



Local gun violence, mental health, and sleep: A neighborhood analysis in one hundred US Cities

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ABSTRACT

Rationale: Community gun violence significantly shapes public health and collective well-being. Understanding how gun violence is associated with community health outcomes like mental health and sleep is crucial for developing interventions to mitigate disparities exacerbated by violence exposure.

Objective: This study examines the associations between community gun violence, insufficient sleep, and poor mental health across neighborhoods in the United States.

Methods: We utilized a novel database covering nearly 16,000 neighborhoods in 100 US cities from 2014 through 2019. Correlated trait fixed-effects models were employed to conduct all analyses while considering various neighborhood covariates such as concentrated disadvantage, demographic composition, population density, and proximity to trauma centers.

Results: Our analysis revealed that greater gun violence is associated with both insufficient sleep and poor mental health in subsequent years. There is a reciprocal relationship between poor mental health and insufficient sleep, with each partially mediating the other's association with community gun violence. Notably, gun violence exhibits the strongest direct association with poor sleep rather than with poor mental health. We found a consistent reciprocal relationship between sleep and mental health at the community level.

Conclusions: The findings highlight a complex interplay between community violence, sleep, and mental health, underlining the importance of reducing community violence through numerous long-term interventions to address health disparities across the US.

Gun violence is an ongoing public health threat in the United States (US). Firearm injuries and deaths have increased in recent years, particularly since the onset of the global COVID-19 pandemic. In 2021, more than 48,000 Americans died as a result of a firearm injury (Simon, 2022). Although non-fatal gun violence is not systematically documented in the US, research suggests non-fatal firearm injuries are roughly twice as prevalent as firearm deaths in any given year (Kaufman et al., 2021; Schnippel et al., 2021). Interpersonal gun violence (e.g., homicides, non-fatal shootings) continues to be highly concentrated in economically disadvantaged communities of color in many of America's cities (Johnson et al., 2021; MacDonald et al., 2022; Semenza et al., 2022a,b). Gun violence imparts a significant toll on mental, physical, and behavioral health for individuals and whole neighborhoods,

contributing to disparities in health and well-being across socioeconomic and racial lines (Buggs et al., 2022b; James et al., 2021; Leibbrand et al., 2021).

To date, much of the research on community violence and well-being has focused on mental health outcomes (Smith et al., 2020). Exposure to violence in one's community is linked to heightened rates of anxiety, depression, hypersensitivity, and post-traumatic stress (PTSD) (Fowler et al., 2009). Although a smaller body of research has considered the physical and behavioral health consequences of gun violence in local communities (Semenza & Stansfield, 2021a, 2021b; Wright et al., 2017), much of the work in this space has focused on individual-level outcomes rather than neighborhood-level assessments. Greater attention is needed to how gun violence exposure shapes varying facets of health across

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whole communities.

Given the dominant focus in the literature on mental health and individual-level outcomes, there has been relatively limited attention to behavioral health outcomes like sleep. Yet sleep is increasingly seen as a critical issue of public health given its downstream influence on wide range of mental and physical health outcomes as well as the prevalence of neurodegenerative diseases (Hale et al., 2020). Sleep is ultimately a function of multiple levels of influence ranging from individual behaviors to community-level factors with implications for health equity and related disparities (Jackson et al., 2015). As such, it is critical to examine the factors that shape collective sleep health across whole neighborhoods. The few studies that have assessed the specific association between community violence and sleep have typically relied on small convenience samples of individuals (Bagley et al., 2016; Cooley-Quille and Lorion, 1999; Lepore and Kliever, 2013; Rubens et al., 2014). No research to our knowledge has assessed the link between gun violence and sleep at the neighborhood level using longitudinal data. Further, there remains no research to account for the well-documented reciprocal relationship between inadequate sleep and poor mental health as it relates to gun violence in the community (Freeman et al., 2020; Palagini and Rosenlicht, 2011).

To address these gaps in the literature, we leverage a novel database of nearly 16,000 neighborhoods across 100 US cities from 2014 through 2019 to analyze the associations between community gun violence, poor mental health, and insufficient sleep. Using a series of correlated trait fixed-effects models over the course of six years, we pay particular attention to lagged relationships between these constructs while accounting for the reciprocal relationship between mental health and sleep. Following the results, we discuss how community gun violence serves to shape health outcomes across entire neighborhoods. We conclude that significantly reducing gun violence in local communities offers a meaningful pathway towards addressing broader health disparities throughout the US.

1. Background

Research on the health effects of violence exposure in local communities includes numerous types of violence encompassing gun violence, intimate partner violence, and other forms of assaultive violence between individuals like sexual assault and robbery. Community violence exposure is linked to poorer mental health (Fowler et al., 2009), physical health (Wright et al., 2017), and aspects of behavioral health such as diet, exercise, and tobacco use (Semenza and Stansfield, 2021b). Direct violent victimization is also harmful to both mental and physical well-being (Lee, 2012; Magee et al., 2022a, 2022b; Semenza et al., 2021, 2022). People are also exposed to violence through pathways that include secondary victimization (i.e., knowing a friend or family member that is attacked and/or killed) and broader vicarious exposure by witnessing or hearing about an attack in one's community (Magee et al., 2023; Semenza et al., 2023a; Sharkey, 2018). Research shows that youth are particularly vulnerable to experiencing multiple forms of community violence exposure, especially in low-income urban areas (Bancalari et al., 2022). Neighborhoods with high rates of violence including shootings and homicides are likely to be comprised of many individuals and families exposed to violence in one or more ways (Semenza et al., 2023b). This cumulative gun violence exposure has been associated with poor mental health outcomes including suicidal ideation and suicide attempt as well as increased symptoms of insomnia among Black and American Indian and Alaska Natives adults (Semenza et al., 2024a,b).

