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Spatial Analysis of the Impact of a School-Level Youth Violence Prevention Program on Violent Crime Incidents in the Community

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Abstract

This study investigated the effect of a school-based violence prevention program on community rates of violence for youth aged 10 to 18 in three urban communities with high rates of crime and poverty. We evaluated the impact of the Olweus Bully Prevention Program (OBPP) combined with a family intervention using a multiple baseline design in which we randomized the order and timing of intervention activities across three schools. Outcomes were police reports of violent crime incidents involving offenders aged 10 to 18 years ($N = 2859$ incidents) across a 6-year period. We used Bayesian hierarchical regression modeling to estimate the reduction of youth violence in the census blocks of the intervention middle school zones. Models controlled for percent female head-of-household, median household income, and percent renter-occupied housing units. Block groups within the attendance zones of schools receiving the intervention had a reduced risk of violence compared with those that did not (relative risk = 0.83, 95% credible interval = 0.71, 0.99). Our findings suggest that the school-level intervention was associated with a significant reduction in community-level youth violence. Public health professionals, program planners, and policy-makers should be aware of the potential community-wide benefit of school-level interventions.

Keywords Youth violence · Violence prevention · Spatial analysis · Community effects

Violence is a serious problem affecting the health and wellbeing of youth in the USA (Mercy et al. 2002). National statistics indicate that homicide is the third leading cause of death for youth 10 to 24 years of age, and it has been the leading cause of death for 10- to 24-year-old Black males and females for several decades (Centers for Disease Control and Prevention [CDC] 2016). Each day an average of 12 10- to 24-year-old youths are victims of homicide, and 1400 are treated in emergency departments for non-fatal assault-related injuries (CDC 2016). Youth are also frequently the perpetrators of violence. While arrest rates for violent crimes committed by 15- to 17-year-olds decreased more rapidly between 1980 and 2012 than for other age groups, other age-related trends have not changed. Typically, criminal rates increase steadily with age until reaching a peak at age 19 after which they begin to decline (Office of Juvenile Justice and Delinquency Prevention 2012). Surveys of high school students provide further evidence of youth involvement in violence. A nationally representative survey of high school students in 2017 indicated that 24% had been in a physical fight in the past 12 months, and 16% had carried a weapon such as a gun, knife, or club on one of more days in the past 30 days (CDC 2018). Youth violence has serious consequences not only for those directly involved, but for the communities in which they live. These include fostering fear and mistrust, restricting freedom of movement, discouraging businesses, and reducing property values (Morrel-Samuels et al. 2016).

Schools are often a key part of efforts to reduce youth violence (Farrell and Vulin-Reynolds 2007). Resource guides recommending strategies for reducing violence often highlight school-based interventions as model programs (e.g., https://www.blueprintsprograms.org/). School-based violence

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prevention programs have also been linked to national goals for reducing rates of violence within the USA (Hahn et al. 2007), and they are typically incorporated into comprehensive efforts to reduce community-levels of violence (e.g., Matjasko et al. 2016). Hahn et al. (2007) provided a conceptual model to account for the role school-based interventions can play in reducing rates of overall violence in communities. According to their model, school-based prevention programs can affect students' skills, attitudes, behaviors, and the school environment. These changes produce reductions in negative social behaviors including violence and aggression that are reflected in students' behavior both inside and outside of school. These reductions in violence lead to reductions in levels of physical harm to victims and those around them within the community.

Although there is theoretical support for the notion that school-based interventions have the potential to produce broader community-level effects on youth violence, the extent to which they produce such effects is rarely examined. More typically, the evidence supporting their effectiveness has relied on studies that evaluated their impact on individual-level measures, such as ratings of student behavior by teachers, parents, or peers, and student self-reports or broader measures of school climate (e.g., see reviews by Matjasko et al. 2012; Wilson and Lipsey 2007). Much less is known about the extent to which they achieve their desired goal of producing changes in more objective indicators of violence and victimization in the surrounding community. Research evaluating community-level effects is urgently needed to determine the role school-based prevention programs can play in broader efforts to address violence within communities and to establish the cost-effectiveness of such efforts (e.g., Aos et al. 2004). The purpose of this study was to address that goal by evaluating the impact of a school-based prevention program on community-levels of violence-related incidents perpetrated by youth.

