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# A decompositional analysis of firearm-related mortality in the United States, 2001–2012

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## ABSTRACT

Prior literature reporting increased rates of firearm-related homicide and suicide with increasing firearm availability is limited by only examining the availability of firearms, which is only one component of firearm-related mortality. The objective of the current study is to separate the rates into their respective components and determine which components contribute to mortality rate changes. To address the objective, nationally representative data from 2001 to 2012 was collected from a variety of publicly-available sources. Utilizing decompositional methodology, a negative binomial regression was used to estimate rate ratios for the association between the components and year category, and relative contributions of each component were calculated. From 2001 to 2012, the homicide and unintentional mortality rate decreased while the suicide rate increased. The suicide rate was only the firearm prevalence rate. The unintentional mortality rate was a factor of firearm prevalence, injury incidence, and case fatality rate. The homicide rate was a factor of firearm prevalence, violent crime rate, injury incidence, and case fatality rate. The current results suggest that the contributors of changes in firearm-related mortality are multi-faceted. Future studies should perform a decompositional analysis utilizing more granular data to examine whether the currently reported results are true associations or a factor of ecologic fallacy.

## 1. Background

While unintentional injury, particularly from motor vehicle collisions, is the leading specific cause of death for the 1–44 year age group (Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, 2005), firearm-related injuries, both intentional (i.e., homicide and suicide) and unintentional, follow close behind. From 2000 through 2014, there were a total of approximately 790,000 homicide or suicide deaths in the United States, the vast majority of which were related to firearms. For those aged 5 to 34, homicide by firearm is the leading cause of violence-related injury death, and suicide by firearm is the top cause of violence-related injury death for those aged 35 and older. Unintentional injury death by firearm, however, is relatively uncommon with 9745 deaths during the same time period.

In recent years there has been an increased focus on both the legislation pertaining to and availability of firearms in the United States,

particularly following the expiration of the Federal Assault Weapons Ban that was in place from late 1994 through late 2004. Examining availability of firearms, early studies evaluated the effect of firearm ownership on homicide risk, reporting positive associations between ownership and both homicide and suicide risk (Kellermann et al., 1993; Grassel et al., 2003; Wiebe, 2003). More recent studies have focused on the relationship between firearm ownership and firearm violent crime and mortality rates. Monuteaux et al. (2015) reported that increased firearm ownership rates were associated with increased rates of firearm assault and robbery. Studies examining mortality rates have reported positive associations with firearm suicides (Miller et al., 2002a, 2007) and firearm homicide (Miller et al., 2002b; Siegel et al., 2013, 2014a), the latter association being particularly among non-stranger firearm homicide (Siegel et al., 2014b).

A meta-analysis (Santaella-Tenorio et al., 2016) reported mixed results for the association between right-to-carry laws and homicide whereas studies that examined the effects of laws on unintentional

*Abbreviations:* ATF, Bureau of Alcohol, Tobacco, Firearms and Explosives; CDC, Centers for Disease Control and Prevention; CI, Confidence interval; FISS, Firearm Injury Surveillance System; FURA, Firearm-utilized robberies and assaults; LOESS, Local regression; NCVS, National Crime Victimization Survey; NEISS, National Electronic Injury Surveillance System; RC, Relative contribution; RR, Rate ratio

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deaths and suicides consistently showed negative associations. Fleegler et al. (2013) observed that those states with more laws regarding firearms had lower suicide and homicide rates. A recent cross-sectional study of firearm legislature enacted in 2009 reported that most firearm legislation had no impact on the firearm-related mortality rate, though the authors did observe that background checks for guns and ammunition as well as the requirement of identification for firearm purchase were associated with decreased rates of overall firearm-related mortality (Kalesan et al., 2016a).

The current literature on the association between firearms and firearm-related mortality is limited by the fact that studies have only examined the pure mortality rate (i.e., deaths per population) rather than examining the components of the rate (e.g., injury incidence, case fatality rate). Examining the components allows for a more thorough examination of the factors that contribute to the mortality rate, thereby elucidating which components are better targeted for prevention efforts. Therefore, the objective of this study is to decompose homicide, suicide, and unintentional firearm-related mortality rates into their constituent parts. In addition, the analysis will examine how these components have changed across the years.

## 2. Methods

### 2.1. Study design and data

The data for this ecological study come from a variety of sources using information from years 2001 through 2012. Population estimates were gathered from intercensal estimates provided by the U.S. Census. Information regarding the number of firearms manufactured, imported, and exported in the United States was derived from the 2015 Report of Firearms Commerce published by the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) (United States Department of Justice, Bureau of Alcohol, Tobacco, Firearms, and Explosives, 2015). Data on the percent of households and adults in households who own a firearm was collected from a report presenting results of a biannual survey of gun ownerships trends in the United States from 1972 to 2014 (Smith & Son, 2015). Data regarding violent crimes (excluding homicide) were derived from the National Crime Victimization Survey (NCVS), a nationally representative survey—conducted by the Bureau of Justice Statistics—of 90,000 households in the United States (United States Bureau of Justice Statistics, 2014). Each household is interviewed twice a year, surveying approximately 160,000 respondents on demographics and characteristics of the violent crime including whether the crime involved the use of a firearm.