Researchers have consistently demonstrated an association between community gun violence exposure and poor mental health outcomes (Magee et al., 2022a, 2022b, 2023). Buggs et al. (2022b) showed that individuals proximate to shootings in their communities were more likely to experience symptoms of depression, especially Black boys, using national data from the Future of Families & Child Well-being

Study linked to shooting data from the Gun Violence Archive ($n = 3086$). In another study, individuals vicariously exposed to gun violence in four cities (Baltimore, New York, Philadelphia, and Washington DC; $n = 1615$) were more likely to report psychological distress, depression, suicidal ideation, and psychosis compared to those not exposed (Smith et al., 2020). In the same study, vicarious exposure to gun violence was significantly more likely among Black and Hispanic individuals, as well as those with low levels of income and education. In a third notable study of more than 50,000 children, those living within two to three blocks of a shooting in Philadelphia were more likely to utilize mental health-related pediatric emergency services two weeks, one month, and two months after the shooting than those not living near shootings (Vasan et al., 2021).

Despite these critical studies, much of the research on gun violence exposure and mental health remains focused on individual-level exposures and outcomes rather than community-level well-being. The emphasis on individual-level research potentially masks the far more expansive dynamics of exposure across entire communities. Research suggests that 99.9% of all Americans will now know a victim of gun violence during their lifetime, regardless of racial/ethnic group membership (Kalesan et al., 2016). In neighborhoods where gun violence is a daily reality, many residents are likely to be exposed to a shooting at any given time. This is especially true in urban communities of color that suffer from high levels of concentrated disadvantage where most residents are not involved in gun violence yet still endure its constant threat (Currie, 2020; Papachristos et al., 2012; Tracy et al., 2016). Given the various means by which an individual can be directly and indirectly exposed to gun violence, it is critical to expand this area of inquiry into how community violence corresponds to collective health outcomes.

1.1. Accounting for the reciprocal dynamics of mental health and sleep

Research on the health harms of community gun violence typically fails to account for a critical correlate of mental well-being: sleep. In a recent review of 23 studies, researchers documented a relationship between exposure to interpersonal violence (including sexual, physical, and psychological aggression) and sleep disturbance in all studies (Gallegos et al., 2021). Further, a substantial body of work has documented an intricate and bidirectional relationship between mental health and sleep (Fang et al., 2019; Thase, 2006). Poor mental health often makes it difficult to sleep properly and conversely, inadequate sleep is frequently harmful to mental well-being. In many cases, each contributes to the development and is also a consequence of one another (Alvaro et al., 2013). Numerous sleep problems including insomnia, insufficient nighttime sleep, daytime sleepiness, and circadian rhythm disturbances are highly comorbid with rates of depression and anxiety disorders (Alvaro et al., 2013; Germain, 2013; Germain et al., 2008; Kobayashi et al., 2007). In the scope of the present study, we thus consider not only how gun violence exposure corresponds to mental health in communities, but also how this exposure affects community sleep while accounting for the reciprocal association and potential for mediation between the two. We draw on a public health conception of community sleep health as a key indicator of overall health in a given population shaped by social and contextual factors with implications for broader health disparities (Curtis et al., 2017; Hale et al., 2020; Jackson et al., 2015).

Those exposed to gun violence either directly or vicariously are likely to have heightened concerns about their own safety, often experiencing states of hyperarousal and heightened vigilance (Bagley et al., 2016; Fowler et al., 2009). This blend of fear, distress, and hypersensitivity is contradictory to good quality sleep since worry about one's safety or that of loved ones can interfere with sleep initiation, sleep duration, and the quality of sleep throughout the night (Dahl, 1996). Further, individuals who have been directly victimized are likely to deal with chronic pain, post-traumatic stress, and substance use, all of which are harmful to proper sleep practices (Lee, 2012). Communities with high

rates of gun violence exposure are likely to have a greater prevalence of poorer mental health among their residents, which may simultaneously serve to harm the collective sleep health of those living in the community.

A handful of studies demonstrates that exposure to community violence is linked to sleep problems, poorer sleep efficiency, and greater incidence of sleep disturbance (Bagley et al., 2016; Cooley-Quille and Lorion, 1999; Lepore and Klierer, 2013). Notably, most of the research in this area has focused on adolescents rather than adult populations. For instance, in a study of 252 adolescents in the southeastern United States, researchers found that concerns about community violence predicted lower sleep efficiency, longer wake episodes, and more sleep/wake problems (Bagley et al., 2016). In a longitudinal study of 498 seventh-graders, the authors found that community violence exposure was associated with lower grade point average indirectly via sleep problems while controlling for depressive symptoms (Lepore and Klierer, 2013). Similarly, Cooley-Quille and Lorion (1999) demonstrated that self-reported exposure to community violence was positively associated with sleep deprivation among a small sample of African American youth ($n = 64$). Taken together, these individual-level studies suggest that gun violence exposure may be associated with poorer sleep outcomes.

