To Treat or to Prevent?

Reducing the Population Burden of Violence-related Post-traumatic Stress Disorder

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Background: Violence-related post-traumatic stress disorder (PTSD) remains a prevalent and disabling psychiatric disorder in urban areas. However, the most effective allocation of resources into prevention and treatment to reduce this problem is unknown. We contrasted the impact of two interventions on violence-related PTSD: (1) a population-level intervention intended to prevent violence (i.e., hot-spot policing), and (2) an individual-level intervention intended to shorten PTSD duration (i.e., cognitive-behavioral therapy—CBT).
Methods: We used agent-based modeling to simulate violence and PTSD in New York City under four scenarios: (1) no intervention, (2) targeted policing to hot spots of violence, (3) increased access to CBT for people who suffered from violence-related PTSD, and (4) a combination of the two interventions.
Results: Combined prevention and treatment produced the largest decrease in violence-related PTSD prevalence: hot-spot policing plus a 50% increase in CBT for 5 years reduced the annual prevalence of violence-related PTSD from 3.6% (95% confidence interval = 3.5%, 3.6%) to 3.4% (3.3%, 3.5%). It would have been necessary to implement hot-spot policing or to increase CBT by 200% for 10 years for either intervention to achieve the same reduction in isolation.
Conclusions: This study provides an empirically informed demonstration that investment in combined strategies that target social determinants of mental illness and provide evidence-based treatment to those affected by psychiatric disorders can produce larger reductions in the population burden from violence-related PTSD than either preventive or treatment interventions alone. However, neither hot-spot policing nor CBT, alone or combined, will produce large shifts in the population prevalence of violence-related PTSD.

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Interpersonal violence is one of the core public health issues in US cities today. Homicide is one of the leading causes of death for individuals under the age of 45 years,[1] and most of the individuals who do survive assaultive violence experience long-term psychological and physical trauma.[2] The problem of violence is especially concentrated in urban areas: in 2012, more than half of all homicides in the US occurred in cities with more than 100,000 residents, and more than a quarter occurred in cities with more 500,000 residents.[2]

One of the central consequences of violence is violence-related post-traumatic stress disorder (PTSD).[3] Assault, mugging, and rape are among the traumatic events with the strongest association with PTSD.[4–6] In violent urban neighborhoods, violence exposure can arise from direct risk of victimization, as well as continuous witnessing of victimization of friends, family, and neighbors. Hence, addressing violence-related PTSD is critical to developing a comprehensive urban mental health agenda.

Only 34.4% of persons with PTSD receive mental health treatment.[7] Among those who receive treatment, it takes an average of 12 years after first onset of symptoms to access treatment.[8] The persistent problem of urban violence, and low treatment access, suggest that primary prevention of the causes of violence-related PTSD may be needed to reduce this problem in urban areas. However, the allocation of resources to primary prevention versus medical treatment of violence-related PTSD requires resource trade-offs, and the potential benefits of this trade-off remain unknown.

The question, then, is to what extent should resources be allocated to primary prevention of the causes of violence-related PTSD in urban areas, and to what extent should they be allocated to medical treatment of the disorder? Building on data from evidence-based interventions, we contrast the impact

of two interventions on the prevalence of violence-related PTSD: (1) a population-level violence preventive intervention, and (2) an individual-level treatment intervention. For violence prevention, we focused on hot-spot policing, which concentrates police crime prevention interventions at crime hot spots.[9–11] This type of policing is based on the findings that small places, or "hot spots" within neighborhoods, generate half of all criminal events,[12] and that crime can be reduced more efficiently if limited police resources are focused on a small number of high-activity areas of crime.[11,13] A meta-analysis found that hot-spot policing reduced citizen calls for service in treatment compared with control sites, and had unintended crime prevention benefits in neighboring areas.[11] For medical treatment, we focused on cognitive behavioral therapy (CBT). CBT is a psychotherapeutic approach that can include confrontation of memories or triggers related to the traumatic event (i.e., exposure therapy), as well as developing skills to manage anxiety and challenge distorted cognitions (i.e., cognitive restructuring).[14] Meta-analyses of randomized trials found that improvement of PTSD symptoms was greater for treatment than for waitlist or supportive control participants.[14,15]

