualization of U.S. rates of military populations can provide important information about the geographic distribution of U.S. suicides. This is especially true when population-specific rates are constructed, as opposed to raw counts, trends, etc., that are ordinarily offered in current DoD and VA analysis.

1. Visualization

Figure 11 provides a geoinformatic visualization of U.S. military population-specific suicide rates, 2003–2008, via ArcGIS mapping. Here, the rates are depicted for U.S. Counties that had average military populations greater than 5000 persons for the reference years, and whose military suicide rates exceed 11 per 100,000. This rate is used as a reference background rate, established and verified in other parts of this thesis as the best estimate of the national civilian suicide rate for the same years. Figure 12, representing the geographic distribution of civilian suicide rates by U.S. county is reproduced from Figure 9 in previous sections, and is placed immediately below Figure 12 for contrast in the differences between geographic distribution of U.S. military and suicide mortality.

By focusing on U.S. military populations that conform to the guidelines above, the suicide rates for the top 74 counties can be visualized for counties with military populations that are large enough to compare to civilian counties, as well as to other military county-populations of the same class. Green circles represent the relative magnitude of the suicide rates for U.S. military county-populations within this class. These are placed concentrically over its county's geographic center. Clearly, some of these symbols exceed the size of their

respective county, and are representative of county-population specific rates only, and representative of the county's relative geographic distribution of suicide mortality, not the size of the county or county population at large.



County background reference boundaries are drawn to scale via ArcGIS; image has been reformatted horizontally to fit page.

Figure 11. Visualization of the geographic distribution of U.S. counties with military populations greater than 500, and whose population-specific suicide rate is greater than 11 per 100,000 (using U.S. national civilian suicide rate as reference), 2003–2008, CONUS (mainland) United States.

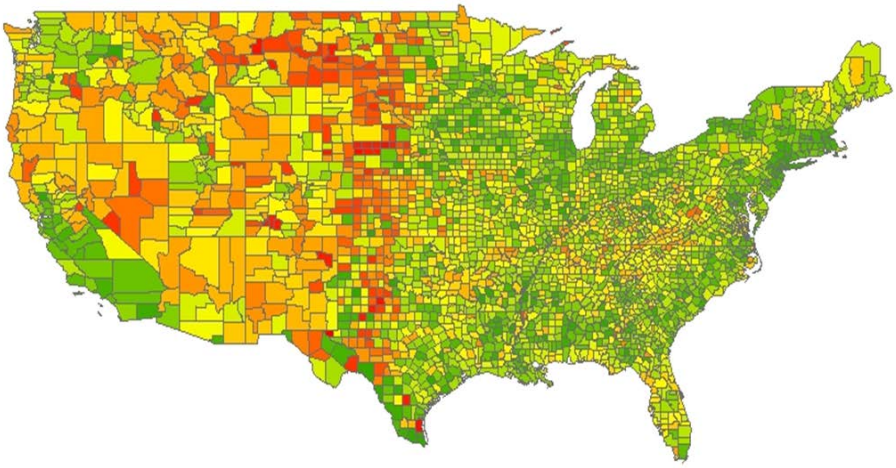


Figure 12. Geographic distribution of suicide rates per 100,000 for the U.S. civilian population, by U.S. county, 2003–2008. Reproduced from Figure 9.

2. Discussion

As might be expected, the military suicide rate analysis and visualization shows a mostly different pattern of geographic distribution than that of the U.S. civilian county populations. It appears that suicide for military populations is in some ways related to the placement of U.S. military bases and populations, though areas that have larger bases and populations do not always exhibit correspondingly high rates.

More importantly, using the techniques embodied by this exploratory thesis reveal the power of advanced statistical techniques and visualization to inform and advance our understanding of a very important national, regional, and local issue. Figure 10 illustrates very important disparity in individual counties that have very large suicide impact footprints. It also identifies at least seven inter-state regions manifesting clusters of suicide rates that should be a high priority for DoD and VA suicide prevention, intervention, and response (if indications from this six year cross-section hold). A combination of these techniques can be used to identify areas where evidence of suicide rates is alarming and rate clusters necessitate tailored intervention in the short- to medium-term, and where long-term infrastructure changes may be required.

C. CIVILIAN RATES OF SUICIDE AND COVARIATES

Several multivariate regression analyses were run for individual covariate groups that are related. Table 4 describes the first group, econometric covariates.