1.2. Current study

Extant literature suggests that gun violence in the community is associated with both poorer mental health and negative sleep outcomes. Much of the research on these two outcomes in relation to gun violence has been conducted among individuals with less attention to analyses at broader levels of the social ecology like neighborhoods. Further, there has been little research to examine how community gun violence impacts both sleep and mental health while accounting for the documented reciprocal link between the two. Using data on nearly 16,000 neighborhoods (i.e., census tracts) in 100 US cities over six years, we offer the following research questions to guide our analyses:

1. What is the association between community gun violence and the prevalence of poor mental health in local neighborhoods?
2. What is the association between community gun violence and the prevalence of insufficient sleep in local neighborhoods?
3. How are poor mental health and insufficient sleep reciprocally associated with one another in local communities?

2. Data & methods

We created a neighborhood-level database including the 100 largest cities in the U.S., amounting to 15,882 census tracts available for analysis (see Appendix for a full list and map of the cities included). We obtained tract-level data on the number of fatal and non-fatal shootings in each census tract from the American Violence Project at Princeton University and combined these data with community health measures from the Centers for Disease Control and Prevention (PLACES Project) and social and economic conditions of neighborhoods from the American Communities Survey (ACS). We collected data for each neighborhood and year from 2014 through 2019.

Health Outcomes. Measures of insufficient sleep and mental health were extracted from the CDC's PLACES project, a collaboration between the CDC, Robert Wood Johnson Foundation, and the CDC Foundation. The project provides census tract estimates of a wide range of health behaviors and general health indicators commonly used in community-health research (Forthman et al., 2021; Nardone et al., 2020). We focus on two measures available in the data. *Insufficient sleep* is measured as the percentage of adults aged 18 or over that sleep less than 7 hours a night on average in each census tract. This measure was created using the Behavioral Risk Factor Surveillance System question, "On average, how many hours of sleep do you get in a 24-hour period?" Responses

were coded to indicate "short sleep duration" if respondents reported sleeping less than 7 hours a night on average. Higher scores indicate a greater prevalence of insufficient sleep, which is associated with a range of additional poor physical health outcomes, mental distress, and mortality (Liu et al., 2016).

Due to inconsistent data measurement by the CDC, we estimated the prevalence of insufficient sleep in 2015, 2017, and 2019 by averaging insufficient sleep the prior year and subsequent year and multiplying it by the slope of the linear trendline across insufficient sleep in 2014, 2016, 2018, and 2020. Random variation was introduced into the estimates by multiplying the slope by a random number selected from a normal distribution with a mean of 0 and a standard deviation equal to the standard error of the slope. This process was deemed an appropriate technique to estimate the prevalence of insufficient sleep in 2015, 2017, and 2019 given a very high degree of stability in insufficient sleep over time. For instance, insufficient sleep in 2014 had a 0.92 correlation with insufficient sleep in 2020, suggesting that neighborhood levels of insufficient sleep vary relatively little over time.

Poor mental health reflects the percentage of adults who reported 14 or more poor mental health days in the past month. A higher prevalence reflects poorer community mental health. This aggregate measure is based on self-reported days of poor mental health, which is widely used to quantify the community prevalence of mental distress (Bor et al., 2018) and is associated with several diagnosed mental conditions (Slaubaugh et al., 2017).

Gun Violence. We measure *number of shootings* by combining the number of fatal and non-fatal shooting incidents per tract-year. We obtained tract-level counts obtained from the American Violence Project (americanviolence.org), an effort by researchers at Princeton University to provide up-to-date neighborhood level data on gun violence for the largest cities in the U.S. based on 2010 census information.

Time Invariant Covariates. Our analyses adjust for variation in measures commonly associated with both community gun violence and poor health outcomes. We utilized a factor analysis to create a measure of *concentrated disadvantage* for each census tract that combined the following: (1) the percentage of families that live below the poverty line [0.904]; (2) the percentage of the working age civilian population unemployed [0.726]; and (3) the percentage of families headed by a female in 2014 [0.808] (RMSEA 0.274; CFI 0.156; TLI 0.044; SRMR 0.630). These items are commonly combined in statistical analyses for empirical and conceptual reasons. Empirically, these measures tend to be highly correlated while conceptually they capture the accumulation of disadvantage from multiple aspects in local communities (McCall et al., 2010).

To capture the age- and sex-structure of a community, we control for the *ratio of female to male residents* (number of females divided by the number of males), and the *percentage of the population* ages 18–34, 35–64, and 65 and over. We additionally include the *% of young males* in a given neighborhood between ages 15 and 24. Given the increasing health risks associated with older age, we also measure older age in five-year increments, including the percentage ages 65–69, 70–74, 75–79, and 80–84. We additionally control for the *distance to the nearest trauma center* since this can influence differences between fatal and non-fatal shooting rates (Circo and Wheeler, 2021). As in prior research (Semenza and Stansfield, 2021a,b), this is measured as the distance from the centroid of each neighborhood to the nearest Level 1 or Level 2 trauma center and created in qGis 3.1.