We used data from empirically guided research on these interventions and agent-based modeling[16] to simulate a series of experiments designed to answer two major questions: (1) what is the comparative impact of hot-spot policing versus CBT on population-level rates of violence-related PTSD? and (2) what is the optimal combination of hot-spot policing and CBT to achieve the greatest reductions in violence-related PTSD? Agent-based modeling consists of computer simulations used to examine the interactions among people, places, and time. It is a type of complex systems approach that is particularly well suited for problems shaped by interactions between individuals and feedback loops in causal mechanisms, such as violence and PTSD. Furthermore, it is well-suited for the evaluation of interventions where the exposure or treatment assignment of one individual is dependent on the outcome of others in the population (i.e., interference)—such is the case with, for example, hot-spots policing.[17] By simulating sets of alternative interventions in the same agent population, agent-based modeling can be interpreted as counterfactual outcomes.[17] It can thus help us refine hypotheses about the sets of interventions that might be most effective in promoting population health.
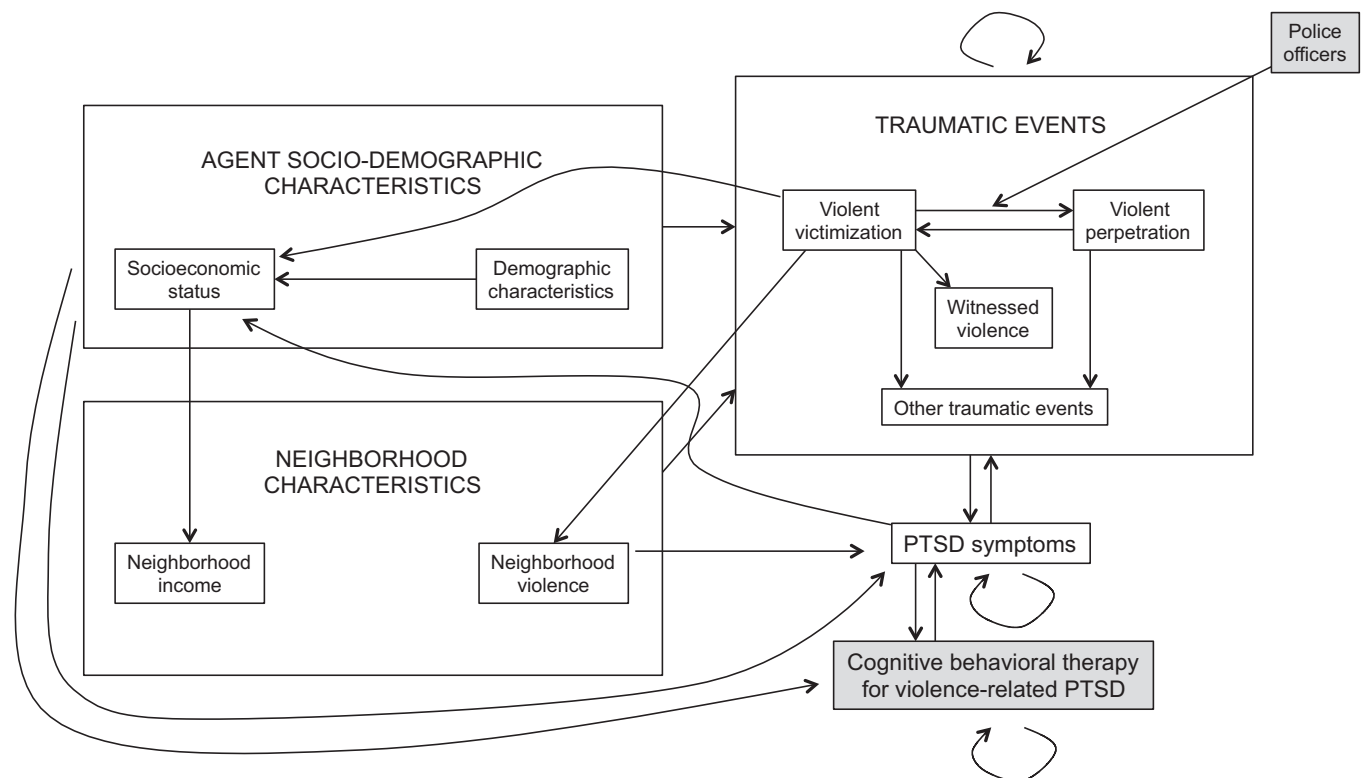
FIGURE 1. Diagram of relations in the agent-based model. Individuals were assigned to neighborhoods based on their age, race/ethnicity, sex, and household income; neighborhood characteristics were averaged from individual residents. Individual experiences of traumatic events (including violence) were influenced by individual socio-demographic characteristics, prior experiences of trauma and PTSD, and neighborhood characteristics. PTSD symptoms were influenced by individual- and neighborhood-level socio-demographic characteristics as well as particular traumatic experiences. Police officers could prevent the occurrence of violence when potential victims and perpetrators came into contact with each other. Mental health treatment for PTSD symptoms resulted in a faster resolution of symptoms.

