Effect of Remediating Blighted Vacant Land on Shootings: A Citywide Cluster Randomized Trial

Ruth Moyer, JD, John M. MacDonald, PhD, Greg Ridgeway, PhD, and Charles C. Branas, PhD

Objectives. To determine if remediating blighted vacant urban land reduced firearm shooting incidents resulting in injury or death.

Methods. We conducted a cluster randomized controlled trial in which we assigned 541 randomly selected vacant lots in Philadelphia, Pennsylvania, to 110 geographically contiguous clusters and randomly assigned these clusters to a greening intervention, a less-intensive mowing and trash cleanup intervention, or a no-intervention control condition. The random assignment to the trial occurred in April and June 2013 and lasted until March 2015. In a difference-in-differences analysis, we assessed whether the 2 treatment conditions relative to the control condition reduced firearm shootings around vacant lots.

Results. During the trial, both the greening intervention, −6.8% (95% confidence interval [CI] = −10.6%, −2.7%), and the mowing and trash cleanup intervention, −9.2% (95% CI = −13.2%, −4.8%), significantly reduced shootings. There was no evidence that the interventions displaced shootings into adjacent areas.

Conclusions. Remediating vacant land with inexpensive, scalable methods, including greening or minimal mowing and trash cleanup, significantly reduced shootings that result in serious injury or death.

Public Health Implications. Cities should experiment with place-based interventions to develop effective firearm violence-reduction strategies.

Trial Registration. This trial was registered with the International Standard Randomized Controlled Trial Number (study ISRCTN92588220; http://www isrctn com/ISRCTN92588220). (Am J Public Health. 2019;109:140–144. doi:10.2105/AJPH.2018.304752)

See also Blais, p. 25; and also Galea and Vaughan, p. 28.

Firearms are responsible for three quarters of all homicides in the United States. Homicides committed with firearms are among the leading causes of death in large central metropolitan areas for males aged 15 to 34 years. In urban areas, such as Philadelphia, Pennsylvania, firearm violence is often concentrated in impoverished neighborhoods. Philadelphia had a homicide rate of 17.86 per 100,000 in 2015, higher than the homicide rates of Los Angeles, California; New York, New York; Phoenix, Arizona; and Houston, Texas. Between 2011 and 2015, there were more than 6000 shooting incidents in Philadelphia, and approximately 1 in 5 of these incidents resulted in the victim’s death.

Vacant and blighted land in US cities is often concentrated in the same neighborhoods that are at greatest risk for firearm violence. Like many older deindustrialized cities in the United States, Philadelphia suffers from unkempt vacant lots in impoverished neighborhoods. Approximately 1 in 13 Philadelphia blocks are 50% or more vacant land. Consistent with other urban areas, gun violence is disproportionately concentrated over time in a small number of Philadelphia blocks. Between 2011 and 2015, approximately 30% of shootings in Philadelphia occurred in only 6% of city block groups (112 of 1816).

In a systematic review of quasieperimental research, Kondo et al. found that remediating vacant land may be an effective approach to addressing the hyperconcentration of gun violence in cities. Additionally, in a citywide cluster randomized controlled trial of vacant land remediation in Philadelphia, Branas et al. found that gun assaults were reduced after lots were treated. However, most gun assaults do not result in an actual shooting that causes serious injury or death. We extended the cluster randomized controlled trial of vacant land restoration by estimating the effect of remediating vacant lots on firearm shootings that resulted in serious injury or death during the trial.

METHODS

We used data from a vacant lot cluster randomized controlled trial and the Philadelphia Police Department to conduct a difference-in-differences analysis of the effect of vacant land remediation on firearm shooting incidents. We compiled a master list of vacant lot data from Philadelphia administrative records in January 2011. We randomly selected 541 vacant lots that were “blighted” per municipal ordinance for the randomized controlled trial. Eligible lots were included if they (1) exhibited actual signs of distress, such as illegal dumping, abandoned cars, or unmanaged vegetation; and (2) had

ABOUT THE AUTHORS

Ruth Moyer, John M. MacDonald, and Greg Ridgeway are with the Department of Criminology, University of Pennsylvania, Philadelphia. Charles C. Branas is with the Department of Epidemiology, Columbia University Mailman School of Public Health, New York, NY.