In addition, given evidence of social isolation as a risk factor for poor health (Holt-Lunstad), we include the percentage of the *population living alone*. We also include percentages of the *number of people living in a household* using the following categories, which make up the large majority of the neighborhoods: two, three, and four persons. We were unable to include additional categories of this measure (e.g., 1 person, 5+ persons) because it rendered the covariance matrix identifiable and prevented our main models from running. Finally, we include a measure of *population density*, measured as the population of the neighborhood

divided into land size in square miles. Due to a high degree of multi-collinearity when introduced into the model, we note that the percentage of residents that identified as Black was not included when estimating the model as a covariate or as a component of the concentrated disadvantage factor.

3. Analytic strategy

We developed a four-part analytic strategy to evaluate the association between neighborhood gun violence (2014–2018) with both poor mental health (2015–2019) and insufficient sleep (2015–2019) across census tracts. First, we produced descriptive statistics for the analytic sample. Second, we estimated a correlated traits model using fixed effects across years (Beasley, 2008). A correlated traits model is an iteration of a path model examining the predictors of two inter-connected dependent variables (Tackett et al., 2019). The correlated traits model for the current study was estimated by regressing poor mental health on neighborhood gun violence and the identified covariates, while simultaneously regressing insufficient sleep on neighborhood gun violence and the identified covariates. A residual covariance between poor mental health and insufficient sleep was specified to adjust for the shared variation between the dependent variables. Given empirical associations observed in prior literature, we anticipated poor mental health and insufficient sleep to be inter-dependent constructs requiring an analytical approach that accounts for the covariance between the two measures (e.g., Owens and Weiss, 2017).

Third, we regressed poor mental health (2015–2019) on insufficient sleep (2014–2018), gun violence (2014–2018), and the identified covariates using a fixed effects linear regression model. We also regressed insufficient sleep (2015–2019) on poor mental health (2014–2018), gun violence (2014–2018), and the identified covariates using a fixed effects linear regression model. Finally, to further examine potential mediation and the interdependence between insufficient sleep and poor mental health, we decomposed the direct, indirect, and total effects of gun violence (2014–2018) on insufficient sleep (2016–2019) through poor mental health (2015–2019) as well as the direct, indirect, and total effects of gun violence (2014–2018) on poor mental health (2016–2019) through insufficient sleep (2015–2019). All models in our analysis thus leverage a lagged year-over-year approach to predict how exposures in one year influence outcomes the following year while simultaneously accounting for the pertinent covariates and reciprocal links between mental health and sleep.

All of the models were estimated using the full information maximum likelihood (FIML) estimator in the R package, Lavaan (Rosseel, 2012). FIML is a missing data technique developed for structural equation models that leverages the available information – under the assumption that the data is missing at random – to compute population estimates that would have given rise to the data (missing and non-missing). FIML does not directly impute values for missing cases, but rather uses both the missing and non-missing information to generate potential estimates that could give rise to the observed covariance between two constructs, with the final estimate representing the estimate with the maximum likelihood of being observed in the population (Enders and Bandalos, 2001). The performance of FIML has been evaluated on multiple conditions with violations of key assumptions against all other imputation techniques. The findings generally suggest that FIML is one of the more robust imputation techniques available (Han and Guo, 2019; Lee and Shi, 2021; Liu and Sriutaisuk, 2021).

With regards to missing data, the number of missing cases on insufficient sleep ranged between 824 in 2015 (~5 percent) to 316 (~2 percent) in 2014. The number of missing values on poor mental health ranged between 824 in 2015 (~5 percent) to 156 (~1 percent) in 2019. No missing values existed on the gun violence measures, while there were less than 100 missing cases across the remainder of the covariates (<1 percent). The R-script for all analyses and the raw results, including

the full models including controls portrayed in the figures below, are available in the following repository: https://anonymous.4open.science/r/gunviolence_mentalhealth_sleep-080F/

4. Results

Table 1 provides the descriptive statistics for the analytic sample of 15,881 neighborhoods. Across the full sample, neighborhoods experienced approximately one shooting (fatal or non-fatal) each year on average, though the number of average annual shootings in a census tract notably ranged widely between 0 and 112, depending upon the year (the outlier of 112 total shootings in 2016 is due to the Pulse nightclub shooting in Orlando that year). On average, the number of shootings increased by about 30 percent from 0.9 shootings per tract in 2014 to 1.2 shootings per tract in 2019. Similarly, there was an increase in the percentage of those reporting poor mental health per tract from 13 percent in 2014 to 15.3 percent in 2019. The percentage of those reporting insufficient sleep varied from 2014 to 2019, ranging between 36.9 percent in 2019 to 38.6 percent in 2018.