METHODS

We developed an agent-based model simulating experiences of violence and violence-related PTSD among the adult population residing in the neighborhoods of the largest US urban area: New York City (NYC). Figure 1 summarizes the relations included in the model. Additional details about model parameters and processes, including a description of the model organized according to the Overview, Design concepts, Details protocol,[18,19] a flow chart illustrating the steps in the model, and pseudo-code, are also included in eMethods 1 and 2 (http://links.lww.com/EDE/A937). Data from NYC sources were used to parameterize the model when possible; when NYC data were not available, national or other community-based data were used (see data sources in eTable 1; http://links.lww.com/EDE/A937).

Model Initialization

Agent Population

The population of 60,000 agents was initialized to approximate a 1% sample of the NYC adult population (18 years and over) in the year 2000 (eFigure 1; http://links.lww.com/EDE/A937).[20] The year 2000 was chosen because most data used to parameterize agent behaviors were only available for the mid-2000s.

Neighborhoods

We assigned each agent to a location on a 400 × 625 cell grid representing the physical area of New York City. The grid was divided into 42 smaller areas reflecting the NYC United Hospital Fund neighborhoods: aggregations of zip codes with similar characteristics used to organize sampling for NYC Community Health Surveys.[21] Agents were assigned to each area to match United Hospital Fund Census data.[22]

Police Officers

Agents serving as police officers were created at baseline: a 1% sample of the number of police officers in NYC in 1990–1993 was generated, based on NYC Police Department data (N = 15,770).[23] These were the years before the police force increased as part of an order-maintenance policing strategy, which served as a baseline estimate of available policing resources. The number of police officers assigned to each neighborhood was in proportion to the population size of the neighborhood, with officers assigned to random locations within the neighborhood.

Agent Behaviors and Experiences

Aging, Mortality, and Movement

At each time step, agents aged by 1 year, they could move to a new location in the model, and some agents died, consistent with 2000 NYC adult mortality rates (eFigure 2; http://links.lww.com/EDE/A937).[24] The probability of moving for each agent was based on the agent's income, duration of residence in the current neighborhood, and experiences of violent victimization in the last time step, based on data from the Detroit Neighborhood Health Study;[25] predictors of movement among NYC residents are assumed to be similar. Each model step represented 1 year in time.

Violence and Policing

At each time step, each agent could experience victimization or perpetration or witness violence (see eMethods 1, Submodels; http://links.lww.com/EDE/A937).[26–28] Violent victimization probabilities were calculated from the World Trade Center (WTC) Study, a large longitudinal study of adult residents of the NYC metropolitan area initiated after the September 11th attacks.[26] Probabilities of violent perpetration were calculated from the National Epidemiologic Survey of Alcohol and Related Conditions, a national study of adult US residents.[27,28] Probabilities were calculated based on sociodemographic characteristics, prior history of violence, PTSD symptoms in the past year, and neighborhood characteristics, and applied to the agents in the agent-based model. Based on these probabilities, potential victims and perpetrators were identified at each time step. Potential perpetrators searched a 15-cell radius around their location for potential victims; any such agents who had not already been victimized at that time step fell prey to the perpetrator, unless a police officer was present within a 4-cell radius of the victim, in which case the potential victim was protected from violence. Thus, violence in the model reflects sporadic instances of interpersonal violence largely among strangers, rather than more chronic types of violence between individuals known to each other. Each violent encounter could also be "witnessed" by agents within a 2-cell radius. Probabilities of witnessed events increased according to the probability with which an event occurred in a public place or during daytime hours.

Other Traumatic Event Exposure

Agents could also experience other traumatic events (i.e., situations causing serious injury or fear of death/serious injury) at each time step (see eMethods 1, Submodels; http://links.lww.com/EDE/A937).[26] Probabilities of exposure to other traumatic events were calculated from the WTC study, and were based on socio-demographic characteristics, prior history of trauma, history of PTSD, and neighborhood characteristics.

Post-traumatic Stress Disorder

Agents who experienced one or more traumatic events were at risk for developing PTSD symptoms. A Poisson regression model calculated from the WTC data was used to assign the number of PTSD symptoms (ranging from 0 to 17) to each agent exposed to trauma, based on socio-demographic characteristics, type of traumatic event exposure, prior history of PTSD, and neighborhood characteristics. Based on a receiver operating characteristic analysis conducted on WTC data, any agent with more than seven PTSD symptoms was considered to meet criteria for PTSD at that time step (eMethods 1, Submodels;

http://links.lww.com/EDE/A937). Violence-related PTSD cases were identified as those with more than seven PTSD symptoms and exposure to violent victimization, perpetration, or witnessed violence at that time step. From a meta-analysis of PTSD treatment effects on symptoms, we used estimates from waiting list conditions to determine the resolution of PTSD symptoms among untreated agents.[14]