Table 4. Multivariate regression outcomes for demographic and economic variables estimated on civilian suicide rate for set of U.S. counties, 2003–2008.

VARIABLES	(y_i) Civilian Suicide Rate - Age Adjusted
PER CAPITA INCOME	0.0001***
	(0.0000)
COUNTY UNEMPLOYMENT RATE	0.7461***
	(0.0936)
PERCENT OF POPULATION NONWHITE	-0.0255**
	(0.0115)
PERCENT POPULATION AGED GREATER THAN 65	-0.0687
	(0.0427)
Constant	6.4540
	(1.2605)
Observations	3,141
R-squared	0.0221

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Here, for the set of included U.S. counties, the estimates on per capita income and county unemployment rate are significant at the 1% level. The county unemployment rate appears to be not only significantly related, but positive and substantial in relationship. Additionally, for the estimate on percent of the population that is non-white is negative, substantial, and significant at the 5% level. The percent non-white operates as a dummy variable, so the estimate on the percent of county populations that is white can be expected to be significant and have the opposite sign.

Table 5 provides parameter estimates for the next set of multivariate regression analysis variables, environmental co-variates.

Table 5. Multivariate regression outcomes for environmental variables estimated on civilian suicide rate for set of U.S. counties, 2003–2008.

VARIABLES	(y_i) Civilian Suicide Rate - Age Adjusted
Average Daily Sunlight (KJ/m^2)	0.0000
	(0.0003)
Average Air Fine Particulate Matter ($g/m^{2)}$	-0.0405
	(0.0923)
Average Daily Precipitation (mm)	0.8361***
	(0.3157)
Average Daily Max Air Temperature (deg. F)	0.2406***
	(0.0818)
Average Daily Max Heat Index (deg. F)	-0.9821***
	(0.1123)
Average Day Land Surface Temperature (deg. F/km^2)	-0.0414
	(0.0543)
Constant	84.8203
	(10.2131)
Observations	3,100
R-squared	0.0429

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Of these, average daily precipitation in millimeters, average daily max air temperature in Fahrenheit, and average daily max heat index in Fahrenheit are all significant at the 1% level. These variables remain significant even when run as part of the same model, indicating their co-variance is robust to the effects estimated on each individual member of this family of variables. It is worth noting here that Average Daily Max Air Temperature has a high significance level, and a large, positive coefficient value, while Average Daily Heat Index has a high significance level and smaller, negative coefficient value. Thus, a plausible interpretation is that counties that are associated with a higher air temperature are associated with a higher rate of suicide, on average and all else

being equal, but that counties associated with an independently high heat index (humidity, less wind), may be associated with a mediated effect. Epidemiologic literature abounds that identifies an independent effect of Relative Humidity and Absolute Humidity on various health outcomes, even when the effects of Air Temperature are controlled. While it is unclear if this outcome is similar in mechanism to these studies, or whether both or all are simply proxies for other omitted variables similar to the altitude study, it appears the effects of Heat Index are significant to suicide mortality, even when the effects of Air Temperature are specified/controlled.

Table 6 summarizes parameter estimates of county-level variables representing Health System Infrastructure.

Table 6. Healthcare system infrastructure variables estimated on civilian suicide rate for set of U.S. counties, 2003–2008.

	(y_i)
VARIABLES	Civilian Suicide Rate - Age Adjusted
CRITICAL CARE ACCESS HOSPITAL LOCATED IN COUNTY (2005)	-1.095***
	(0.367)
FEDERAL RURAL CLINIC LOCATED IN COUNTY (2005)	-0.796**
	(0.349)
FEDERALLY QUALIFIED HEALTHCARE CENTERS LOCATED IN COUNTY	0.989***
	(0.347)
# PHYSICIAN SPECIALISTS	-0.000191***
	(0.00006)
# GENERAL PHYSICIANS	0.00151*
	(0.0008)
Constant	12.28
	(0.319)
Observations	3,147
R-squared	0.013