Correspondence should be sent to John M. MacDonald, Department of Criminology, 3718 Locust Walk, McNeil Building, Suite 483, University of Pennsylvania, Philadelphia, PA 19104 (e-mail: johnmm@upenn.edu). Reprints can be ordered at http://www. ajph.org by clicking the “Reprints” link.

This article was accepted August 29, 2018.

doi: 10.2105/AJPH.2018.304752
been abandoned, as confirmed through contact or nonresponse from the owner of record. The city owned some of the lots in the randomized controlled trial. We excluded lots that had insufficient blight, had an area greater than 510 square meters, or were paved parking lots. The sample size was determined on the basis of detecting a small effect size with power at 0.80, α set to 0.05, and an anticipated within-lot intraclass correlation coefficient (ICC) of 0.20.13 The observed within-lot and within-cluster ICCs were 0.24 and 0.25, respectively, with an actual power of 0.86 power at α set to 0.05.

Vacant lot clusters served as the intervention unit. We separated the 541 lots into 110 clusters; lots within a cluster were geographically proximate to one another. We randomly assigned each of the 110 clusters to 1 of 3 study arms: (1) a greening intervention ("greening"), (2) a less-intensive mowing and trash cleanup intervention ("mowing"), or (3) no intervention ("control"). The greening intervention involved removing trash and debris, grading the land, planting new grass and a small number of trees to create a parklike setting, installing low wooden perimeter fences, and regularly maintaining the lot.13 The mowing intervention involved moving existing grass and weeds, removing trash and debris, and regularly maintaining the lot.

A repeat randomization procedure ensured that the clusters were balanced on potential confounding variables, including the total area and mean separating distance of the vacant lots, the resident population, and the number of Summary Reporting System Part I serious violent and property crimes, such as robbery and burglary. We used the random assignment of treatment by cluster to guard against potential spillover and contamination effects across the 3 study arms.

Of the 110 vacant lot clusters, we randomly assigned 37 (206 lots) the greening intervention, 36 (174 lots) the mowing intervention, and 37 (161 lots) the no-intervention control. We randomly assigned vacant lots to these conditions between April and June 2013 (post). All lots remained in the trial until March 2015. Starting in April 2015, the control lots were scheduled to receive remediation in the future (all treated).13

The Philadelphia Police Department provided data for all recorded (n = 6093) shooting incidents that occurred in the city between January 2011 and December 2015, excluding officer-involved shootings.6 Data for 2015 were accessible from the Philadelphia Open Data Web site; we obtained the 2011 to 2014 data through an informal “right-to-know” request. The data included the date, time, and address of the shootings. We geocoded the addresses of shootings to exact latitude–longitude coordinates for all but 2 of the recorded shootings. Victims in the data were wounded in the head (n = 915; 15.0%), limb or shoulder (n = 2333; 38.3%), pelvic area (n = 287; 4.7%), torso (n = 1041; 17.1%), or multiple locations (n = 1517; 24.9%). Approximately 81% (n = 4907) of shootings were nonfatal. The shooting incidents that the police collected are consistent with records found in hospital data for Philadelphia.14

We calculated point-based and area-based geographic metrics for shootings. We used the latitude–longitude locations of each shooting to calculate a kernel density estimate of the monthly rate of shootings per square kilometer at the centroid of each lot, using a bandwidth of 500 meters. The kernel density provides a smoothed estimate of the monthly shootings per kilometer around each vacant lot. This approach assigns more weight to shootings that occur closer to a vacant lot15 and provides a lot-specific estimate of shootings. To measure area-based metrics of monthly shootings, we created buffers around each of the 110 vacant lot clusters. We created 2 buffer zones. The first zone encompassed 300 meters around each cluster and captures the effect of the vacant land remediation on shootings in the nearby areas. The second zone encompassed the area 300 to 600 meters from the cluster (the area within 300 m surrounding the first zone). The second zone is where we might observe nearby displacement if the greening or mowing interventions pushed shootings into nearby areas.