Cognitive Behavioral Therapy

Agents who developed PTSD were eligible for treatment with CBT for 1 year. Probabilities of using CBT were calculated based on age, sex, race/ethnicity, and prior CBT use. PTSD symptom resolution was greater for PTSD cases undergoing CBT than for untreated cases, following a meta-analysis of the effects of group CBT on PTSD symptoms (eMethods 1; http://links.lww.com/EDE/A937).[15]

Neighborhood Characteristics

Average neighborhood income and violence emerged at each time step from the characteristics of agents residing in the neighborhood. Neighborhood characteristics contributed 5% of the agent's probabilities of violence and PTSD symptom count.[29] Neighborhoods with above-average levels of violence were considered "high-violence."

Model Calibration

During model calibration, we compared agent-based model estimates to empirical data on total and neighborhood-specific population composition and average income; annual mortality rates; annual moves to new residences; prevalence of violent victimization, perpetration, and witnessed violence; PTSD symptom count and prevalence among those exposed to traumatic events; and mental health service use among those with PTSD. We then used an iterative process to adjust predictive equations and initial conditions in the model until estimates closely matched the empirical data (see eTable 3; http://links.lww.com/EDE/A937).[30]

Model Scenarios

Each model was run for 40 time steps, representing 40 years in time. The first 10 time steps were regarded as a "burn-in period,"[31] during which agents and neighborhoods developed a history of violence and PTSD but other characteristics remained the same. Only results from the final 30 time steps were included in analyses. The "no intervention" model scenario consisted of the relations and baseline values as described above. Three intervention scenarios were also considered:

Increased CBT Use Among Those with Violence-related PTSD in High-violence Neighborhoods

Interventions were implemented for durations of 5 to 30 years in 5-year increments, and probabilities of CBT use were increased in 25% increments, up to 300% of the probabilities in the "no intervention" scenario (Table). Agents entering CBT treatment used it for 1 year; predicted efficacy was a reduction

of 3.39 PTSD symptoms, on average, during implementation (versus a reduction of 1.05 symptoms for those not treated).[15]

Hot-spot Policing

To operationalize hot-spot policing, the model physical area was divided into smaller "patrol areas" consisting of 9×9-cell squares. At the end of each time step, the average level of violent victimization within each patrol area was calculated. At the next time step, one police officer was assigned to each of the highest-violence patrol areas. Hot-spot policing was expected to reduce violence by 10% in the years in which it was implemented; this reduction was estimated from three studies included in a systematic review reporting the effects of increased hot-spot patrol strategies.[11,32–34] It was implemented for 5 to 30 years in 5-year increments, and the number of police officers was increased in 5% increments from 0% to 15% (Table). Officers were assigned to patrol areas with the highest levels of violence during the intervention, thereafter returning to being assigned based only on neighborhood population size.

TABLE. Example Agent-based Model Scenarios: Average Annual CBT Use and Density of Police Officers[a]

	CBT Use (%)	Number of Police Officers Per 100 Adults
No intervention	16.0	2.5
CBT intervention		
50% increase	23.3	2.5
100% increase	30.9	2.5
200% increase	42.5	2.5
300% increase	49.4	2.5
Policing intervention		
0% increase	15.5	2.5
5% increase	15.5	2.7
10% increase	15.6	2.8
15% increase	15.5	2.9
Combination intervention		
50% increase in CBT, 15% increase in police	21.6	2.9
100% increase in CBT, 15% increase in police	28.3	2.9
200% increase in CBT, 15% increase in police	38.8	2.9
300% increase in CBT, 15% increase in police	44.9	2.9

[a]In these example scenarios, interventions (if applicable) were implemented for 30 years. The CBT intervention consisted of increasing the probability of CBT use among individuals with violence-related PTSD in high-violence neighborhoods; the CBT use column indicates the percentage of all individuals with violence-related PTSD who used CBT in each scenario. The hot-spot policing intervention consisted of targeting police officers to hot-spot locations with a history of violence, with or without increasing the size of the police force; the density of police officers thus only increases when increasing police manpower in addition to implementing targeted policing. The combination intervention shown is just one example of many combinations of the CBT and hot-spot policing interventions.

Combination CBT and Hot-spot Policing Interventions

To identify optimal strategies for reducing violent victimization and violence-related PTSD, we also simulated combination intervention scenarios, in which both increased CBT use and hot-spot policing were implemented for 5–30 years. We tested different combinations of increased levels (e.g., 100% increase in CBT use and 10% increase in police officers), to identify the smallest increases and shortest durations that could achieve reductions in victimization and violence-related PTSD, and to estimate the maximum possible reductions in victimization and violence-related PTSD.