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Of the included variables, the number of physician specialists and whether the county had a critical care access hospital or Federally Qualified Health Center is highly significant to the rate of Civilian Suicides, at the 1% level. Additionally, the number of general physicians is significant at the 10% level, with controls for age and population. This should not be attributed to causality. Instead, this can be interpreted as evidence that counties with higher civilian suicide rates are associated with less physician specialists, less healthcare system infrastructure (that is qualified for federal funding), and more general physicians, on average and all else being equal. While the parameter estimate is on general physicians is only significant at the 10% level, this may be a reflection that the healthcare system incentivizes general physicians to "spread out" over the country, while physician specialists are less concentrated in counties that have higher rates of suicide. This comports with general background knowledge that specialist physicians and their offices tend to be located in metropolitan population centers. Given the concurrence between CDC data maps (Chapter IV) and ArcGIS mapping produced by this study (Chapter V), a reasonable explanation is that physician specialists are less likely to be located in isolated counties (on average, all else being equal), while those isolated counties are often much more likely to experience suicides. Here, the danger in accepting a one-cause, one-explanation approach, such as that adopted by the suicide-altitude study (Brenner *et al*. 2006, Section II) becomes apparent. Higher rates of suicide are clearly associated with healthcare system infrastructure at the county-level, in this case to classes of physicians and healthcare system access/infrastructure, which some other authors may have overly attributed to altitude.

Table 7 summarizes the parameter estimates on accidental causes of death family of variables.

Table 7. Accidental Causes of Death covariates estimated on Civilian Suicide Rate for set of U.S. counties, 2003–2008.

VARIABLES	(y_i) Civilian Suicide Rate - Age Adjusted
Accidents - Contact and Exposure	-0.0475
	(0.0294)
Accidents - Vehicle and Transport	0.1695***
	(0.0136)
Accidents - Undermined Intent	-0.1181***
	(0.0402)
Constant	3.0411
	(0.4687)
Observations	507
R-squared	0.4821

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Of these, accidents due to vehicles and transportation and accidents due to undetermined intent are both highly significant, at the 1% level. These results indicate that that counties that have a higher suicide rate are associated with lower rates of mortality due to accidents of undermined intent and higher rates of mortality due to vehicle and transportation accidents, on average, all else being equal and controlling for age and population effects. While these results evade specific interpretation, the overall take away may be that civilian suicide rates are highly related to mortality due to transportation accidents across U.S. counties to a very high degree of evidence, and further inquiry may yield specific results.

Tables 8 through 11 summarize parameter estimates for variables representing disease and medically-related causes of mortality. The will be presented singly (beginning this page) and discussed en masse at the conclusion of this section.

Table 8. Intentional and undetermined intent causes of death covariates estimated on civilian suicide rate for set of U.S. counties,2003–2008.

VARIABLES	(y_i) Civilian Suicide Rate - Age Adjusted
Assault, including Sexual Assault	-0.2146
	(0.3101)
Neglect and Maltreatment	2.3661
	(7.1902)
Accidents - Undermined Intent	2.5123
	(2.4212)
Constant	9.7237
	(2.9103)
Observations	10
R-squared	0.1585

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9. Clinical setting causes of death covariates estimated on civilian suicide rate for set of U.S. counties, 2003–2008.

VARIABLES	(y_i) Civilian Suicide Rate - Age Adjusted
Abnormal Symptoms and Findings	-0.0714
	(0.0727)
Mental and Behavioral Disorders	0.1660***
	(0.0477)
Sequelae of Self Harm	-6.4920**
	(3.1324)
All Sequelae	0.9890
	(0.7386)
Medical and Surgical Complications	0.2118
	(1.2436)
Constant	7.0784
	(1.1085)
Observations	39
R-squared	0.3315

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This family of covariates is grouped in such a way because they are all clinically-intensive forms of mortality relative to other groups of healthcare outcomes which are related in different ways, on average all else being equal.

Table 10 bears specific discussion. These variables are grouped in this way because they are logically-connected in that they are all represent forms of clinically intensive mortality. For example, “sequelae” is a medical terminology defining an ICD code for mortality for patients/decedents who do not immediately die from another causes of mortality. So, for a patient who attempts to commit suicide, and survives the immediate period but subsequently dies of chronic injuries stemming from that attempt, mortality is associated as “sequelae of self-harm” instead of “self-harm.” In these cases, on average, there is almost always clinical interaction with the decedent in between the initial suicide attempt and their death some time later. Likewise, by definition, mental and behavioral health disorders are defined by their necessary clinical interaction with a practitioner or clinician, as is abnormal symptoms and findings. Unlike mortality stemming from a vehicle accident or a cardiac event (circulatory family), which may or may not involve the intervention of a clinician, variables grouped in this family almost always do.

Table 10. Pregnancy and Infancy Related Causes of Death covariates estimated on Civilian Suicide Rate for set of U.S. counties, 2003–2008.

