Published in final edited form as:

Health Place. 2014 July ; 28: 142–149. doi:10.1016/j.healthplace.2014.04.005.

The association between neighborhood residential rehabilitation and injection drug use in Baltimore, Maryland, 2000-2011

Sabriya L. Linton^{1,2}, Jacky M. Jennings^{1,3}, Carl A. Latkin⁴, Gregory D. Kirk¹, and Shruti H. Mehta¹

¹Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

²Department of Behavioral Sciences and Health Education, Rollins School of Public Health at Emory University, Atlanta, GA, USA

³Department of Pediatrics, Johns Hopkins School of Medicine, Baltimore, MD, USA

⁴Department of Health, Behavior, and Society, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

Abstract

This study utilized multilevel cross-classified models to longitudinally assess the association between neighborhood residential rehabilitation and injection drug use. We also assessed whether relocating between neighborhoods of varying levels of residential rehabilitation was associated with injection drug use. Residential rehabilitation was categorized into three groups (e.g. low, moderate, high), and lagged one visit to ensure temporality. After adjusting for neighborhood and individual-level factors, residence in a neighborhood with moderate residential rehabilitation was associated with a 23% reduction in injection drug use [AOR=0.77; 95% CI (0.67,0.87)]; residence in a neighborhood with high residential rehabilitation was associated with a 26% reduction in injection drug use [AOR=0.74; 95% CI (0.61,0.91)]. Continuous residence within neighborhoods with moderate/high rehabilitation, and relocating to neighborhoods with moderate/high rehabilitation, were associated with a lower likelihood of injection drug use. Additional studies are needed to understand the mechanisms behind these relationships.

Keywords

Urban redevelopment; Urban health; Drug abuse; Injection drug use

© 2014 Elsevier Ltd. All rights reserved.

Corresponding author: Sabriya L. Linton, Department of Behavioral Sciences and Health Education, Rollins School of Public Health at Emory University, 1518 Clifton Road NE, GCR 527, Atlanta, GA 30322, Tel: +1 404 727 8295, Fax: +1 404 727 1369, sabriya.linton@emory.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Introduction

Empirical evidence of a relationship between poor neighborhood conditions and drug abuse is growing [1-11]. However, less research has explored whether strategies focused on improving neighborhoods impact drug abuse. Urban redevelopment is one strategy that aims to improve economic, physical, and social conditions in cities by revitalizing and constructing physical infrastructure [12]. Globally, an emerging field of research has revealed the potential implications of urban redevelopment on the health of residents living in socially and economically distressed areas [13-18]. Few of these studies, however, have focused on drug abuse, despite the role of decaying neighborhood conditions on drug abuse and the social and economic costs of drug abuse.

Urban redevelopment can impose a mixed combination of positive and negative consequences that are relevant to drug abuse. For instance, revitalization of abandoned and substandard housing can deter drug abuse and drug market activity (e.g. the sale of illicit drugs) [19], and thereby reduce potential cues for drug abuse [5-7, 20]. Revitalization has also been shown to reduce violence [15], increase collective efficacy [21], which has been associated with preventing crime [22], and reduce housing-related stress [21], which together with reductions in crime may improve mental health, an important mediator of the relationship between neighborhood conditions and substance abuse [2, 21, 23]. Indeed, one of the few studies exploring the relationship between urban redevelopment and substance use, conducted by Blackman and colleagues, demonstrated significant reductions in psychological distress and smoking cessation among residents following redevelopment in Northern England [16].

Likewise, resident relocation resulting from urban redevelopment may encourage drug cessation, as exemplified in prior research conducted in the Southeastern United States, by Cooper and colleagues [24]. Specifically, Cooper and colleagues demonstrated an association between relocation to less economically deprived and socially disordered communities and reductions in substance use, among a predominantly substance using sample of African American adults relocated from public housing complexes slated for demolition [24]. The investigators demonstrated an association between relocation to economically deprived areas and psychological distress in another analysis [25], as similarly shown in prior research [26-30], and this may have been a potential mechanism through which relocation influenced the observed patterns of substance use. While not explored by the investigators to date, relocation may have also influenced substance use by altering social network composition. Prior research conducted by Curley and colleagues suggests that relocation due to urban redevelopment may disrupt connections to “draining ties” (e.g. negative or straining social networks) [31], which could include relationships to drug using or other risky social networks .