Technical Details

The model was developed using Recursive Porous Agent Simulation Toolkit for Java (RepastJ, version 3.0), and implemented in Eclipse (version 4.2). To account for the stochastic nature of the modeling, each model scenario was run 50 times, with the mean, 2.5th percentile and 97.5th percentile reported from across 50 simulations. Sensitivity analyses tested the robustness of the results to changes in the initial conditions and other assumptions of the model (sensitivity analyses in the eAppendix; http://links.lww.com/EDE/A937). The study protocol was approved by the institutional ethical review boards of the participating universities. Study members of the WTC, Detroit Neighborhood Health Study, and National Epidemiologic Survey of Alcohol and Related Conditions studies used for model calibration gave informed consent before participating.

RESULTS

Figure 2 presents the annual prevalence of violent victimization and violence-related PTSD given CBT interventions; Figure 3 presents prevalence estimates for policing interventions. Hot-spot policing produced greater reductions in violent victimization for all intervention durations. For example, by implementing hot-spot policing for 10 years, the annual prevalence of violent victimization decreased from 3.9% (95% confidence interval [CI] = 3.9%, 4.0%) to 3.8% (95% CI = 3.8%, 3.8%). Increases in the number of police officers did not increase reductions in these rates. In contrast, it was necessary to increase CBT use by 100% for 30 years (i.e., doubling use among those with violence-related PTSD in high-violence neighborhoods) to produce a reduction in victimization (3.8%; 95% CI = 3.8%, 3.9%).