VARIABLES	(y_i) Civilian Suicide Rate - Age Adjusted
Perinatal and Neonatal	0.3497**
	(0.1629)
Pregnancy, Childbirth and Puerperium	-8.0732***
	(2.5490)
Constant	10.5218
	(1.0498)
Observations	83
R-squared	0.1215

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11. Internal medicine and pathology related causes of death covariates estimated on civilian suicide rate for set of U.S. counties, 2003–2008.

VARIABLES	(y_i) Civilian Suicide Rate - Age Adjusted
Congenital and Chromosomal	0.6976***
	(0.1437)
Genitourinary	-0.1116***
	(0.0260)
Musculoskeletal	0.3973***
	(0.1099)
Skin and Subcutaneous	-0.0099
	(0.2157)
Digestive System	0.1240***
	(0.0314)
Respiratory System	0.0541***
	(0.0107)
Circulatory System	-0.0107***
	(0.0037)
Nervous System	0.0212*
	(0.0126)
Endocrine, Metabolism and Nutrition Disorders	-0.0336**
	(0.0148)
Blood and Immune System	-0.3510**
	(0.1508)
Neoplasms, including Cancer and Tumors	0.0209***
	(0.0073)
Infectious and Parasitic Diseases	-0.0315*
	(0.0177)
Constant	2.4973
	(0.6809)
Observations	518
R-squared	0.4732

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

It is worth nothing that none of the intentional and undetermined family of mortality (Table 8) is significantly related to suicide rates at the county level, although vehicle and transport accidents appear to be highly related. County-level rates of mortality from several classifications of diseases and mortality conditions are highly significant to county suicide rates, on average, all else being equal, and controlling for age and population. While these results evade specific interpretation, they indicate significant areas for future research; that is, other health outcomes (in this case mortality by those diseases and conditions) appear to be highly related to the geographic distribution of county suicide rates. Taken together, they may reveal important areas that indicate there is a healthcare and health-outcome discontinuity across U.S. counties, similar to the difference in estimates on the number of physician specialists and general physicians. On average, all else being equal and controlling for age and population, they provide a strong indication that healthcare system infrastructure and related health mortality rates matter to the geographic distribution of county suicide rates.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY AND CONCLUSIONS

This study is an exploratory attempt to advance the understanding of the national problem of suicide, particularly in identifying and analyzing the geographic distribution and patterns at the county-level. Several conclusions follow from this analysis. First, it shows that the "where" of suicide in the U.S. matters, and especially matters at the local- and county-level. Larger aggregations are informative of national trends, but much of the variation in where suicide occurs is in the local and county "tails" of the statistical distribution. This variation can inform analysis and provide health practitioners and policymakers with sound analysis with which to design future prevention, intervention, and response measures. Second, multivariate regression analysis and other advanced statistical techniques can and should be utilized in the reporting on and public education of suicidality in the United States, especially utilizing information pertinent at the more-localized community levels such as U.S. counties or municipal aggregations. Fourth, by and large, geographic isolation, population and age considerations, economic factors, environmental measures, and several other forms of mortality matter to civilian rates of suicide and its geographic distribution.

For military populations, during the cross-section of six years from 2003–2008, patterns of geographic distribution of military suicide mostly differed from those of civilian counties. This pattern of variation is to be expected for the military population, which tends to train and distribute personnel in very different ways than the civilian community system. Despite these apparent differences, important conclusions can be drawn from this research. Chief of these is that patterns of uneven distribution of suicidality exist in military populations for this large cohort, large cross-section study by U.S. county. These uneven patterns represent massive opportunities for DoD and VA health professionals and policymakers to lead in the area of suicide research, prevention, and response.

Very significantly, some of these uneven patterns of distribution even show regional areas of suicide "clusters," in which multiple counties seem to be alerting to increased need for suicide intervention and "post-vention." These clusters represent areas

in which not one, but multiple localities within a relatively compact subsection of the country seem to be pointing at dramatically increased suicide rates and risk among Servicemembers. Under any circumstances where marginal effort, dollars, and attention become available for allocation to suicide prevention, intervention, and response, these areas should be considered as prioritization targets.

Finally, though outside the scope of this study, important new areas of research and practice that DoD and VA professionals can combine with the findings of this study. These include suicide post-vention processes, aimed at stopping the effects of one suicide from influencing others in the same cohort, and trained Certified Psychological Autopsy Investigators, a field in which the DoD and its healthcare arm could invest to produce a small cadre of professionals to collect and maintain detailed proximate and distal cause information on suicides within its ranks.