Figure 1 shows the geographic placement of the interventions by cluster and the kernel density of shooting incidents per year before randomization (January 2011 through March 2013).

We relied on a difference-in-differences mixed-effects regression model to estimate the effect of the greening and mowing interventions. We used 2 regression models, 1 for the point-based (kernel density per lot) estimate of shootings and 1 for the area-based (within 300 m of each cluster) number of shootings. For each regression model, we analyzed the relationship between the treatments and the timing of the treatments on either the point-based kernel density estimate of the shooting rate or the area-based number of shootings in lot i in study month t (Yit).

In each regression model, we included terms for each treatment arm to control for pretreatment differences relative to the no-intervention (control) study arm (β1, and β2), terms to capture differences in the shooting rate for all lots in the trial period (β3) and after the trial ended (β4), and interaction terms whose coefficients provide the difference-in-differences estimate of the effect of the greening and mowing interventions during the trial period (β5 and β6, respectively) and after the trial ended (β7 and β8) relative to the preperiod. The difference-in-differences estimate of the greening and mowing interventions during the trial (β5 and β6, respectively) are the causal estimates of the treatment. Each regression model is estimated as:

\[ Y_{it} = \beta_0 + \beta_1 \text{Greening}_i + \beta_2 \text{Mowing}_i + \beta_3 \text{Post}_t + \beta_4 \text{AllTreated}_t + \beta_5 \text{Greening}_i \times \text{Post}_t + \beta_6 \text{Greening}_i \times \text{AllTreated}_t + \beta_7 \text{Mowing}_i \times \text{Post}_t + \beta_8 \text{Mowing}_i \times \text{AllTreated}_t + \alpha_{w(i)} + \delta_i + \xi_{i(t)} + \epsilon_{it} \]

The regression models also included controls for seasonal trends using indicator terms, \(\alpha_{w(i)}\), where \(w(i)\) denotes the month (1, . . . , 12) t; differences by region of the city using indicator terms, \(\delta_i\), where \(i\) denotes the index of lot i’s geographic region (1, . . . , 4). The regression model controls for dependence caused by cluster randomization by including a group-level random effect term, \(\xi_{i(t)}\), where \(i(t)\) denotes the cluster index for lot i (1, . . . , 110). For point-based estimates, we used a linear regression model because the kernel density are weighted counts and not integers. For the area-based analysis, we estimated a Poisson regression model, as the outcome is a count of shootings. For ease of interpretation, we converted coefficients into the percentage change in shootings.

RESULTS

Table 1 shows the descriptive statistics for the average monthly rate of shootings per
square kilometer for the greening, mowing, and control conditions in the pretreatment, posttreatment, and all-treated periods, as well as the estimates from the difference-in-differences regression models. The greened lots tended to have a slightly higher average shooting rate in the baseline period (pre), which we accounted for in the regression estimates. Shooting rates were lower during the trial period (post) for all groups during the trial, but the largest decreases occurred in the greening and mowing interventions. All groups experienced a rise in shootings in the period after the trial ended (all treated), consistent with the 6-month citywide increase in shootings of 77% between May and October 2015.

The results from the difference-in-differences estimates show that the monthly shootings per square kilometer during the trial (post) relative to the baseline period (pre) was −6.8% (95% confidence interval [CI] = −10.6%, −2.7%; P < .01) lower for the greening intervention and −9.2% (95% CI = −13.2%, −4.8%; P < .001) lower for the mowing intervention. A Wald test of the difference-in-differences estimates during the trial (post) for the greening and mowing interventions were jointly significant (P < .001), further corroborating that the vacant lot remediation caused reductions in shootings.