Policing and CBT had to be implemented for 10 years to produce a reduction in violence-related PTSD. For the 10-year duration, reallocation of police to targeted, hot-spot policing (without any addition of more police) produced the same reduction in violence-related PTSD as a 200% increase in CBT (no intervention: 3.6% [95% CI = 3.5%, 3.6%]; policing: 3.4%; [95% CI = 3.3%, 3.5%]; CBT: 3.4%; [95% CI = 3.3%, 3.5%]), while a 15% increase in hot-spot policing resulted in a comparable reduction to a 300% increase in CBT
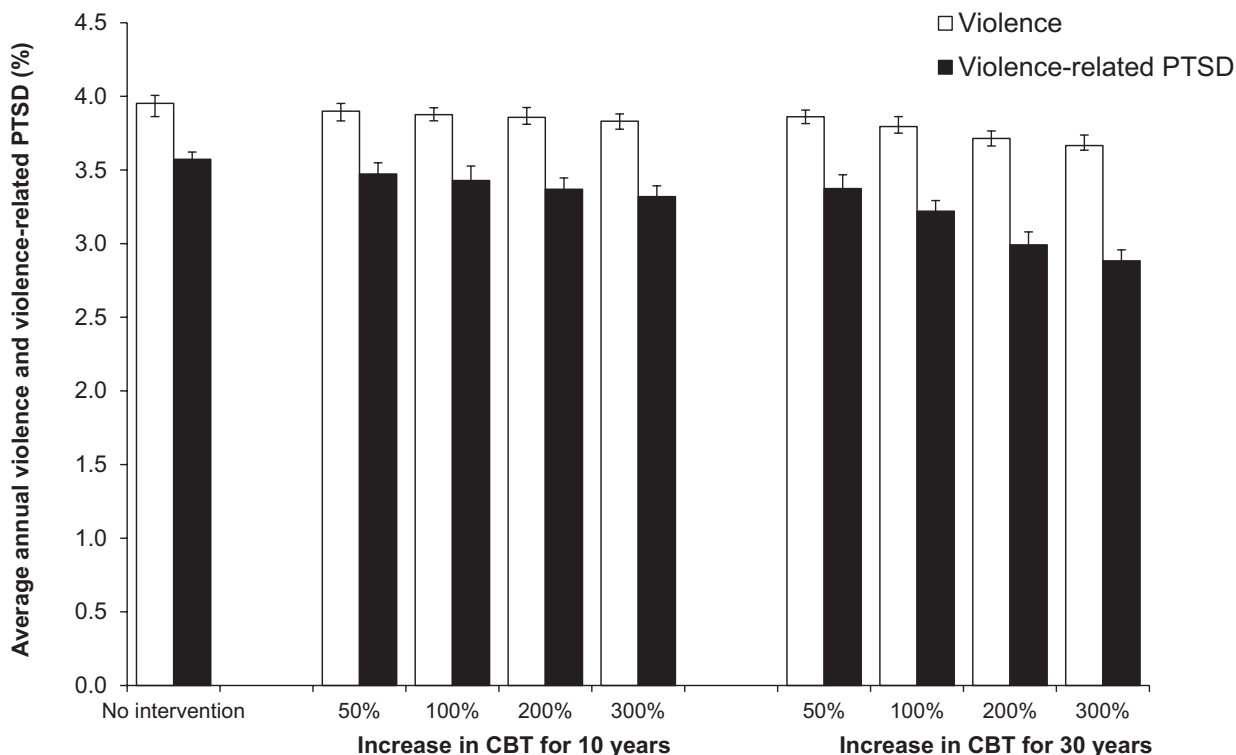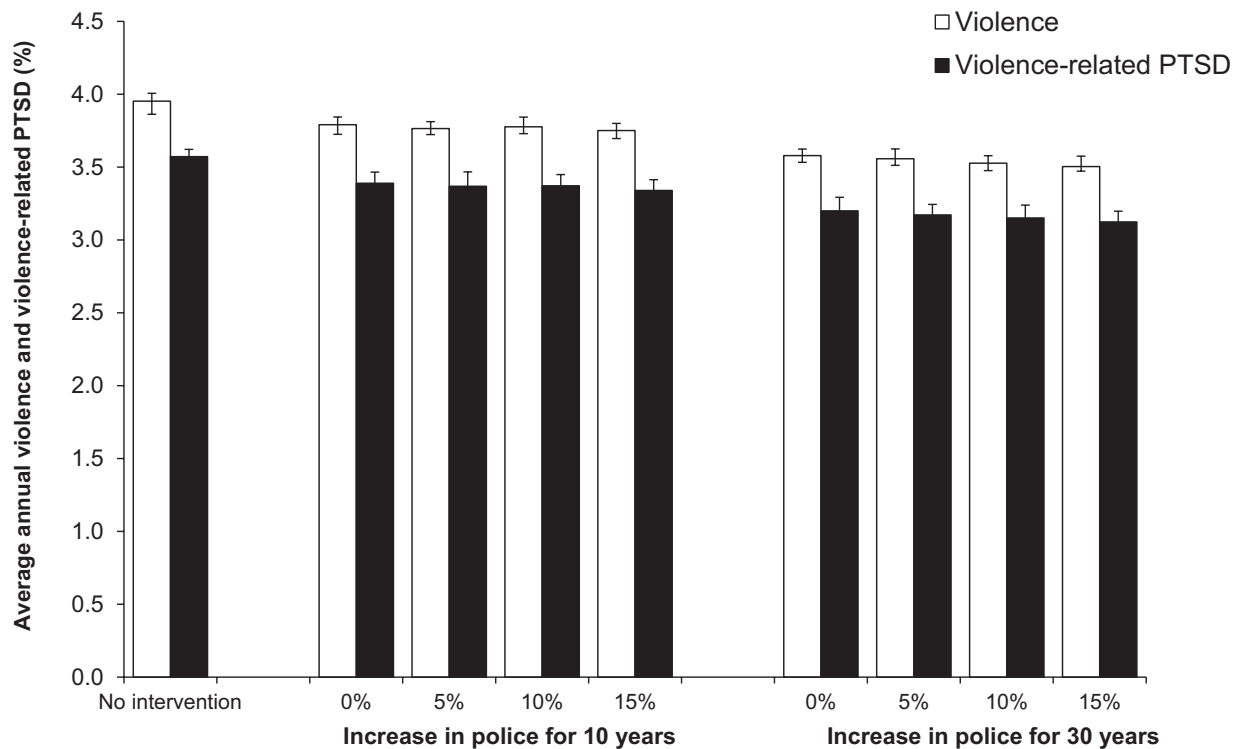

FIGURE 2. Average annual prevalence (and 95% confidence intervals) of violent victimization and violence-related PTSD given hypothetical increases in CBT for 10- and 30-year durations.

FIGURE 3. Average annual prevalence (and 95% confidence intervals) of violent victimization and violence-related PTSD given hypothetical increases in hot-spot policing for 10- and 30-year durations.

(policing: 3.3% [95% CI = 3.3%, 3.4%]; CBT: 3.3% [95% CI = 3.2%, 3.4%]). Assuming a 30-year duration, a 300% increase in CBT resulted in a larger reduction than a 15% increase in hot-spot policing (CBT: 2.9% [95% CI = 2.8%, 2.9%]; policing: 3.1% [95% CI = 3.0%, 3.2%]).