Despite these potential positive consequences, however, negative consequences may also result from urban redevelopment which may burden people with a history of drug abuse and discourage cessation and recovery. Housing costs (e.g. rent and property values) can increase as a result of redevelopment and this can lead to housing instability as these costs become unaffordable for some residents [32]. Resident relocation due to urban

redevelopment may disrupt supportive social networks, reduce access to community resources, cause stress, and lead to housing instability [29, 32-36]. Displaced residents may experience isolation in their new communities [29], and if relocation is facilitated by the provision of subsidized rental housing vouchers that enable relocated residents to obtain subsidized housing elsewhere, marginalized groups, including people with a history of drug abuse, may be discriminated against and experience barriers to obtaining such housing benefits [29].

Lastly, urban redevelopment may displace drug activity rather than reduce it altogether [19, 37]. Such displacement may result from increased collective efficacy but may also be a consequence of intensified police activity that may accompany urban redevelopment [37]. Intensified enforcement of anti-drug laws has been associated with encouraging injection related risk behavior (e.g. sharing of syringes and other equipment, unsafe disposal of syringes/equipment) among people who inject drugs, further isolating substance users, increasing drug market activity, and hindering access to harm reduction and health care services [38-41].

While urban redevelopment has the potential to influence drug abuse through several pathways (both positive and negative) as described, few studies have quantified major components of urban redevelopment and measured their impact on drug abuse. The objective of this study was to assess the longitudinal relationship between residential rehabilitation and injection drug use in Baltimore, Maryland, located in the Eastern mid-Atlantic region of the United States. Injection drug use, a major risk factor for the transmission and burden of HIV and hepatitis C (HCV) globally [42-48], has been associated with economic deprivation, social disorder, and physical decay in several settings [1, 2, 4, 9-11]. As done in other urban centers, the city of Baltimore has implemented various urban redevelopment strategies to address these conditions locally, and they have largely included residential rehabilitation as part of their plans. In addition to assessing the association between residential rehabilitation and injection drug use, we assessed whether prior patterns of injection drug use modified the relationship, and assessed the association between moving in and out of neighborhoods of varying levels of residential rehabilitation and injection drug use. To accomplish the objectives of this study, individual level data from a cohort of current and former injection drug users (IDUs) in Baltimore was linked to neighborhood level data across a decade of follow-up.

Material and Methods

Ethics Statement

All participants provided informed consent. The study was approved by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board.

Sample

Individuals enrolled in the AIDS Linked to the Intravenous study (ALIVE), were included in this analysis. ALIVE has been previously described [49]. Briefly, a community-based sample of 2,921 former and current IDUs in Baltimore was recruited between 1988 and

1989. Participants were eligible if they were 18 years, reported injection drug use within the past 11 years, and if HIV positive, were not diagnosed with AIDS at enrollment. A total of 1,510 participants were enrolled across four additional recruitment waves using similar inclusion criteria. Participants attend biannual visits during which laboratory tests are performed, and self-reported information is captured by interviewer-administered questionnaires and Audio Computer-Assisted Self Interview (ACASI). Recently in the ALIVE cohort, mortality has ranged from 3-5% per year, and loss to follow-up has ranged from 5-7% per year among surviving participants.

The study sample included participants who reported residence in a Baltimore City residential neighborhood, and attended more than one follow-up visit from 2000-2011, when the primary exposure, residential rehabilitation, was available. This included 1,852 participants contributing 17,419 visits. Visits were excluded if data on drug abuse and other covariates were missing or gaps between visits exceeded 2 years. The final sample included 1,818 participants contributing 15,005 visits. The distribution of characteristics in the final sample did not significantly differ from that observed prior to when missing observations were excluded. Participants' residential locations were joined to Baltimore city neighborhood statistical areas (NSAs) using ArcMap version 10 (ESRI, Redlands, CA). Among participants who reported homelessness, the location of temporary housing was geocoded to NSAs, if available.

The Baltimore City Department of Planning initially defined the boundaries of NSAs in the 1970's using census data and resident input. NSA boundaries tend to be smaller than administrative census blocks and larger than census block groups, and may encompass residential areas, non-residential areas (e.g. cemeteries; industrial sites) and natural boundaries (e.g. parks, lakes). The NSA boundaries have since been modified with each decennial US Census; the boundaries established in 2000 were used in this study. In total, 271 NSAs were distinguished by the 2000 boundaries and had a mean size of 374.8 acres (Range 46.5-1592.6 acres; SD 419. 2); 239 neighborhoods were residential.