The Olweus Bullying Prevention Program (OBPP) is a widely disseminated school-based prevention program that includes multiple components designed to address risk factors for bullying behaviors and promote social and behavioral competencies that foster positive peer relationships. The OBPP is consistent with the framework Hahn et al. (2007) proposed to account for the potential community-level impact of school-based prevention programs. The OBPP may also be viewed within the broader framework of socio-ecological theory, which highlights the growth of individuals within social networks and their ecologies (Lerner and Castellino 2002; Bronfenbrenner 1979). As such, it focuses on multiple levels of the school ecology (i.e., individual, classroom, and school), incorporates parents, and includes a community component (Limber 2011). Although its focus is on bullying, it includes components, such as class meetings that address broader risk and protective factors for aggression (e.g., managing emotions, developing positive relationships, and

respect for others) and adult intervention in response to aggressive behaviors and victimization. It is therefore not surprising that the OBPP is included in reviews of more general violence prevention programs (e.g., http://www.blueprintsprograms.org/).

The OBPP operates at the mesosystem level to connect a child's environments or microsystems (e.g., school and family or school and community) to decrease bullying. A key component involves developing a bullying prevention coordinating committee that leads the training of staff, assures awareness of the school's anti-bullying rules, refines the school's safety monitoring plan as needed, and conducts school-wide student kick-offs each year. This committee also involves parents (e.g., provides program information at school meetings and hosts a kick-off event for families). At the classroom-level, teachers assure awareness of and enforce the school's anti-bullying rules and conduct regular class meetings with students that include content on bullying prevention, skills that address risk and protective factors related to bullying, and related topics. At the individual-level, school staff intervene in response to incidents of bullying behavior, hold follow-up meetings with parents and students, and develop individual intervention plans as needed. The community component varies across communities. Examples include having community members serve on the coordinating committee and efforts to disseminate anti-bullying messages beyond the school into the community.

Several factors suggest that the OBPP has the potential to reduce incidents of youth violence at the community level. Qualitative interviews with youth, parents, and school and community center staff in a disadvantaged urban community found that conflicts that originate in the home and neighborhood often spill into the school and vice versa (Farrell et al. 2007). For example, incidents that occur at school such as bullying, relational aggression, perceived slights, verbal insults, and displays of disrespect may lead to retaliation after school or in the community. A key focus of the OBPP is on increasing awareness of bullying behaviors, encouraging students to report these behaviors, and providing a process for intervening. This could prevent incidents at school from escalating into more serious incidents of violence within the community. Moreover, components of OBPP, such as class meetings, address risk and protective factors, such as managing emotions, developing positive relationships, and respect for others that are also related to violent behavior. The OBPP's focus on creating a more positive school climate also has the potential for reducing violence by providing students with positive socialization experiences. At a broader level, the OBPP includes efforts to promote changes outside the school setting. Informing parents about OBPP practices that are linked with the skills students are learning at school could support these skills at home. Thus, the components of the OBPP at the individual, parent, school, and community-level form connections in the delivery of this intervention across

contexts that may broaden its effects beyond the school setting.

Evaluations of OBPP conducted outside of the USA have found decreases in student reports of bullying perpetration and victimization (Olweus and Limber 2010). Other studies have found decreases in self-reported victimization, but mixed findings for self-reported bullying perpetration including both decreases (O'Moore and Minton 2005) and increases (Pepler et al. 1994). Studies conducted within the USA have found reductions in student self-reports of bullying (e.g., Melton et al. 1998). Others found reductions in observations of bullying incidents within the school, though results varied across schools and there were no effects on student reports of bullying (Black and Jackson 2007). Most recently, Farrell et al. (2018) found several intervention effects in their evaluation of the OBPP in urban schools within the USA. They found significant reductions in teachers' ratings of students' frequency of aggression and victimization, with effects emerging in different years of implementation for different forms of aggression. They did not, however, find similar effects on student reports of their frequency of aggression or victimization.

The purpose of this study was to evaluate the effect of a school-based violence prevention program on community-level rates of youth violence. More specifically, we evaluated the impact of the OBPP supplemented with a family intervention implemented with a subset of students and their parents. We used spatial modeling to determine the extent to which the intervention, as implemented in the Farrell et al. (2018) study, was associated with changes in rates of violence based on police reports of violence-related incidents among youth living in the middle school attendance zones of the three participating schools. Spatial analysis methods allow the examination of community-level intervention effects while handling spatial dependence between neighboring areas that may not be directly controlled for through measured variables. This enabled us to examine community-level intervention effects within the communities where youth attending the participating schools were living to determine if there was spillover from the school level to the community level. We hypothesized that the intervention would be associated with reduced rates of youth violence in intervention communities and that the intervention may have an indirect, or spillover, effect by producing positive changes in people who have not directly received it.