B. FURTHER RECOMMENDATIONS

Taken along with some of the techniques utilized in this study for advancing the reporting and analysis of military suicides, major advances in the prevention and response of suicide are available and must be adopted by our country's leading institutions. The U.S. Departments of Defense and Veterans Affairs, and their constituent services and branches are in primary position to lead in these emerging areas of public health and applied academic theory. Clearly, additional research is indicated by this study, a quite possibly future policy and prevention action.

APPENDIX. SUMMARY STATISTICS

Summary statistics for all healthcare system infrastructure, demographic and economic, environmental, and disease and condition mortality variables specified in study model, representing merged 2003–2008 data sets.

VARIABLE	N	Mean	sd
CIVILIAN SUICIDES COUNTS (Counties with)	3,147	62.60	169.7
MILITARY SUICIDES COUNTS (Counties with)	1,502	0.336	1.915
COUNTY POPULATION	3,147	567,510	1.843 e+06
CIVILIAN SUICIDE RATE (per 100k, age-adjusted)	3,147	11.85	9.362
TOTAL PHYSICIANS	3,147	1,480	6,240
GENERAL PHYSICIANS	3,147	138.8	422.2
PHYSICIAN SPECIALISTS	3,147	1,341	5,874
FEDERALLY QUALIFIED HEALTHCARE CENTERS	3,147	6.371	18.18
FEDERAL DESIGNATED RURAL CLINICS	3,147	6.946	11.07
PER CAPITA INCOME	3,144	28,16	7,457
UNEMPLOYMENT RATE (% of eligible population)	3,142	5.505	1.997
% IN POVERTY	3,144	14.36	5.709
% POPULATION WHITE	3,143	86.76	16.11
% POPULATION NONWHITE	3,143	13.24	16.11
% POPULATION AGED (>65)	3,147	15.03	4.174
CRITICAL ACCESS HOSPITALS	3,142	0.401	0.607
GENERAL HOSPITALS (2005)	3,142	0.391	0.597
AVERAGE DAILY SUNLIGHT (KJ/m2)	3,108	16,28 6	1,511
AVG FINE PARTICULATE MATTER (g/m2)	3,108	11.96	2.111
AVG DAILY PRECIPITATION (mm)	3,108	2.710	0.913
AVG MAX AIR TEMP (deg. F)	3,108	65.11	8.867
AVG MAX HEAT INDEX (deg. F)	3,100	89.62	3.146

SUICIDE MORTALITY (low-frequency suppressed)	2,309	14.46	6.198
ASSAULT MORTALITY	1,103	6.497	4.917
ACCIDENTS MORTALITY—CONTACT, EXPOSURE	2,792	29.19	10.42
ACCIDENTS—VEHICLE AND TRANSPORT	3,051	77.02	24.34
NEGLECT AND MALTREATMENT	10	0.193	0.190
ACCIDENTS—UNDETERMINED INTENT	508	3.743	4.444
ABNORMAL SYMPTOMS AND FINDINGS	2,105	16.70	16.50
CONGENITAL AND CHROMOSOME DISORDERS	1,116	4.103	1.477
PERINATAL AND NEONATAL	1,181	5.398	2.599
PREGNANCY AND CHILDBIRTH	83	0.339	0.140
GENITOURINARY	2,715	28.23	11.63
MUSCULOSKELETAL	1,511	6.323	2.888
SKIN AND SUBCUTANEOUS	546	1.829	1.069
DIGESTIVE SYSTEM	2,902	36.97	12.19
MORTALITY SYSTEM	3,066	104.9	35.66
CIRCULATORY SYSTEM	3,121	356.1	111.7
NERVOUS SYSTEM	2,925	50.86	22.75
MENTAL AND BEHAVIORAL DISORDERS	2,672	30.42	14.77
ENDOCRINE SYSTEM AND METABOLISM	2,925	44.30	18.84
BLOOD AND IMMUNE SYSTEM	1,103	4.143	1.922
NEOPLASMS—CANCER AND TUMORS	3,115	231.9	57.23
INFECTIOUS AND PARASITIC DISEASES	2,539	23.60	10.52
SEQUELAE OF SELF HARM	39	0.290	0.187
ALL SEQUELAE	262	0.926	0.478
MEDICAL AND SURGICAL COMPLICATIONS	351	1.119	0.666

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