Neighborhood Measures

The primary exposure, residential rehabilitation, is measured annually by the Baltimore City Department of Housing and Community Development, and is defined as the percentage of residential properties where investment in interior or exterior maintenance exceeded \$5,000 USD for a given year. This information is estimated from rehabilitation permits, which are required for any electrical, mechanical, or physical alteration to a property. The \$5,000 USD cut-off established by the city reflects major work and investment. Rehabilitation permits have been used to measure urban redevelopment in other research [50].

Residential rehabilitation was treated as time-varying and initially categorized into four groups, with the lowest percentage as the reference. The distribution of residential rehabilitation was positively skewed each year. Therefore, the cut-offs for each category were determined among residential neighborhoods for each year in ArcMap using natural break classification. Natural breaks have been used in cartography to map values that are not evenly distributed, and cut-offs are established according to where the variance within a category is minimized and the variance between categories is maximized [51]. Upon linking

individual data with neighborhood data, a small number of observations existed in neighborhoods in the 4th category (n=116) of residential rehabilitation. Thus for this analysis, the 3rd and 4th categories were combined, which established 3 categories of residential rehabilitation for analysis: low (reference), moderate, and high residential rehabilitation.

Neighborhood economic deprivation was included as a confounder due to its association with injection drug use [1, 4] and residential rehabilitation [12]. Economic deprivation was measured by an index of the following items from the 2000 U.S. census: percentage of individuals employed in professional occupations (reverse-coded), percentage of households with crowding, percentage of households in poverty, percentage of female-headed households with dependent children < 18 years, percentage of households on public assistance, percentage of households earning low income, percentage of individuals with less than a high school education, and percentage of unemployed individuals 16 years. These items have been included in other indexes used and validated in Baltimore [1, 52]. Principal components analysis performed on the items demonstrated that the first component, economic deprivation, explained 50% of the total variability across residential Baltimore neighborhoods in 2000. The items were standardized by z-score, weighted by factor loadings, and summed to create an index that ranged from -3.73 to 7.41 (SD=2.0). Economic deprivation was categorized into tertiles according to its distribution across residential neighborhoods.

Individual-level Measures

The outcome was injection drug use, defined as self-reported injection of heroin, cocaine, speedball, and/or other drug not prescribed by a health care provider, within the last six months. Self-reported drug use has demonstrated adequate reliability and validity [53]. Injection drug use was treated as dichotomous with no reported injection as the reference. All covariates were identified a priori and selected based on prior research [1, 4, 54, 55]. Gender (male vs. female) and race (black vs. white/other) were defined at the first visit. The following covariates were treated as time-varying and coded as yes or no unless otherwise stated: age (dichotomized at the median: 45 years) current employment, and the following factors measured in the last six months: legal income (dichotomized at the mid-point: \$5000 USD); incarceration (1 week vs. less); frequency of injection drug use (none, less than daily, or daily), non-injection drug use (crack, cocaine, heroin, or marijuana); methadone maintenance; detoxification; and sex with an IDU partner.

Statistical Analysis

We assessed the demographic and spatial distribution of participants. Logistic multilevel cross-classified models [56, 57] were used to longitudinally assess the association between neighborhood residential rehabilitation and injection drug use, given that individuals could be classified into multiple neighborhoods over time. Random intercepts for individuals and neighborhoods were added to the model. To establish temporality, residential rehabilitation and all covariates were lagged one visit.