Data for non-fatal firearm-related injury were derived from the Firearm Injury Surveillance System (FISS) for years 2001–2012, the latter being the most recent year in which data is available. The FISS—in operation since 1993 and a collaborative effort between the CDC and Consumer Product Safety Commission (CPSC)—is part of the National Electronic Injury Surveillance System (NEISS), a stratified probability sample of 99 hospitals (100 hospitals in 2000 and 2001) in the United States including large inner-city hospitals with trauma centers and large urban and rural children's hospitals (United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, 2015). Data for the NEISS-FISS are entered for non-fatal firearm-related injuries by trained coders at each participating hospital, and are then sent to the CPSC where data are adjudicated to ensure quality and to determine the cause of the injury based on narratives derived from notes provided by doctors and nurses in the medical record for a given case. Data on fatal injuries were derived from the annual mortality file provided by the CDC's Web-based Injury Statistics Query and Reporting System, which queries data from the National Vital Statistics System operated by the CDC (Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, 2005).

### 2.2. Variable definitions

The number of firearms in the United States was calculated by first using an estimate of firearms in the United States published by the ATF in 2000 (U.S. Department of the Treasury, Bureau of Alcohol, Tobacco and Firearms, 2002). Annual firearm estimates were computed by summing the number of manufactured and imported firearms and subtracting the number of exported firearms as provided in the Report of Firearms Commerce (United States Department of Justice, Bureau of Alcohol, Tobacco, Firearms, and Explosives, 2015). In order to check that the estimates were accurate, the computed estimate of 296 million for 2007 was compared to the reported estimate of 294 million for the same year by Krouse (2012), and the estimates were considered to be similar. Violent crime was defined as robbery, assault, homicide, or non-negligent manslaughter, a definition that has been used in prior research on the relationship between firearms and violent crime (Monuteaux et al., 2015). Since homicides are not included in the NCVS, the total number of violent crimes for each year was calculated as the sum of the violent crime estimate from NCVS data and the homicide estimate from NVSS data. For each type of crime, a separate categorization was defined as the number of crimes in which a firearm was utilized to perpetrate the crime. Firearm-related injuries and deaths were defined as being due to assault, self-harm, or unintentional injury from a gunshot, with injuries and deaths due to legal intervention or justifiable homicide excluded from estimates; in addition, injuries and deaths related to BB or pellet guns were excluded from the analysis. The main exposure of interest was year category, and was defined as 2001–2003, 2004–2006, 2007–2009 and 2010–2012.

### 2.3. Decomposition method

Firearm-related deaths were separated into unintentional deaths, suicides, or homicides. The rate of each was calculated by dividing the number of deaths for each respective category by the population of the United States. To examine factors associated with change in the firearm-related mortality rate, the rates were separated into components based on the decomposition method, which was first described by Li and Baker (1996) to examine bicycling-related injury, and has been used for motor vehicle collision-related injury as well (Li et al., 1998; Dellinger et al., 2002; Zwerling et al., 2005). The decomposition method is based on the notion that a population death rate can be separated into components comprised of the number of deaths per injury (i.e., the case fatality rate), the injury incidence per unit of exposure, and the amount of exposure per individual. For the current study, the rates of firearm-related deaths overall, suicide, and unintentional mortality can be decomposed using the following equation:

$$\text{Rate}\left(\frac{\text{Deaths}}{\text{Population}}\right) = \frac{\text{No. firearms}}{\text{Population}} \times \frac{\text{Injuries}}{\text{No. firearms}} \times \frac{\text{Deaths}}{\text{Injuries}} \quad (1)$$

In the above equation, the first factor (i.e., the ratio of firearms to population) is a measure of public access to firearms (i.e., the exposure per individual); the second factor is the incidence of combined fatal and non-fatal injury related to the number of firearms (i.e., the injury incidence per unit of exposure); and the third factor is the case-fatality rate for firearm-related injury. The homicide rate includes the first and third factors; however, since these deaths are a result of violent crime, factors related to crime, particularly firearm-utilized robberies and assaults (FURAs) must be included in the equation:

$$\text{Rate}\left(\frac{\text{Deaths}}{\text{Population}}\right) = \frac{\text{No. firearms}}{\text{Population}} \times \frac{\text{FURAs}}{\text{No. firearms}} \times \frac{\text{Injuries}}{\text{FURAs}} \times \frac{\text{Deaths}}{\text{Injuries}} \quad (2)$$

For homicide, the second factor provides a measure of whether the stock of available firearms is related to the utilization of firearms (both legally and illegally obtained) in robberies and assaults, a notion

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