Fig. 1 depicts the primary estimates derived from the fixed effects correlated traits model. Greater levels of gun violence in 2014–2018 were associated with increases in poor mental health in 2015–2019 and insufficient sleep in 2015–2019, after accounting for the correlation between the dependent variables. A one shooting increase was associated with a roughly 0.014 percent increase in local residents who report 14 or more days of poor mental health in the past month. In other words, between 1 and 2 additional people would be expected to experience 14 or more days of poor mental health per shooting in a neighborhood of 10,000 people. Similarly, a one shooting increase was associated with a 0.204 percent increase of neighborhood residents reporting insufficient

Table 1
Descriptive statistics (N = 15,881 census tracts).

	Mean	SD	Min	Max
<i>Number of Shootings</i>				
2014	0.9	2.0	0.0	44.0
2015	1.0	2.3	0.0	35.0
2016	1.2	2.9	0.0	112.0
2017	1.2	2.6	0.0	48.0
2018	1.1	2.5	0.0	48.0
2019	1.2	2.5	0.0	47.0
<i>% Poor Mental Health</i>				
2014	13.0	3.8	4.9	30.3
2015	13.1	3.6	4.8	29.8
2016	13.2	3.5	5.2	29.4
2017	14.0	3.7	5.8	32.6
2018	14.6	3.8	5.9	35.5
2019	15.3	3.9	6.5	38.6
<i>% Insufficient Sleep</i>				
2014	38.1	6.7	20.0	59.8
2015	37.9	6.4	20.9	58.2
2016	37.6	6.2	20.9	58.7
2017	38.1	6.1	21.1	58.5
2018	38.6	6.3	21.3	60.8
2019	36.9	5.9	21.5	57.3
<i>Time Invariant Covariates</i>				
Concentrated Disadvantage	13.7	9.2	0.0	100.0
Male Female Sex Ratio	5.0	3.8	0.0	4.4
% Young Males (15–24)	3.0	2.7	0.0	82.3
Miles to Trauma Center	4.7	8.4	0.0	141.3
Percent Living Alone	5.0	3.8	0.0	60.5
% Age 18–34	28.1	11.2	0.0	100.0
% Age 35–64	37.7	7.2	0.0	100.0
% Age 65–69	3.7	2.0	0.0	55.0
% Age 70–74	2.7	1.7	0.0	30.0
% Age 74–79	2.0	1.5	0.0	25.4
% Age 80–84	1.6	1.4	0.0	30.3
% 2-Person Household	40.8	14.8	0	100
% 3-Person Household	23.8	6.2	0	100
% 4-Person Household	18.7	6.4	0	100
Population Density	14690.6	21723.2	0.9	245883.9

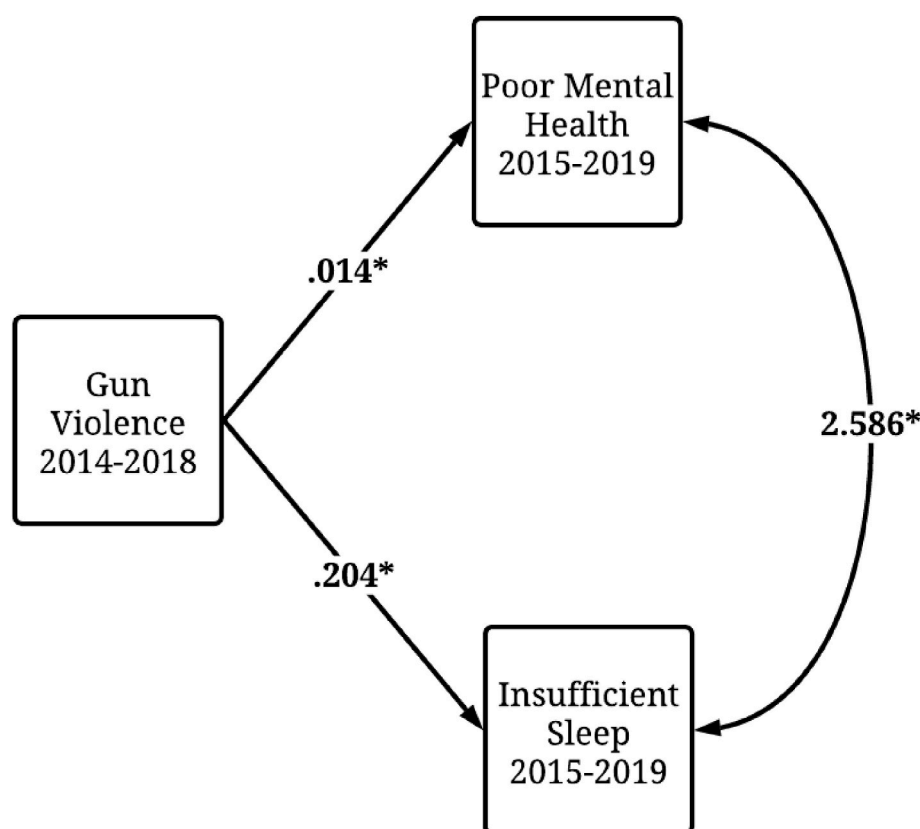


Fig. 1. Correlated Traits Fixed-Effects Model Estimating the Lagged Effects of Gun Violence on Poor Mental Health and Insufficient Sleep.