A series of models were used to assess the association between residential rehabilitation and injection drug use. The first model assessed the unadjusted association between all covariates and injection drug use. The second model assessed the association between residential rehabilitation and injection drug use, after adjusting for covariates and study recruitment wave. Our prior research suggests that current and former IDUs can transition in and out of injection drug use and exhibit multiple trajectories of substance use overtime, [54, 58], and that the factors that influence these patterns may vary [54, 55, 58-60]. Therefore, in the third model an interaction term between injection drug use at the lagged visit and residential rehabilitation was added to the adjusted model. Lastly, we assessed the association between basic patterns of relocation into and out of neighborhoods experiencing similar or varying levels of residential rehabilitation and injection drug use across visit pairs (the lagged and current visit). This was conducted among a sub-group of visits where residential address was available at the lagged and current visit (1758 participants contributing 13707 observations). In this model, residential rehabilitation was treated as dichotomous, with low rehabilitation still treated as the reference group as in the main analysis, but the moderate and high rehabilitation categories were combined to create the comparison group (moderate/high). Using this categorization, the likelihood of injection drug use was assessed among the following patterns of relocation across visits, with continuous residence in neighborhoods with low residential rehabilitation considered the reference (e.g. living in a neighborhood with low residential rehabilitation at t-1 and living in the same neighborhood at t): continuous residence in neighborhoods with moderate-high residential rehabilitation, relocation between different neighborhoods with low residential rehabilitation, relocation between different neighborhoods with moderate/high neighborhood residential rehabilitation, relocation from moderate/high neighborhood residential rehabilitation to low, and relocation from low to moderate/high neighborhood residential rehabilitation. Analysis was conducted using STATA version 12 (STATACorp., College Station, TX).

Results

Sample Characteristics

Among 1,818 participants included in analysis, 66.8% (n=1215) were male, 90.9% (n=1,653) were African American, and 49.2% were 45 years of age at the first visit. At the first visit, residence in a neighborhood with moderate to high levels of residential rehabilitation, as compared to residence in a neighborhood with low residential rehabilitation, was more common among those who were white/other, HIV positive, and reported homelessness, detoxification, non-injection drug use, and residence in an economically deprived neighborhood in the prior six months (Table 1).

Across follow-up the residence of participants was concentrated within 85% (202/239) of residential Baltimore City neighborhoods, and the majority of visits were linked with neighborhoods that were in the lowest category of residential rehabilitation (68.4%), and the highest tertile of neighborhood deprivation (69%). Across all Baltimore city residential neighborhoods, the average proportion of residential properties undergoing rehabilitation was greatest in 2007 (5.1%) and lowest in 2003 (2.2%). Across follow-up, resident

relocation occurred among 24% (n=3,261) of observations, and among these observations 45% denoted relocation between neighborhoods with low residential rehabilitation, 15% denoted relocation between neighborhoods with moderate/high residential rehabilitation, 23% denoted relocation from low to moderate/high residential rehabilitation, and 16% denoted relocation from moderate/high to low residential rehabilitation.

The Association between Residential Rehabilitation and Injection Drug Use

In unadjusted analysis, there was a dose-response relationship between residential rehabilitation and injection drug use. Residence in a neighborhood with moderate or high levels of residential rehabilitation was significantly associated with a lower likelihood of injection drug use, as compared to residence in low rehabilitating neighborhoods (Table 2). Other correlates of injection drug use included age < 45, white/other race, male gender, income < \$5000 USD, unemployment, homelessness, incarceration, sex with an IDU partner, detoxification, not attending methadone maintenance, daily injection drug use, non-injection drug use, and HIV negative status. Neighborhood economic deprivation was associated with injection drug use but the association was not statistically significant in the 2nd tertile and was borderline significant in the 3rd tertile.

After adjusting for individual-level covariates, recruitment wave, and neighborhood economic deprivation, the dose response relationship between injection drug use and residential rehabilitation persisted (Table 3). Residence in a neighborhood with a moderate level of residential rehabilitation was associated with a 23% reduction in the likelihood of injection drug use [AOR=0.77 95% Confidence Interval (CI) = (0.67, 0.87)], and residence in a neighborhood with a high level of residential rehabilitation was associated with a 26% reduction [AOR=0.74; 95% CI (0.61, 0.91)].

There was no statistically significant interaction between residential rehabilitation and status of injection drug use at the previous visit ($p > 0.05$ for all categories). This data is not shown.

Relocation and Injection Drug Use

In the unadjusted model, the following patterns of relocation were significantly associated with a lower likelihood of injection drug use when compared to continuous residence in neighborhoods with low residential rehabilitation: continuous residence in neighborhoods with moderate/high residential rehabilitation, relocation between neighborhoods with moderate/high residential rehabilitation, and relocation from low to moderate/high residential rehabilitation (Table 4). Relocating between neighborhoods with low residential rehabilitation was associated with an increased likelihood of injection drug use. Relocating from moderate/high to low residential rehabilitation was not significantly associated with injection drug use.