The results for the area-based analysis show a significant reduction in the monthly number of shootings in the treatment zone (0–300 m buffer) around clusters that received the greening intervention by −10.6% (95% CI = −20.2%, 0.2%) during the trial (post). For lots that received the mowing intervention, there was a nonsignificant, −8.4% (95% CI = −19.1%, 3.8%), reduction in the treatment zone during the trial. The analysis of the displacement zone (300–600 m) shows that shootings were nonsignificantly lower by −3.3% (95% CI = −11.6%, 5.8%) in the areas adjacent to the greening intervention and were significantly lower by −13.6% (95% CI = −22.1%, −4.2%) in areas adjacent to the mowing intervention during the trial. These results suggest spillover

### TABLE 1—Descriptive Statistics and Difference-in-Differences Results on Shooting Outcomes: Philadelphia, PA, January 2011–December 2015

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Pre</th>
<th>Post</th>
<th>% Change Pre–Post vs Control (95% CI)</th>
<th>P</th>
<th>All Treated</th>
<th>% Change All Treated Pre–Post vs Control (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Point based, per km²</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greening</td>
<td>12 360</td>
<td>1.25</td>
<td>0.98</td>
<td>−6.8 (−10.6, −2.7)</td>
<td>&lt; .01</td>
<td>1.25</td>
<td>−9.7 (−13.5, −5.5)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Mowing</td>
<td>10 440</td>
<td>1.20</td>
<td>0.91</td>
<td>−9.2 (−13.2, −4.8)</td>
<td>&lt; .001</td>
<td>1.15</td>
<td>−13.7 (−17.6, −9.3)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Control</td>
<td>9 660</td>
<td>1.09</td>
<td>0.89</td>
<td>−1.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Treatment zone, 0–300 m</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greening</td>
<td>12 360</td>
<td>0.33</td>
<td>0.26</td>
<td>−10.6 (−20.2, 0.2)</td>
<td>.05</td>
<td>0.34</td>
<td>−16.2 (−27.3, −3.3)</td>
<td>.01</td>
</tr>
<tr>
<td>Mowing</td>
<td>10 440</td>
<td>0.26</td>
<td>0.21</td>
<td>−8.4 (−19.1, 3.8)</td>
<td>.17</td>
<td>0.25</td>
<td>−22.1 (−33.5, −8.8)</td>
<td>≤ .001</td>
</tr>
<tr>
<td>Control</td>
<td>9 660</td>
<td>0.25</td>
<td>0.23</td>
<td>−0.32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Displacement zone, 300–600 m</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greening</td>
<td>12 360</td>
<td>0.34</td>
<td>0.46</td>
<td>−3.3 (−11.6, 5.8)</td>
<td>.47</td>
<td>0.57</td>
<td>−13.3 (−22.6, −2.9)</td>
<td>.01</td>
</tr>
<tr>
<td>Mowing</td>
<td>10 440</td>
<td>0.36</td>
<td>0.28</td>
<td>−13.6 (−22.1, −4.2)</td>
<td>.01</td>
<td>0.35</td>
<td>−21.2 (−30.8, −10.2)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Control</td>
<td>9 660</td>
<td>0.38</td>
<td>0.34</td>
<td>−0.48</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. CI = confidence interval. No. = the number of lots in each study arm (greening = 206, mowing = 174, no intervention = 161) × 60 mo. Pre = preperiod (27–29 mo); post = postperiod (21–23 mo); all treated = 9-mo period after trial ended when control lots were scheduled for remediation.
benefits of vacant lot remediation rather than displacement.