We examined this spillover effect on violence rates in nearby neighborhoods. Failure to account for these indirect effects may result in underestimation of the total effect of a program that may have significant implications for policy-making and health care expenditure (Savitz and Raudenbush 2009). Spillover effects have been found in several studies of community-level interventions. For example, Verbitsky-Savitz and Raudenbush (2012) estimated the effect of community policing on crime rates in a specific area that received

it and the effect on neighboring beats; they found a significant reduction in a district's crime rate when increasing community policing in neighboring districts. Similarly, a community action program targeting assaults at areas licensed to sell alcohol in Swedish cities did not show a statistically significant direct effect of the program, but showed a significant indirect effect of the intervention on violent assaults in local municipalities (Brännström et al. 2015). Although we were not able to find any studies examining spillover effects for school-based violence prevention programs, we found it plausible that such effects could occur. Because the activities of adolescents are not restricted to their middle school attendance zones, we hypothesized that intervention effects would not be limited to the geographical boundaries defined by the schools or their attendance zones.

Methods

Setting and Design

We conducted the project in three public middle schools within the city of Richmond that served a predominantly African American student population from low-income families. Most of the students (i.e., 74 to 85%) were eligible for the federal free and reduced price meals program. We identified these schools based on community surveillance data indicating that their student attendance zones (study area shown in Fig. 1) had rates of youth violence that were among the highest in the city, and because they had historically received fewer resources to address youth violence. Administrators at all three schools agreed to participate. Enrollments at the start of the school year across the 5 years of the project ranged from 401 to 493 for school A, from 519 to 575 for school B and from 419 to 610 for school C. Each school received $1000 per year for their participation. The intervention was evaluated using a multiple baseline design (Farrell et al. 2018) in which the order the schools received the intervention and the timing of implementing the intervention in the second and third communities was determined by randomization. We initiated the intervention in the first middle school (school A) in October 2011, the second middle school (school B) in October 2012, and did not initiate intervention activities in the third middle school (school C) during the course of this study. Because of this, school C is considered part of the control community in the analysis. Once the schools were initiated, intervention activities in schools A and B continued through the end of the 2014–2015 school year.

Intervention

The intervention included a school and family-based intervention (see Farrell et al. 2018 for more details about the
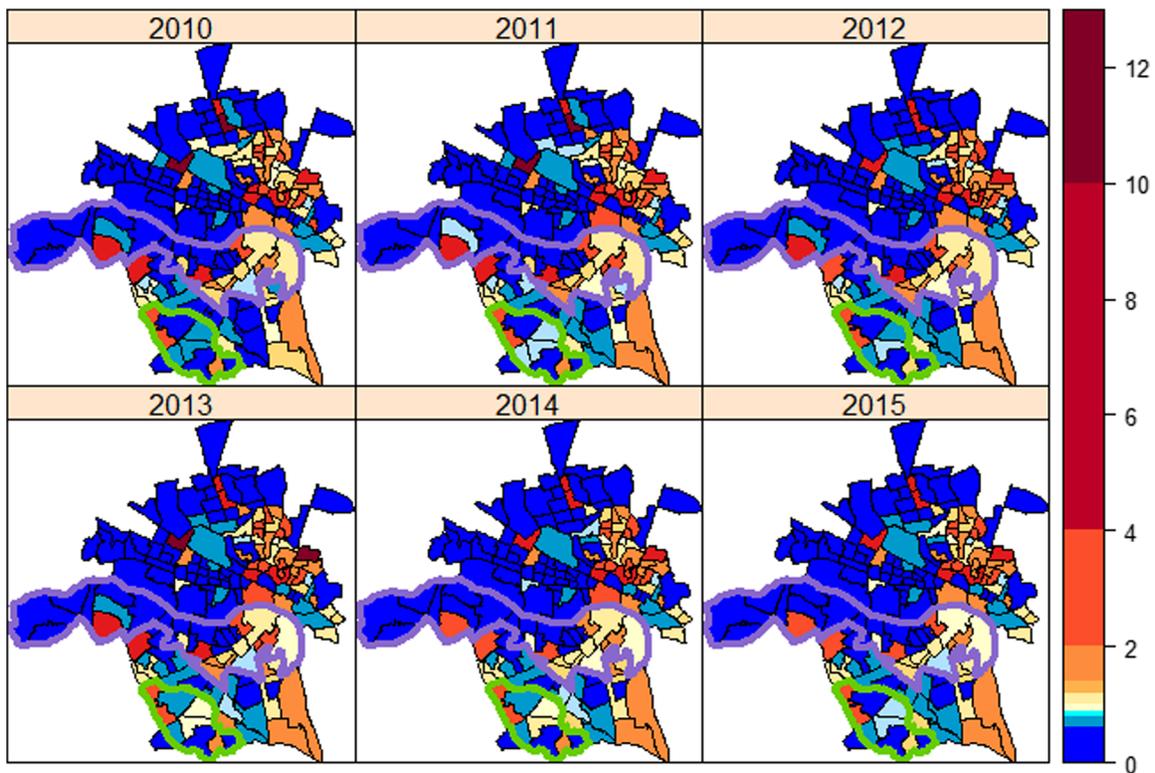
Fig. 1 Estimated relative risk of youth violence for 10- to 18-year-old offenders by census block group by year. The block groups outlined in green and purple outline middle school zones 1 and 2, respectively. Values below 1 (shades of blue) indicate a decreased risk