When assessing the relationship between relocation and injection drug use in adjusted analysis, the following patterns were significantly associated with a lower likelihood of injection drug use when compared to continuous residence in neighborhoods with low residential rehabilitation (Table 4): continuous residence in neighborhoods with moderate/high residential rehabilitation [AOR=0.72; 95% CI(0.61,0.83)], relocation between neighborhoods with moderate/high residential rehabilitation [AOR=0.68; 95%

CI(0.51,0.90)] and relocation from low to moderate/high neighborhood residential rehabilitation [AOR=0.65; 95% CI(0.52,0.81)]. The association between relocating between neighborhoods with low residential rehabilitation and a higher likelihood of injection drug use remained, but it was not statistically significant [AOR=1.12; 95% CI (0.95, 1.28)]. The association between relocating from moderate/high to low neighborhood residential rehabilitation and injection drug use remained non-significant [AOR=0.90; 95% CI (0.70, 1.17)].

Discussion

In this cohort of current and former IDUs in Baltimore, we observed a positive association between residential rehabilitation and a lower likelihood of injection drug use independent of selected neighborhood and individual-level factors. The benefit appeared to extend to individuals who consistently lived in rehabilitating neighborhoods and to those who moved into rehabilitating neighborhoods.

The findings from this study are consistent with prior research that suggests that residential rehabilitation may encourage substance use cessation [16, 21], and that relocation to neighborhoods with improved economic and social conditions can encourage reductions in substance use [1, 24].

Additionally, similar to prior research, including past research in ALIVE, we observed an association between economic deprivation and injection drug use. This association was not statistically significant, however, as observed in prior research [1, 4]. The discrepancies in significance may have been due to differences in the geographic scales at which constructs of interest were measured (e.g. census tracts were used in prior studies and neighborhood statistical areas were used in this study), and differences in the analytic methods used.

Several mechanisms may explain the association between residing or relocating to neighborhoods experiencing residential rehabilitation and a lower likelihood of injection drug use observed in this study. Residential rehabilitation may reduce the availability of drugs by deterring drug market activity and discouraging the use of vacant properties as settings for drug use [19], improving mental health [16, 17], and strengthening neighborhood attachment and collective efficacy [21], which may increase social control of drug market activity and drug use.

Accordingly, relocating to neighborhoods experiencing greater investment in housing, may similarly translate into positive outcomes related to drug abuse. While, resident relocation is a complicated phenomenon that has also been associated with poor health outcomes in prior literature, as it may reflect housing instability and loss of positive community ties [32-36], the benefits of relocation may largely depend on the quality of the neighborhoods where residents are relocated and the manner in which social networks are affected. Presumably, relocating to neighborhoods experiencing rehabilitation may have provided residents with the opportunity to benefit from the positive implications of neighborhood investment and disengage from negative social networks that may have been maintained in their previous neighborhoods of residence. In contrast, relocating to neighborhoods experiencing little to

no rehabilitation may be associated with harms related to lack of investment in neighborhood maintenance and development.

While we could not quantitatively assess whether these mechanisms explain this study's findings, our prior qualitative research conducted among ALIVE participants residing in or surrounding an area targeted by one of the largest redevelopment projects conducted in Baltimore during the last decade, The East Baltimore Development Initiative, supports these inferences [61]. Respondents in this study specifically reported increased perceptions of safety, improved mental health, and collective efficacy in the neighborhood that was being revitalized. Extensive resident relocation occurred as part of the East Baltimore Development Initiative, and several respondents in our study, who experienced the process, attributed relocation with providing residents with an opportunity to relocate to areas that were less conducive of substance abuse.

Our qualitative study [61], however, also elucidated negative consequences of residential rehabilitation and resident relocation, as part of the urban redevelopment project, which were similar to findings from other studies conducted in the US and internationally [19, 32, 36, 37, 62, 63]. For instance, respondents in the study reported that residential rehabilitation increased housing costs, and resident relocation led to housing instability for some households, and a loss of community resources and supportive social networks. Further, the displacement of visible drug activity to other neighborhoods and the transformation of visible drug activity to become more hidden was reported. Moreover, many respondents suggested that neither the displacement of drug activity nor resident relocation may encourage cessation among drug users whom were not ready to stop. Thus, while we observed an overall positive association between residential rehabilitation and injection drug use in this sample, it is likely that some individuals experienced negative consequences, which potentially blunted the overall association.