Notes: The single headed arrows represent regression coefficients, while the double headed arrow represents the residual covariance between the dependent variables. The estimates presented in the model adjusted for the confounding effects of concentrated disadvantage (2014–2019), percent living alone, male female ratio, percent male between 15 and 24, miles to nearest trauma center, percent age 18 to 34, percent age 35 to 64, percent age 65 to 69, percent age 70 to 74, percent age 75 to 79, percent age 80 to 84, percent 2 person households, percent 3 person households, percent 4 person households, and population density. Nobservations = 79,410, Nneighborhoods = 15,882.

* $p < 0.001$.

sleep, meaning that in a neighborhood of 10,000 people, about 20 more people would experience insufficient sleep for every additional shooting. Higher levels of insufficient sleep covaried with greater levels of poor mental health at the $p < 0.001$ level. Taken together, these findings suggest that gun violence was associated with increases in both poor mental health and insufficient sleep the subsequent year.

Fig. 2 provides the abridged results of the fixed effects models estimating the effects of gun violence and poor mental health on insufficient sleep (Panel A) and the effects of gun violence and insufficient sleep on poor mental health (Panel B). As shown in Panel A, a one shooting increase was associated with a 0.193 percent increase in neighborhood residents reporting insufficient sleep, while increases in poor mental health were associated with a 0.795 percent increase in neighborhood residents reporting insufficient sleep. Importantly, gun violence (2014–2018) and poor mental health (2014–2018) covaried at the $p < 0.001$ level.

Panel B shows that after accounting for the covariance between gun violence and insufficient sleep in the same years (2014–2018), gun violence was associated with a slight reduction in subsequent poor mental health in 2015–2019, where a single shooting was associated with a 0.016 percent decrease in local residents who report 14 or more days of poor mental health in the past month. Nonetheless, higher levels of insufficient sleep were associated with greater levels of poor mental health, where a 1 percent increase in insufficient sleep was associated with a 0.150 percent increase among neighborhood residents with poor mental health.

To disentangle potential mediation, Table 2 provides a breakdown of

the direct, indirect, and total effects of gun violence (2014–2018) on insufficient sleep (2016–2019) accounting for the mediating effects of poor mental health (2015–2019) and the direct, indirect, and total effects of gun violence (2014–2018) on poor mental health (2016–2019) accounting for the mediating effects of insufficient sleep (2015–2019). The estimates provided in Table 2 were produced using the Delta method for testing mediation effects (MacKinnon et al., 2002). These findings suggest that the effects of gun violence (2014–2018) on insufficient sleep (2016–2019) are partially mediated by poor mental health (2015–2019), with gun violence having a statistically significant total effect and indirect effect through poor mental health (2015–2019). Similarly, the findings suggest that gun violence (2014–2018) had a statistically significant total effect and indirect effect on poor mental health (2016–2019), with insufficient sleep (2015–2019) partially mediating the association.

5. Discussion

Ample evidence supports the hypothesis that exposure to violence in local communities is harmful for mental and physical health. As a result, the study of mental health has become essential to violence intervention and prevention, especially for individuals from disadvantaged neighborhoods (Johnson et al., 2021; MacDonald et al., 2022; Semenza et al., 2022a,b). Physical health is also a critical area of inquiry; however, there has been limited research about the impact of gun violence exposure on sub-domains of physical health, including sleep. Findings from our study support the hypothesis that gun violence is associated

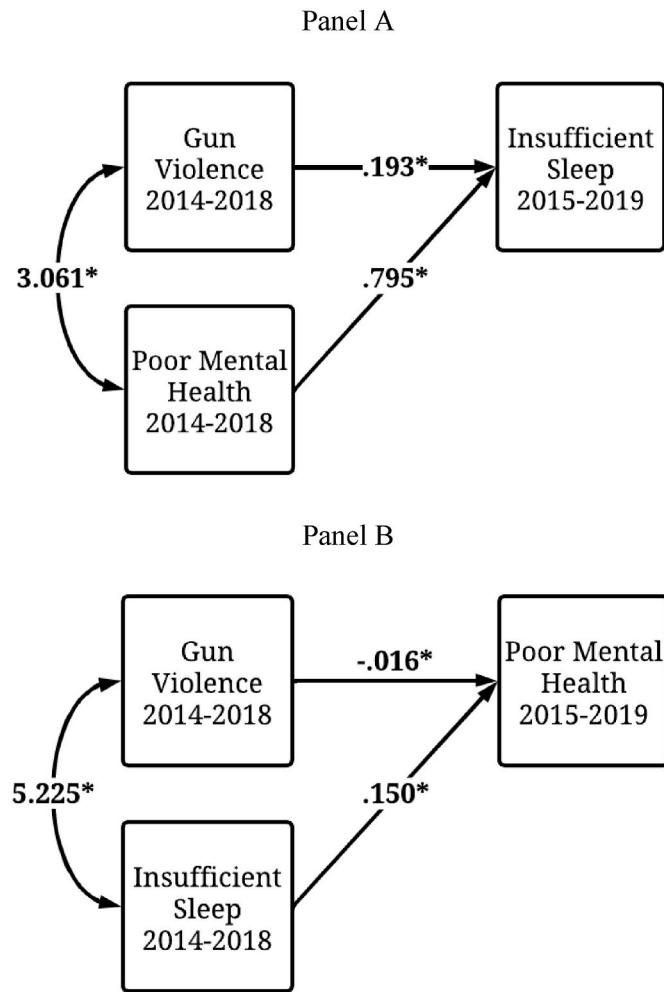


Fig. 2. Fixed-Effects Model Estimating the Lagged Effects of Gun Violence and Poor Mental Health on Insufficient Sleep (Panel A) and Gun Violence and Insufficient Sleep on Poor Mental Health (Panel B).