Finally, Figure 4 presents the average annual prevalence of violent victimization and violence-related PTSD for combination interventions. If hot-spot policing and CBT were simultaneously implemented, only 5 years would be necessary to see reductions in victimization and violence-related PTSD. For example, implementation of hot-spot policing (without any increase in police officers) and a 50% increase in CBT over 5 years resulted in a reduction in the annual prevalence of victimization from 3.9% to 3.8% (3.7%, 3.8%) and the prevalence of violence-related PTSD decreased from 3.6% to 3.4% (3.3%, 3.5%)—the same reduction that would have been achieved by implementing hot-spot policing or increasing CBT by 200% for 10 years. Running the combination intervention for 30 years also produced greater reductions in violence and violence-related PTSD than either intervention alone, with the lowest estimates observed for a 30-year intervention in which CBT use was increased by 300% and police officers by 15%, with an average victimization prevalence of 2.9% (95% CI = 2.9%, 3.0%) and violence-related PTSD prevalence of 2.3% (95% CI = 2.2%, 2.3%).

The results were not driven solely by initial conditions in the agent-based model, including proximity between victims and perpetrators, the magnitude of the influence of neighborhood conditions, or spillover effects of policing strategies (see sensitivity analyses in the eAppendix; http://links.lww.com/EDE/A937).

DISCUSSION

Using an empirically informed, calibrated simulation, we found that investment in the primary prevention of violence-related PTSD could achieve the same population-level outcomes as a much larger investment in treatment. In this case, changing the allocation of police, without increasing the police force, resulted in the same reduction of violence-related PTSD as providing treatment to 43% of those affected by violence-related PTSD—something that would require substantial resources in patient outreach, screening, and treatment services. Hot-spot policing is illustrative of many population-level violence prevention opportunities with potential impacts on preventing violence-related PTSD, suggesting that a focus on the determinants of violence may be a fruitful PTSD prevention strategy. By preventing violence, primary prevention approaches reduce the incidence of violence-related PTSD among a large population, and thus have a sustainable impact on its prevalence. While there is a strong interest in the prevention of PTSD, the focus has been on the use of mental health interventions to prevent the onset of symptoms among individuals already exposed to traumatic events, or on the prevention of symptom intensification among individuals with PTSD symptomatology.[35–37]
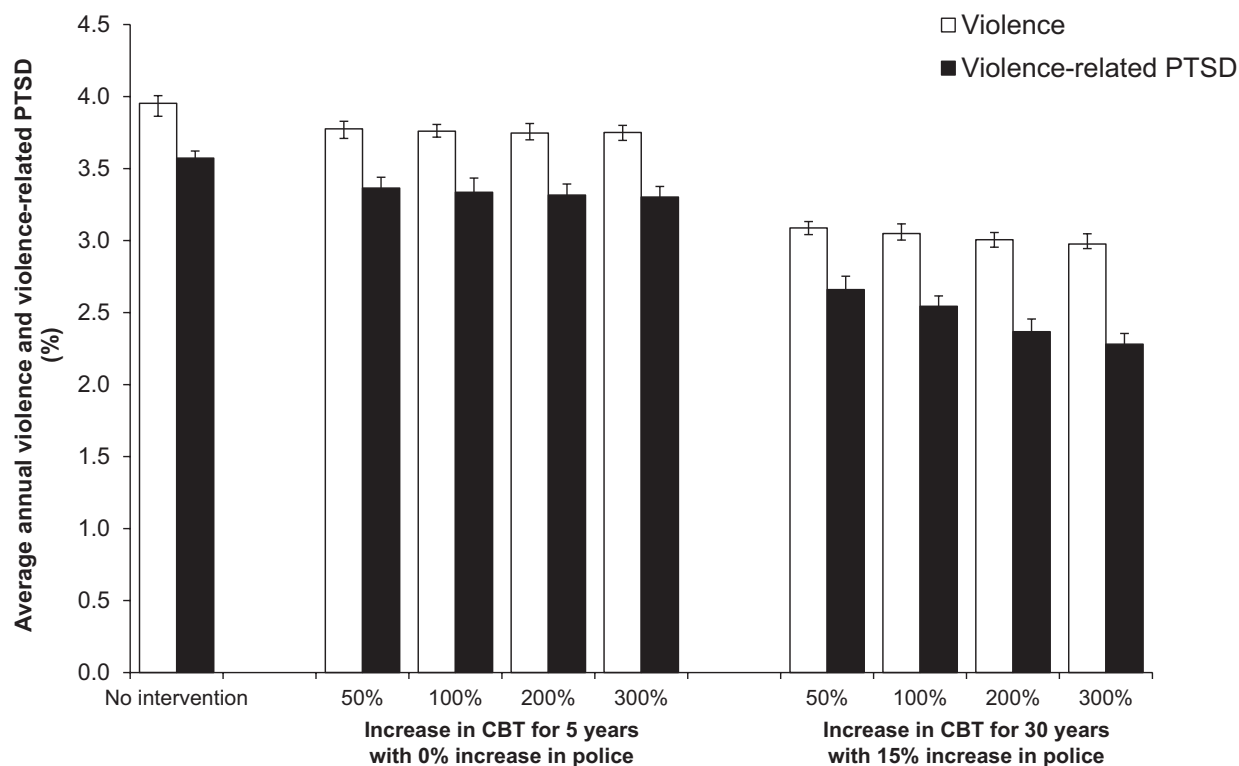
FIGURE 4. Average annual prevalence (and 95% confidence intervals) of violent victimization and violence-related PTSD given hypothetical increases in CBT and hot-spot policing for 10- and 30-year durations.