Additional quantitative assessment of the mechanisms that link residential rehabilitation to drug abuse is needed. Based on the data which was available, we could not quantitatively elucidate whether collective efficacy, changes in social networks, and other factors were mediating the relationships we observed. Additionally, we could not quantitatively differentiate between voluntary relocation and forced displacement due to residential rehabilitation.

Other limitations should be considered in interpreting the findings from this study. Urban redevelopment strategies are diverse and we could not capture the heterogeneity of urban redevelopment with one indicator. For instance, economic development may not have been entirely captured by the measure of residential rehabilitation used in this study. However, the implications of urban redevelopment on individual economic empowerment have been mixed [14, 61, 64] and this may largely depend on the extent to which residents benefit from economic investment and growth related to urban redevelopment.

For instance, respondents in our prior qualitative research, reported little inclusion in employment opportunities provided through the urban redevelopment project under study [61], and similar concerns have been voiced by the community at large [65]. However, there

are examples in Baltimore, where marginalized populations have been employed to assist smaller community-driven redevelopment initiatives [64]. Similar efforts made by other redevelopment projects would be expected to benefit people with a history of drug abuse given the established relationships between poverty and drug abuse [1, 4, 8, 11], and the relationships among employment, community mobilization, and improvements in health, including reductions in drug abuse [18, 66-68]. We were unable to determine the extent to which participants may have been employed through urban redevelopment in this study. Additionally, although we did not capture economic development, focusing on residential rehabilitation alone may have aided interpretation, given that the two phenomena may have distinct effects.

Endogeneity of residential rehabilitation to injection drug use could also be an issue, however we attempted to account for this by lagging the exposure by one visit prior to when injection drug use was assessed. We also performed sensitivity analysis evaluating the relationship between residential rehabilitation lagged by two visits prior to when injection drug use was assessed and similar results were observed. Additional research is needed to explore the extent to which varying windows of exposure to redevelopment influence health outcomes.

Additionally, we used neighborhood of residence as the unit of analysis which makes the assumption that this spatial unit is most relevant to drug abuse. This assumption could be incorrect if exposure to other neighborhoods has more influence on drug abuse. However, research in Baltimore has demonstrated that purchasing drugs in one's neighborhood, and living in a neighborhood with considerable drug market activity, are associated with persistent injection drug use [69] and a higher likelihood of positive illicit drug tests among probationers [70]. Another potential limitation of using neighborhoods is that residential rehabilitation may be more heterogeneous at the neighborhood level than at smaller geographies (e.g. census block groups), and this could have underestimated the magnitude of the association observed. However, this study was not powered to assess the relationship at a smaller geographic level.

Survival bias is also a concern; however in order to partially account for survival bias, the ALIVE cohort has been replenished through multiple recruitment waves during follow-up. Additionally, we accounted for age in all of our analysis, as age has been associated with declines in substance use overtime.

Lastly, the characteristics of ALIVE participants may not reflect the demographic characteristics (e.g. age and race/ethnicity) of current and former IDUs in other settings. Additionally, the context of redevelopment in Baltimore may vary from that observed in other settings in the United States and abroad. However, the links between decaying communities and drug abuse, and the relationship between improvements in neighborhood conditions and substance use in multiple settings, suggests that the findings from this study are relevant to other locations where drug abuse is prevalent.

Despite these limitations, this study highlights the value of using a cohort study to assess the impact of unanticipated historic events on health outcomes. This study suggests that

residential rehabilitation, a major component of urban redevelopment, was associated with a reduced likelihood of injection drug use, and lends support towards the revitalization of decaying neighborhoods. The findings from this study also support increasing coverage of recovery centers and homeless shelters in less distressed neighborhoods to facilitate drug cessation and recovery.

Due to the social, economic, and health implications of drug abuse, and growing concern over the impact of drug law enforcement internationally [39-41], determining what impact community-based strategies have on drug abuse is important. Residential rehabilitation may be one strategy that reduces the likelihood of drug abuse. However, additional research is needed to identify the mechanisms at play and determine the longevity of the potential effect. Research should also examine the impact of neighborhood revitalization on healthcare costs related to drug use, HIV, and HCV, and costs related to law enforcement. Greater understanding of the health impact of neighborhood revitalization will better inform how urban planning can address structural determinants of health.