interventions). The school-based component was based on the *Olweus' Bullying Prevention Program* (Olweus and Limber 2007). A full-time youth development specialist was included on the project to assist intervention schools with OBPP implementation. The school-level component was led by a bullying prevention coordinating committee comprised of school staff who met six to eight times per year. They led all-staff OBPP training, held student and parent events, identified positive and negative consequences for students' behavior, and reviewed the school's supervisory system. Teachers implemented the classroom-level component, which involved instituting the anti-bullying rules and delivering 21 to 23 weekly class meetings per year that addressed topics related to bullying prevention, emotion management, and leadership. The average of observer ratings of teachers' adherence and competence in delivering the class meetings were in the range of *acceptable* to *excellent* (Farrell et al. 2018). At the individual-level, school staff monitored students' behaviors and intervened when they observed bullying behaviors. This involved referring the students involved for follow-up, which included meetings with students and parents and individual interventions as needed.

The OBPP encourages extending its principles and anti-bullying messages into the community (Limber 2011). We addressed this by sharing information about OBPP with parents and community members and conducting an after-school leadership program (Fuentes et al. 2015). Kick-off events

were generally well attended; many were attended by over 100 parents and students. Participants were students who displayed leadership skills, but were not considered active school leaders, and focused on school and community service consistent with the OBPP principles. It also included some lessons from the Youth Empowerment Solutions curriculum (Zimmerman et al. 2011) to foster cooperative learning, discussion, and conversations about social issues related to positive youth development and bullying prevention. Each group met 8 to 12 times, with an average of nine students attending each meeting.

A family intervention component was implemented concurrently with OBPP. We implemented Staying Connected to Your Teen (Haggerty et al. 2007) with English-speaking families and a Spanish version of Parenting Wisely (Gordon 2000) for Spanish-speaking families. The formats included self-directed versions with phone and in-person support and multi-family parenting groups conducted at the schools and in community settings. Participants were students attending one of the schools, while the OBPP was being implemented who were referred for truancy or disciplinary issues or self-referred by parents. At school A, 92 families participated in the family intervention, with 48 (52%) completing all lessons. At school B, 53 families participated in the family intervention, with 15 (28%) completing all lessons. Spanish-speaking families represented 37% of those who completed all the lessons.

Surveillance Data

We evaluated outcomes on violent crime incident data from the Richmond City Police Department. The data included violent crime incidents involving offenders aged 10 to 24 years across a 6-year period from October 2009 to September 2015 (i.e., school years ending in 2010 to 2015). Violent crime offenses included murder, non-negligent manslaughter, aggravated and simple assault (domestic and non), aggravated battery, criminal sexual assault, and robbery, which includes incidents considered violent crime by the Federal Bureau of Investigation's Uniform Crime Reporting definition (FBI 2018). We focused on violent crime incidents involving minors aged 10 to 18 years of age, of which there were 2959 incidents (31.9% of the total reported incidents). Although students ranged from 11 to 15 years of age, while they were attending middle school, the age of those who participated during the first few years of the intervention increased up to 18 across the 5 years of data collection. We felt that sampling this broader age range enabled us to evaluate the preventative effects of the intervention not only on those currently receiving it, but on those who had some exposure to it while they were in middle school. This seemed particularly important given the higher rates of violence committed by older adolescents. We excluded incidents that lacked spatial coordinates from the analysis ($N = 100$), resulting in a total of 2859 incidents. The majority of the offenses were simple assault (59.3%), domestic simple assault (20.7%), and aggravated assault (7.8%). The average age of offenders was 15.9 years old (SD = 2.3). Violent crime incidents were examined at the Census block group level (in accordance with the 2010 US Census block groups in Richmond, VA) using a spatial overlay function in the R computing environment. A total of 170 census block groups had at least one violent crime incident during the period 2004–2015. Three additional block groups were included to define a spatially contiguous study area (Fig. 1).

Covariates

We considered several variables from the 2010 US Census data as possible confounders between the intervention and youth violence, including percent of female head-of-households (FHHP), median household income (MINC), percenter of renter-occupied housing units (RENTERP), average household size, and other demographic variables listed in Table 1 and compared between the intervention and control communities. Previous studies have established links between these variables, economic deprivation, and neighborhood violence (Messer et al. 2006; De Coster et al. 2006; Karriker-Jaffe et al. 2011; Messer et al. 2006). The percent RENTERP was the only variable significantly different in the intervention and non-intervention groups according to an independent two

sample t test ($t(171) = 2.6$, $P = 0.009$, see Table 1). We adjusted for this variable along with the covariates percent of FHHP and MINC in our analysis.