Notes: The single headed arrows represent regression coefficients, while the double headed arrow represents the residual covariance between the dependent variables. The estimates presented in the model adjusted for the confounding effects of concentrated disadvantage (2014–2019), percent living alone, male female ratio, percent male between 15 and 24, miles to nearest trauma center, percent age 18 to 34, percent age 35 to 64, percent age 65 to 69, percent age 70 to 74, percent age 75 to 79, percent age 80 to 84, percent 2 person households, percent 3 person households, percent 4 person households, and population density. Nobservations = 79,410, Nneighborhoods = 15,882.

* $p < 0.001$.

with both insufficient sleep and poorer mental health outcomes in local communities. Yet our results highlight the complex reciprocal relationship that exists between gun violence, sleep sufficiency, and mental health at the community level.

We found that gun violence was associated with increases in both poor mental health and insufficient sleep the subsequent year. Importantly, our main models accounted for the bidirectional relationships between health constructs. The results depicted in Fig. 1 suggest that gun violence in a community corresponds to heightened risk for both poorer mental health and insufficient sleep, which influence one another in subsequent years. The heightened stress, anxiety, and fear that accompanies living in a violent neighborhood are harmful to mental health, which serves to interrupt sleep. At the same time, gun violence exposure in its various forms (i.e., hearing shots or witnessing a shooting, knowing a friend or family member that was shot) is likely to compound in neighborhoods to inhibit proper sleep, which may

Table 2

Reciprocal mediating effects on the association between gun violence (14–18) and insufficient sleep (16–19) and poor mental health (16–19).

	b	SE	p-value	ci. lower	ci. upper	Std.all
DV: Insufficient Sleep (16–19)						
<i>Indirect Effects</i>						
Gun Violence (14–18) Through Poor Mental Health (15–19)	0.011	0.002	<0.001	0.006	0.015	0.004
<i>Direct Effects</i>						
Gun Violence (14–18) on Insufficient Sleep (16–19)	0.196	0.007	<0.001	0.183	0.208	0.078
<i>Total Effects</i>						
Gun Violence (14–18)	0.206	0.007	<0.001	0.193	0.220	0.082
DV: Poor Mental Health (16–19)						
<i>Indirect Effects</i>						
Gun Violence (14–18) Through Insufficient Sleep (15–19)	0.032	0.001	<0.001	0.030	0.034	0.021
<i>Direct Effects</i>						
Gun Violence (14–18) on Poor Mental Health (16–19)	–0.016	0.003	<0.001	–0.022	–0.010	–0.010
<i>Total Effects</i>						
Gun Violence (14–18)	0.016	0.003	<0.001	0.010	0.022	0.010
N Observations	79,405					

generate additional harms to mental well-being (Alvaro et al., 2013).

However, the reciprocal results depicted in Fig. 2 and the decomposed mediation effects in Table 2 offer nuance to the main findings. Although gun violence and poor mental health appear to have significant, positive associations with insufficient sleep (Panel A, Fig. 2), the results for mental health in Panel B are less consistent, suggesting that gun violence was actually negatively associated with mental health. This was a surprising finding given much of the individual-level research showing the gun violence is associated with poorer mental health outcomes (Fowler et al., 2009; Smith et al., 2020). However, the mediation results depicted in Table 2 provide clarity, indicating that gun violence is most clearly associated with mental health via an indirect pathway through insufficient sleep. On the other hand, gun violence is most strongly associated with insufficient sleep via a direct pathway, through it still imparts smaller effects through an indirect pathway via poor mental health.

Taken together, our results suggest that community gun violence may be particularly consequential for collective sleep health with downstream consequences for mental well-being in local neighborhoods. Community members who consistently experience inadequate or disrupted sleep are at increased risk of developing various physical and mental health problems (Gallegos et al., 2021; Fang et al., 2019; Thase, 2006). Over time, sleep deprivation can contribute to the development of chronic conditions such as obesity, diabetes, cardiovascular disease, and compromised immune function (Freeman et al., 2020). It can also negatively impact cognitive function, memory consolidation, and overall mental well-being. Our findings are consistent with previous work that explores how inadequate sleep is related to mood disorders, such as depression and anxiety, and can contribute to heightened stress levels and irritability (Freeman et al., 2020). Poor mental health is also likely to exacerbate sleep issues (Mirchandaney et al., 2023; Nutt et al., 2008), though our findings suggest the magnitude of this particular directional association is smaller. Overall, the long-term consequences

of poor sleep underscore the importance of prioritizing and maintaining healthy sleep habits in communities where violence is not uncommon for optimal health and well-being.