Acknowledgments

This research was funded by the National Institute on Drug Abuse (Grant numbers: R01DA012568 and R01DA04334). Additional support for this research was provided by the National Institute on Drug Abuse (Grant numbers: T32DA007292 and K01DA022298-05). The authors would like to thank ALIVE study staff and participants, without whom an understanding of neighborhood conditions and substance use would not be possible. We also appreciate the assistance provided by Matthew Kachura (Baltimore Neighborhood Indicator Alliance) and Cheryl Knott (Baltimore Neighborhood Indicator Alliance), who compiled data from the Baltimore City Department of Housing and Community Development.

References

1. Genberg BL, et al. The Effect of Neighborhood Deprivation and Residential Relocation on Long-term Injection Cessation among Injection Drug Users (IDUs) in Baltimore, Maryland. *Addiction*. 2011; 106(11):1966–1974. [PubMed: 21592251]
2. Latkin CA, et al. Direct and indirect associations of neighborhood disorder with drug use and high-risk - Sexual partners. *American Journal of Preventive Medicine*. 2007; 32(6):S234–S241. [PubMed: 17543716]
3. Furr-Holden CD, et al. The growth of neighborhood disorder and marijuana use among urban adolescents: a case for policy and environmental interventions. *J Stud Alcohol Drugs*. 2011; 72(3): 371–9. [PubMed: 21513673]
4. Nandi A, et al. Neighborhood Poverty and Injection Cessation in a Sample of Injection Drug Users. *Am J Epidemiol*. 2010; 171(4):391–398. [PubMed: 20093307]
5. Delva J, et al. Ecological Factors and Adolescent Marijuana Use: Results of a Prospective Study in Santiago, Chile. *International Journal of Environmental Research and Public Health*. 2014; 11(3): 3443–3452. [PubMed: 24662965]
6. Storr CL, Chen CY, Anthony JC. “Unequal opportunity”: neighbourhood disadvantage and the chance to buy illegal drugs. *Journal of Epidemiology and Community Health*. 2004; 58(3):231–237. [PubMed: 14966238]
7. Lambert SF, et al. The relationship between perceptions of neighborhood characteristics and substance use among urban African American adolescents. *Am J Community Psychol*. 2004; 34(3-4):205–18. [PubMed: 15663207]
8. Galea S, Nandi A, Vlahov D. The social epidemiology of substance use. *Epidemiol Rev*. 2004; 26:36–52. [PubMed: 15234946]
9. Cruz MF, et al. A qualitative exploration of gender in the context of injection drug use in two US-Mexico border cities. *AIDS Behav*. 2007; 11(2):253–62. [PubMed: 16865542]