Statistical Analysis

We used a Bayesian hierarchical regression model to estimate the overall intervention and spillover effects for youth violence rates (Bernardo et al. 2007). Additional details on Bayesian hierarchical modeling can be found in Lawson (2009) and Waller and Gotway (2004). We assumed a Poisson distribution for the number of youth violence incidents within each of the block groups for each year between October 2009 and September 2015 (school years ending 2010 to 2015) with a mean of the product of the relative risk θ_{it} and the expected count e_{it} in block group i at year t for a total of $T = 6$ years. Following convention, the expected counts are the product of the overall annual youth violence rate r_t and the at-risk population size in each block group. We analyzed intervention effects within the two middle school zones where it was implemented. The middle school zones overlapped a total of 37 of the 173 block groups. The third middle school zone was not included as an intervention community because the intervention began in October 2016 and data were only available until 2015.

We modeled the log of the relative risk θ_{it} for block group i at time t as:

$$\log(\theta_{it}) = \beta_1 \times FHHP_i + \beta_2 \times MINC_i + \beta_3 \\ \times RENTERP_i + \gamma Z_{it} + \nu_{it} \tag{1}$$

where Z_{it} indicates whether block group i received the intervention at time t, and ν_{it} is a spatio-temporal random effect. The parameter β_1 is the log relative risk associated with a percent increase in the female head-of-households (FHHP) in a block group, β_2 is the effect for median household income (MINC), and β_3 is the effect for percent renter-occupied housing units (RENTERP). The intervention term γ corresponds to the log relative risk for youth violence for those block groups receiving the intervention compared to those that did not receive the intervention. Finally, the spatio-temporal random effect ν_{it} represents spatially structured, temporally correlated heterogeneity in violence rates that is unexplained by the covariates and intervention. These random effects may generally be considered to account for residual confounding, or factors not accounted for in the model, and accommodate spatial autocorrelation in the data.

Prior distributions were required to complete the Bayesian hierarchical model. The intervention, spillover, and covariate effect parameters were given non-informative normal priors centered at 0 with variance of 1000 and the spatio-temporal random effects followed an intrinsic multivariate

Table 1 Census block group level factors in the intervention and control communities reported as mean and associated standard deviation in parentheses

Covariate	Intervention community			Control community	P value*
	Total $N = 37$	Middle school zone A $N = 8$	Middle school zone B $N = 29$	$N = 119$	
Percent female head-of-households[a]	19.2 (5.6)	16.8 (5.1)	19.9 (5.7)	20.0 (8.0)	0.508
Median Household income ($)[a]	44,883.5 (21,199.0)	39,169.1 (9549.1)	46,462.3 (23,303.6)	38,358.4 (25,170.4)	0.151
Percent renter-occupied housing[a]	37.6 (20.7)	41.0 (17.8)	36.6 (21.6)	48.1 (22.1)	0.009
Percent Black residents	51.1 (29.7)	62.6 (10.6)	47.9 (32.6)	54.9 (35.1)	0.545
Percent male residents	47.5 (5.1)	47.9 (1.6)	47.1 (2.6)	47.3 (2.4)	0.833
Percent White residents	37.7 (34.1)	19.9 (7.4)	47.5 (32.7)	41.5 (31.2)	0.528
Percent Hispanic residents	5.3 (10.3)	18.9 (10.5)	3.0 (1.7)	6.4 (8.2)	0.550
Median age (years)	35.8 (9.6)	34.9 (5.4)	39.7 (8.0)	38.7 (7.7)	0.096
Average household size	2.3 (0.4)	2.6 (0.1)	2.3 (0.4)	2.3 (0.3)	0.704
Average middle school population (students) 2010–2015	488.1 (57.93)	445.0 (29.15)	531.2 (45.35)	558.2 (159.81)	0.0490

*P values are from an independent two sample t test between intervention and control communities for each covariate

[a] These variables are adjusted for in the analysis

conditionally autoregressive prior. This is an extension of the standard conditionally autoregressive prior (Besag et al. 1991), which conditions a variable on its neighbors' values based on a spatial adjacency matrix. The multivariate conditionally autoregressive prior had a Wishart covariance structure with a diagonal of 5. The multivariate conditionally autoregressive prior is furthered described in Wheeler et al. (2008) and was previously used in Carlin and Banerjee (2003) for spatio-temporal effects. The vague Wishart covariance is also adopted from similar hyper-priors from Carlin and Banerjee (2003) and Wheeler et al. (2008).