Our study demonstrates that the relevant health policy question is not about prevention versus treatment, but about devising combined approaches to achieve an optimum improvement in mental health. The greatest reduction in the prevalence of violence-related PTSD was achieved through a combination of preventive and treatment interventions: with such an approach, it was possible to achieve more with fewer resources and in a shorter period of time than with the isolated implementation of either prevention or treatment.[38] Such a finding applied to mental illness is consistent with findings reported for infectious diseases[39] and chronic diseases, such as cardiovascular disease.[40] Current US spending on public health services, including primary prevention, is estimated to constitute only 3%–9% of the national health budget[41–43]—our findings suggest that this is disproportionate to the contribution that prevention makes to population health.

This study also highlights the value of integrating public health and criminal justice interventions to address violence. Public health and criminal justice share a common concern in preventing violent attacks that result in physical injury. While there has traditionally been a division in the approaches to understanding and controlling violence in the two fields, there is an increasing call for the two fields to work together to develop a more effective set of strategies to investigate, prevent, and treat violence.[44,45] As illustrated in this study, a criminal justice focus on policing potential offenders can be integrated with a

public health focus on treating the consequences of violence, to achieve greater impact on violence than either sector would achieve in isolation. Hence, the study points to a way the two disciplines could connect to address an important problem.

While the study provides an empirically informed illustration of the value of a combined prevention-treatment approach to address urban mental health, it also shows that two of the leading empirically supported approaches to prevent violence and treat violence-related PTSD—hot-spot policing and CBT—have small impacts on the population prevalence of violence-related PTSD. To have a profound population-level impact on violence and its mental health consequences, it may be necessary to invest in broader preventive interventions that address the structural determinants of violence. This is consistent with prior research, which found that to reduce racial/ethnic inequalities in urban violence, isolated interventions such as promoting collective efficacy were not sufficient—inequalities were only reduced by eliminating residential segregation.[46]

Study findings should be considered with the following limitations. First, our findings are based on a simulation, and are dependent on a series of modeling assumptions. For example, we assumed that the effectiveness of targeted policing was constant over time, which may not be realistic; we also assumed that targeted policing did not result in spillover benefits reducing violence in adjacent areas, which may

underestimate the true effects of the hot-spots policing intervention.[11,47] Second, the validity of the model was contingent on the quality of data used to inform the model parameters. For example, data on violent perpetration were not available from New York City data sources, so we assumed that the dynamics of violent perpetration reported in a national sample would apply to New York City. In addition, data on CBT use were not available and were approximated by data on more general mental health service utilization (specifically, visits to a psychologist or counselor). However, extensive calibration and sensitivity analyses allayed concerns about the dependence of the model on modeling assumptions: the model replicated known distributions of victimization, perpetration and PTSD before hypothetical interventions were simulated, and results were not contingent on assumptions about initial conditions, such as proximity between victims and perpetrators or the magnitude of the influence of neighborhood conditions. Third, the model was specific to New York City—hence, generalizability to other contexts may be limited.

We highlight two cautions about the policy implications of our findings on the impact of hot-spot policing on victimization and violence-related PTSD. First, our model represented a simplified example of hot-spot policing that focused on intervention in violent events. The potential impact of hot-spot policing may depend on the types of strategies adopted and the context of the targeted hot spots.[11] Second, our study did not consider the potential downsides of policing. Hot-spot policing strategies grant the police considerable discretion, and the outcomes depend on how the police choose to address hot-spot locations. While community policing strategies could potentially reduce problems of excessive use of force, brutality, and racial profiling, aggressive policing without adequate training, and supervision could exacerbate such problems.[48] Thus, while our simulations suggest that investment in hot-spot policing holds promise for the prevention of violence and its associated mental health consequences, we endorse earlier calls for careful cost–benefit calculations and a balance of the goals of violence prevention with the preservation of social justice.[49,50]

We evaluated the relative contribution that primary prevention versus medical care make to violence-related mental illness in urban neighborhoods. Mental illnesses are the leading cause of disability-adjusted life years worldwide, and they account for 37% of health years lost from noncommunicable diseases.[51] Combined investment in primary prevention of the social determinants of mental illness and in treatment of mental disorders may have the largest population-level impact on mental illness.

ACKNOWLEDGMENTS

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