DISCUSSION
To our knowledge, this is the first citywide randomized controlled trial to assess whether vacant land remediation reduced firearm shootings that result in injury requiring medical treatment or death. The remediation of vacant land through greening or mowing and trash pickup significantly reduced shooting incidents around lots. These findings provide strong causal evidence in support of place-based initiatives that remediate the built environment as an effective gun violence–reduction strategy.3,17

Several mechanisms may explain the reductions in shootings. In ethnographic research from the randomized controlled trial, we found that newly greened vacant lots encourage residents to venture outside their homes for recreation and socialization and that previously unkempt lots were often used for illegal activities, including drug dealing.13 Routine activities theory posits that predatory crime is most likely to occur when a motivated offender, a desirable target, and a lack of effective guardians converge in time and place.19 The increased presence of residents using these spaces may have provided effective guardianship and reduced the opportunities for altercations and shootings associated with drug dealing19–22 or other negative outside behaviors.

Consistent with a theory of collective efficacy, the remediated vacant lots may have also promoted a sense of social cohesion and a willingness to act for the common good, thus normalizing nonviolent behavior in these spaces.23 The removal of trash and debris and the maintenance of these vacant lots reduced the physical signs of disorder and, consistent with the broken windows theory, may have promoted a greater sense of social order and control of these vacant spaces and adjoining areas.24

Conclusions
Firearm violence exacts a substantial financial toll on urban communities. By conservative estimates, between 2006 and 2014, the cost of initial hospitalizations for firearm–related injuries averaged more than $700 million annually, creating financial burdens for government insurance programs and low-income paying patients.25 These financial estimates do not include the social and emotional costs that firearm violence exacts on gunshot victims, their families, and communities.26

Remediating unkempt vacant lots with inexpensive, scalable methods significantly reduced firearm shooting incidents in Philadelphia. Other cities should experiment with similar place-based interventions to develop effective firearm violence–reduction strategies. AJPH

Limitations
Several study limitations prevented us from knowing the causal mechanisms that produced the reductions in shooting incidents. Although we were able to randomly assign vacant lot clusters to remediation, this random assignment does not account for other activities that the remediation of vacant land could have facilitated. For example, law enforcement may have been able to more effectively police gun “hot spots” because of better lines of sight once vacant lots were remediated. Similarly, the remediation of vacant land may have empowered civilian-based efforts, such as those of block captains, to organize more neighborhood events, pick up trash on the streets, and increase community initiatives to maintain safe and healthy blocks.

Additionally, we were able to isolate the effect of vacant land remediation only during the trial period. After the trial ended, control lots became eligible for remediation, and other lots in the areas nearby could have been remediated. This limits what we can say after the trial ended. The fact that remediated vacant lots did not experience as large an increase as control lots during a time when shootings increased citywide, however, suggests that the intervention produced lasting gun violence–reduction benefits.

REFERENCES

CONTRIBUTORS
R. Moyer constructed the shooting data set, conducted the analyses, and drafted the first version of the article. J. M. MacDonald supervised the study and helped write all sections of the article. J. M. MacDonald and C. C. Brañas conceptualized the study and were the principal investigators and coinvestigators on grants that supported this work. G. Radgeway reviewed statistical analysis code and revised the statistical analysis section of the article. C. C. Brañas reviewed drafts and added substantive content to all sections of the article. All authors contributed to the design, analysis, and interpretation of findings and reviewed, revised, and approved the final draft of the article.

ACKNOWLEDGMENTS
This study was funded in part by the National Institutes of Health (grant R01AA020331) and the Centers for Disease Control and Prevention (grant R49CE002474).

We owe special thanks to the Pennsylvania Horticultural Society and the Philadelphia Police Department for their collaboration and data.

Note. The funders had no role in the design and conduct of the study; collection management, analysis, and interpretation of the data; preparation, review, or approval of the article; or decision to submit the article for publication.

CONFLICTS OF INTEREST
No conflicts of interest.

HUMAN PARTICIPANT PROTECTION
This study was approved by the University of Pennsylvania institutional review board.

CONFLICTS OF INTEREST
No conflicts of interest.

HUMAN PARTICIPANT PROTECTION
This study was approved by the University of Pennsylvania institutional review board.

CONFLICTS OF INTEREST
No conflicts of interest.


mitigate community impact of gun violence: conceptual framework and intervention design. *BMJ Open* **10**:10, e040277. [Crossref]