We estimated the model parameters using Markov chain Monte Carlo (MCMC) in WinBUGS (Spiegelhalter et al. 2002) and the R computing environment. We ran one MCMC chain for 70,000 iterations with a burn-in of 60,000. The remaining sample was thinned to every three iterations, yielding a final posterior sample of size 3333 for computing posterior summaries. We assessed convergence for the intervention parameter through visualization of the MCMC chain and Geweke's diagnostic (Geweke 1992), which should be between -1.96 and 1.96 for a converged Markov chain. For parameter estimates, we sampled from the joint posterior distribution and report the mean posterior estimate and the 95% credible interval on the relative risk scale. We also mapped the estimated relative risks for block groups annually (Fig. 1).

As a secondary analysis, we included a spatial spillover effect in the model

$$\log(\theta_{it}) = \beta_1 \times FHHP_i + \beta_2 \times MINC_i + \beta_3$$
$$\times RENTERP_i + \gamma Z_{it} + \rho N_{it} + \nu_{it}, \quad (2)$$

where N_{it} indicates whether any first order neighbor of block group i received the intervention at time t, and ρ corresponds to the log relative risk for youth violence in block groups neighboring the intervention zones at time t.

Results

The primary model converged based on visual inspection of trace and density plots for the relative risk, intervention, and covariate effects. Overall, relative risk of youth violence decreased over time in the study area (Fig. 1). There was a noticeable decrease in the relative risk of violence in the eastern end of middle school zone B (outlined in purple). In the southeast, one block groups' relative risk even falls below 1 by the end of the study period.

The mean relative risks for the intervention and non-intervention communities showed decreases in violence over time, with a larger decrease in relative risk in the intervention communities relative to the other communities (Fig. 2). The pattern of decreasing relative risks was observed between the school years ending in 2011 and 2012 in both the intervention and control communities, with an uptick in violence in middle school zone A between school years ending in 2012 and 2013, which was the intervention's first year of implementation. Following this, in 2013, we noticed a decrease in relative risk for both middle school zones A and B compared with the control community. This decrease continued through 2015.

The overall decrease in relative risk associated with the direct intervention was significant (Table 2). Specifically, block groups receiving the intervention had 0.83 times the risk of violence compared to those that did not receive the intervention (95% credible interval = 0.71, 0.99) after controlling

Fig. 2 Mean relative risk for youth violence over time for school years ending in 2010 to 2015 in the intervention and control communities for 10- to 18-year-old offenders. The dashed and dotted lines, respectively, mark when the intervention began in middle school zones 1 and 2 (i.e., school years ending in 2012 and 2013, respectively)
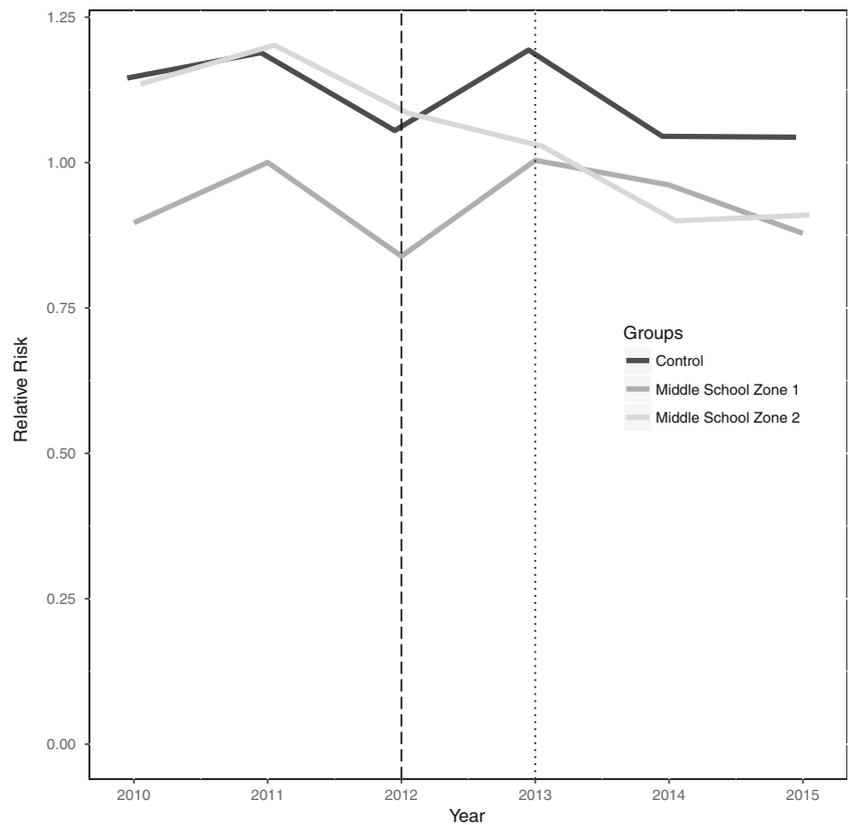
for percent female head-of-household, median household income, and percent renter-occupied housing units.