Gun violence is situated within the unique socio-historical context of the US and rooted deeply in racial, economic, and social injustices. Many factors contribute to the concentration of violence in communities across the U.S., including poverty and neighborhood disadvantage (Semenza et al., 2022a,b). Black and Hispanic individuals are most likely to live in these communities and are disproportionately impacted by gun violence. These circumstances thus shape increased risk for adverse physical and mental health outcomes particularly for Black and Hispanic communities (Buggs et al., 2022b; James et al., 2021; Leibbrand et al., 2021, Bamwine et al., 2020). We posit that any meaningful effort to address health disparities in the US across socioeconomic and/or racial lines must include evidence-based and properly funded strategies to reduce gun violence.

Reducing gun violence in disadvantaged neighborhoods can positively influence community health outcomes through several mechanisms. First, it can decrease the immediate physical harm caused by firearm injuries, saving lives and reducing the burden on healthcare systems. Second, it can mitigate the psychological trauma experienced by individuals and communities affected by gun violence, improving mental health and well-being. Third, reducing gun violence can alleviate fear, restore community trust, and promote social cohesion, which is critical for fostering healthy and resilient communities. Our results demonstrate that gun violence is linked to both mental well-being and sleep outcomes, highlighting the need to consider each of these mechanisms for continuing violence reduction efforts.

To achieve sustainable improvements in community health outcomes, comprehensive strategies for gun violence reduction are necessary. A holistic, wrap-around approach that combines culturally relevant, trauma-informed, and evidence-based interventions provides the most inclusive model for intervention and prevention. Strategies should include but not be limited to enhancing firearm regulations, promoting safe storage practices, and investing in community-based prevention programs such as job-skills training, school-based socio-emotional learning curriculums, and hospital-based interventions to improve overall well-being.

Some evidence suggests that community violence intervention (CVI) programs can significantly reduce gun violence, though the success of these programs is likely dependent on adequate funding and local organizational context (Bhatt et al., 2024; Buggs et al., 2022a; Ross et al., 2023; Webster et al., 2013, 2023). Police-community partnerships based on a focused deterrence model have also been found to substantially decrease shootings in many places around the country (Braga et al., 2018; Braga et al., 2019). However, any strategy that involves policing efforts must be embedded within a framework that takes seriously the implications for procedural and social justice in the communities where these programs are implemented (Brunson, 2015; Trinkner, 2019). Community-based and police-inclusive programs to reduce gun violence are not necessarily mutually exclusive, but rather must be synthesized effectively to reduce community harm in the most effective yet equitable manner possible. By adopting a multi-faceted and multi-level approach that combines policy, evidence-based interventions, and community engagement, neighborhoods can strive towards creating safer environments and improving overall health outcomes.

5.1. Study limitations

This study is not without certain limitations. The CDC PLACES database provides valuable information on sleep duration and mental health at the population level. However, we cannot make inferences about individual level dynamics using these data. Researchers should continue to evaluate how different types of gun violence exposure correspond to diverse sleep and mental health outcomes, especially

among populations at disproportionate risk for exposure including Black, American Indian and Alaska Native (AI/AN), and Hispanic men and women. We encourage future researchers to consider factors unavailable in our data that may contribute to insufficient sleep in local neighborhoods related to community differences in noise, light, season, heat, and prevalence of shift work. Researchers should additionally work to account for further neighborhood-level factors related to policing presence and gang dynamics likely to shape gun violence exposure in local neighborhoods. Although the CDC PLACES database enables a lagged analytic approach like the one used in this study, the data do not facilitate the direct measurement of temporal changes within populations since the same population for census tracts is used across multiple years in the CDC's estimates. Future studies should aim to assess change models using individual or population-level data with extended timeframes wherever possible.

We also note limitations associated with reliance on self-reported measures of sleep duration and mental health. Self-report questionnaires are susceptible to recall bias, social desirability bias, and individual interpretation differences. Sleep duration, in particular, can be influenced by individual perceptions of time spent in bed versus actual sleep time, variations in sleep quality, and discrepancies between weekday and weekend sleep habits (Lauderdale et al., 2008). Similarly, self-reported mental health measures may not capture the full range of psychiatric conditions, symptom severity, clinical diagnoses, or comorbidities that impact physical and mental health (Fleishman and Zuvekas, 2007). Future investigations should incorporate objective measurements of health where possible, such as actigraphy or polysomnography, to assess sleep duration objectively. Additionally, including clinical diagnoses would provide a more precise understanding of the relationship between sleep and mental health.

6. Conclusion

Despite these limitations, this study provides valuable insight into the complex relationship between gun violence, sleep duration, and mental health in local communities. Our findings support the notion that a truly comprehensive solution to address population health disparities must include long-term, multi-faceted, and financially supported efforts to reduce gun violence. This is particularly important for communities that experience high rates of gun violence and suffer from heightened concentrated disadvantage. Gun violence is an epidemic in the US and its broader damages to collective well-being will undoubtedly continue without comprehensive and decisive action.

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CRediT authorship contribution statement

Daniel C. Semenza: Conceptualization, Data curation, Investigation, Supervision, Writing – original draft, Writing – review & editing. **Ian A. Silver:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Richard Stansfield:** Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. **Patricia Bamwine:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing.

Data availability

All data and accompanying code for our analyses are publicly available using the link provided in the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.socscimed.2024.116929>.

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