For a sensitivity analysis, we modeled the youth violence rate for 10- to 24-year-old offenders. This included 8815 reported incidents of which 410 lacked spatial coordinates and were removed from the analysis. The average offender age in this analysis was 19.2 years old (SD = 3.5). Our model adjusted similarly for the intervention and the three covariates controlled for in the primary analysis. We found a similar significant association with the intervention. Block groups receiving the intervention had 0.87 times the risk of violence compared to those that did not (95% credible interval = 0.77, 1.00) after controlling for percent female head-of-household, median household income, and percent renter-occupied housing units.

For the secondary analyses, we found a non-significant spatial spillover effect of 1.18 on the relative risk scale (95% credible interval: 1.00, 1.39). When we expanded analysis to the 10- to 24-year-old population, we still found a non-

significant spatial spillover effect of 1.0 (95% credible interval: 0.87, 1.17).

Discussion

Our findings provide support for the premise that a school-based prevention program has the potential to reduce community-level rates of serious incidents of youth violence in the attendance zone served by the school. These findings are consistent with the argument that schools can play a central role in efforts to reduce youth violence (Farrell and Vulin-Reynolds 2007). They are also consistent with criminological theories that delineate the mechanisms by which schools can discourage delinquent behaviors (Gottfredson 2001) and with the notion that schools can address risk factors and promote protective factors that lead to changes in behavior not only in schools, but in the broader communities they serve (Hahn

Table 2 Posterior relative risk estimates and 95% credible intervals for youth violence in 10- to 18-year-old offenders

Effect	Posterior mean	95% credible interval	
Intervention	0.83	0.71	0.99
Percent female head-of-household	2.24	1.73	2.93
Median household income	1.00	1.00	1.00
Percent renter-occupied	0.96	0.34	2.92

et al. 2007). Components of OBPP that may have been particularly helpful in this regard were those that focused on increasing awareness of bullying behaviors, encouraging students to report these behaviors, teachers' intervening immediately when they observed or heard about bullying behaviors, and meetings with involved students and parents followed up with individual interventions as needed. These aspects of OBPP may have prevented issues originating in the home or neighborhood from escalating and provided interventions that helped students resolve a current situation and prevent future acts of aggression. Other components that may have contributed to these effects were our efforts to extend OBPP into the community through sharing information with parents and community member, our implementation of an after-school program focused on school and community service, and our implementation of a family intervention with a subset of students and their parents. Because our design involved implementing all of these components simultaneously, we can only speculate about the extent to which any observed effects are due to our particular implementation of OBPP or the family intervention component.

The results of this study need to be reconciled with the findings of a prior study by Farrell et al. (2018) that examined the impact of the OBPP on student outcomes for this project. More specifically, they found that implementing the OBPP was associated with significant reductions in teachers' ratings of students' frequency of physical violence; they did not find similar effects on students' self-reports of their frequency of physical aggression or victimization. They speculated that this may have meant that intervention effects were limited to the school context. This is because teacher reports were limited to their observations of students at school, but student reports reflected behavior in multiple contexts. This conclusion appears to be at odds with the findings of the current study. Our study also suggests that there may be a temporal lag between implementation and observing reductions in youth violence (Fig. 2).

Prior studies that have found variability in the effects of school-based violence prevention programs provide a potential explanation for this apparent inconsistency. Farrell et al. (2013) reviewed the literature on subgroup effects in studies evaluating universal school-based violence prevention programs. They identified 20 studies that examined the extent to which intervention effects varied as a function of scores on pretest measures of aggression or related indicators. The majority of these studies (i.e., 12 of 17 unique intervention trials) found that interventions were more likely to benefit students who had higher levels of aggression at baseline. Indeed, some studies did not find significant intervention effects for the overall sample, but found significant reductions in aggression only for those students who reported higher frequencies of aggression at pretest. Such findings suggest that although the prior evaluation of the OBPP did not find

significant main effects for the full sample, the intervention may have benefited a subset of youth who engaged in higher frequencies of physical aggression. Such youth would be more likely to commit the more extreme acts of violence reflected in incidents of violence reported to police, which were the focus of the present study. Although this appears plausible, we are not able to test this assumption as the police data were not coded in such a way that they could be linked to the data collected in the prior evaluation.

In our secondary analyses, we did not find evidence that the intervention produced a spatial spillover effect on neighborhoods adjacent to the school attendance zones. Such effects on gun violence have been found in studies that evaluated community-level interventions that have focused on gang violence (Braga et al. 2013) or used street outreach workers embedded in the community (Webster et al. 2013). We are not aware of prior studies that have examined such effects for school-based interventions. There are several reasons our intervention may not have produced a spatial spillover effect. The middle school attendance zones were selected based on high rates of poverty and crime. Parents of middle school aged youth may have discouraged them from traveling to other neighborhoods. Meetings with students involved in bullying incidents and their parents were also limited to incidents that occurred among students attending the school. A key component of the OBPP involved providing students with skills to address bullying situations and support for the use of those skills. Participants may have opted not to use these skills in contexts where they did not feel they would be supported. Prior qualitative studies that focused on African American adolescents in urban schools have identified contextual factors that influence the likelihood they will fight or use a nonviolent response to a problem situation. These factors include the presence of bystanders, peer influences, and the extent to which they believe alternative responses will be effective in a particular situation (Farrell et al. 2010). A separate study of middle school students who had participated in a universal violence prevention program indicated that although many students understood problem solving and emotion regulation skills taught by the intervention, they were less likely to use them in situations where they did not believe they would be effective (Farrell et al. 2015). Adolescents in the current study might have found sufficient support to use skills taught by the intervention within the school setting and within their own community, but found less support for their use in other contexts.

The absence of spillover effects highlights a missed opportunity in the delivery of OBPP. Enhancing the community-level component of OBPP might have increased its reach into adjoining neighborhoods. For example, adoption of OBPP principles and practices by local community centers or recreations and parks services could extend the reach of this intervention into neighborhoods outside of the middle school

attendance zones. The adoption of a district-wide policy for the implementation of OBPP in all middle schools could also expand the scope of intervention effects for this school-based violence prevention program. Another way to extend the scope of OBPP would be to continue this intervention into the high school setting. These extensions might have broadened the impact of the intervention.

This study had several limitations that should be considered in interpreting our findings. Although we were able to adjust for important geographic-level variables, we were not able to adjust for all possible factors related to youth violence rates, including such factors as family background, family history of incarceration or household crowding factors. However, the spatial random effects serve as a proxy for some of these confounders. Further research is needed to examine the specific influence of these other factors on youth violence. There were also differences in participation rates in the family intervention that may have led to differences in the effects across the two intervention communities. We also relied on police data for youth violence reports and are omitting any incidents that occurred and were not reported to the police.

Our design involved comparing community-level outcomes in three communities. We cannot rule out the possibility that the observed effects were due to other concurrent changes within these communities. Our secondary analysis revealed a similar pattern of community-level changes in a broader sample that included 19- to 24-year-old youth who would not have had direct exposure to the middle school intervention. Several components of the intervention may have contributed to this more widespread effect. These include the potential influence of students on their older siblings, components that involved parents, back to school nights, and other events that attempted to reinforce OBPP principles and community norms regarding violence. Conversely, this could also raise questions about the extent to which it is reasonable to attribute these changes to the intervention versus other changes within the communities.

Our use of a multiple baseline design reduces a variety of threats to internal validity (Biglan et al. 2000). In particular, attributing changes in the outcome measure to an event within the community unrelated to the intervention (e.g., changes in policing policies, opening of a new community center, assignment of a new principal to a school) is less plausible when a consistent pattern of intervention effects is found across replications because it is unlikely that such an event would co-occur with the introduction of the intervention within each community. Within the present study our randomization of both the order in which the intervention was implemented at each school (six possible combinations) and the timing of implementing the intervention in the second and third school (four possibilities) resulted in the random selection of one of 24 possible patterns. This reduces the probability that we selected the specific pattern that coincided with other potential confounding factors (Krotochwill and Levin 2010). We should, however, acknowledge that the pattern of effects were not as consistent across the two communities as we might have liked (see Fig. 2). Nonetheless, this is the first study we are aware of that has examined the effects of a school-based violence prevention program on community-levels of violence, and further work is clearly needed to see if these findings can be replicated.

A major goal of youth violence prevention is reducing community levels of homicide and-related injuries (Mercy et al. 2002). Such efforts require the development of comprehensive strategies that include multiple components that focus on risk factors that operate at multiple levels of the social ecology (Matjasko et al. 2016) and strategies for collecting data on community-level outcomes (Masho et al. 2016). Although school-level interventions are often a key component of comprehensive efforts (Matjasko et al. 2016), prior studies have focused on changes in individuals rather than on community-level changes. The present study found some support for the notion that interventions conducted within school settings could be capable of having a broader community-level effect. We offer this conclusion with many caveats as it is based on a single study with inherent limitations. Moreover, we do not wish to imply that school-based programs alone will be sufficient, but suggest that they may play an important role in broader comprehensive efforts. Further research is needed to see if these findings can be replicated in other communities with different school-based interventions and to examine impacts on a broader range of community-level indicators. Toward that end, we believe that the use of spatial analysis provides a valuable tool with considerable potential to advance prevention science by identifying programs with wider impacts.

Compliance with Ethical Standards

Conflicts of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was not obtained for analyses that were based on de-identified archival data.

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