10. Medhi GK, et al. Spatial distribution and characteristics of injecting drug users (IDU) in five Northeastern states of India. *Bmc Public Health*. 2011; 11:64. [PubMed: 21281465]
11. Nasir S, Rosenthal D. The social context of initiation into injecting drugs in the slums of Makassar, Indonesia. *Int J Drug Policy*. 2009; 20(3):237–43. [PubMed: 18554892]
12. Kromer, J. *Fixing Broken Cities: The Implementation of Urban Redevelopment Strategies*. New York, NY: Taylor & Francis; 2010.
13. Mehdipanah R, et al. An evaluation of an urban renewal program and its effects on neighborhood resident's overall wellbeing using concept mapping. *Health & Place*. 2013; 23:9–17. [PubMed: 23727619]
14. Thomson H, et al. Do urban regeneration programmes improve public health and reduce health inequalities? A synthesis of the evidence from UK policy and practice (1980-2004). *J Epidemiol Community Health*. 2006; 60(2):108–15. [PubMed: 16415258]
15. Garvin EC, Cannuscio CC, Branas CC. Greening vacant lots to reduce violent crime: a randomised controlled trial. *Inj Prev*. 2012
16. Blackman T, et al. Neighbourhood renewal and health: evidence from a local case study. *Health & Place*. 2001; 7(2):93–103. [PubMed: 11470223]
17. Egan M, et al. Health effects of neighborhood demolition and housing improvement: a prospective controlled study of 2 natural experiments in urban renewal. *Am J Public Health*. 2013; 103(6):e47–53. [PubMed: 23597345]
18. Kelaher M, Warr DJ, Tacticos T. Evaluating health impacts: Results from the neighbourhood renewal strategy [corrected] in Victoria, Australia. *Health Place*. 2010; 16(5):861–7. [PubMed: 20472489]
19. Curtis R. Crack, cocaine and heroin: Drug eras in Williamsburg, Brooklyn, 1960-2000. *Addiction Research & Theory*. 2003; 11(1):47–63.
20. Crum RM, Lillie-Blanton M, Anthony JC. Neighborhood environment and opportunity to use cocaine and other drugs in late childhood and early adolescence. *Drug Alcohol Depend*. 1996; 43(3):155–61. [PubMed: 9023071]
21. Fullilove M, Green L, Fullilove Rr. Building momentum: an ethnographic study of inner-city redevelopment. *Am J Public Health*. 1999; 89(6):840–4. [PubMed: 10358672]
22. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science*. 1997; 277(5328):918–924. [PubMed: 9252316]
23. Hill TD, Angel RJ. Neighborhood disorder, psychological distress, and heavy drinking. *Social Science & Medicine*. 2005; 61(5):965–975. [PubMed: 15955398]
24. Cooper HL, et al. The aftermath of public housing relocation: Relationship to substance misuse. *Drug Alcohol Depend*. 2013
25. Cooper H, et al. The Aftermath of Public Housing Relocations: Relationships between Changes in Local Socioeconomic Conditions and Depressive Symptoms in a Cohort of Adult Relocaters. *Journal of Urban Health*. 2013:1–19.
26. Orr, L., et al. *Moving to Opportunity for Fair Housing Demonstration: Interim impact evaluation*. U.S. Department of Housing and Urban Development; Washington, DC: 2003.
27. Leventhal T, Dupere V. Moving to Opportunity: does long-term exposure to 'low-poverty' neighborhoods make a difference for adolescents? *Soc Sci Med*. 2011; 73(5):737–43. [PubMed: 21821323]
28. Brooks, F.; Wolk, J.; Adams, M. *Evaluation of performance and impact of HOPE VI community revitalization (Harris Homes): Evaluation of relocation services*. Atlanta Housing Authority; Atlanta, GA: 2003.
29. Popkin, S., et al. *Families in transition: a qualitative analysis of the MTO experience Final Report*. US Department of Housing and Urban Development, Office of Policy Development and Research; Washington, D.C.: 2002.
30. Leventhal T, Brooks-Gunn J. Moving to opportunity: an experimental study of neighborhood effects on mental health. *Am J Public Health*. 2003; 93(9):1576–82. [PubMed: 12948983]
31. Curley AM. Draining or gaining? The social networks of public housing movers in Boston. *Journal of Social and Personal Relationships*. 2009; 26(2-3):227–247.

32. Davila A. Dreams of place: Housing, gentrification, and the marketing of space in El Barrio. *Centro Journal*. 2003; 15(1):112–137.
33. Fullilove, MT. *Root shock: how tearing up city neighborhoods hurts American and what we can do about it*. First. New York, NY: The Random House Publishing Group; 2004.
34. Fullilove MT. Psychiatric Implications of Displacement: Contributions from the Psychology of Place. *Am J Psychiatry*. 1996; 153:1516–1523. [PubMed: 8942445]
35. Fullilove MT. Root Shock: The Consequences of African American Dispossession. *Journal of Urban Health*. 2001; 78(1):72–80. [PubMed: 11368205]
36. Cao Y, Hwang SS, Xi J. Project-induced displacement, secondary stressors, and health. *Soc Sci Med*. 2012; 74(7):1130–8. [PubMed: 22341203]
37. Hoffer LD, Bobashev G, Morris RJ. Researching a local heroin market as a complex adaptive system. *Am J Community Psychol*. 2009; 44(3-4):273–86. [PubMed: 19838792]
38. Werb D, et al. Effects of police confiscation of illicit drugs and syringes among injection drug users in Vancouver. *International Journal of Drug Policy*. 2008; 19(4):332–338. [PubMed: 17900888]
39. Small W, et al. Impacts of intensified police activity on injection drug users: Evidence from an ethnographic investigation. *International Journal of Drug Policy*. 2006; 17(2):85–95.
40. Best D, et al. Assessment of a concentrated, high-profile police operation. No discernible impact on drug availability, price or purity. *British Journal of Criminology*. 2001; 41(4):738–745.
41. War on Drugs: Report of the Global Commission on Drug Policy. Global Commission on Drug Policy. Jun.2011
42. Mehta SH, et al. Changes in Blood-borne Infection Risk Among Injection Drug Users. *J Infect Dis*. 2011; 203(5):587–94. [PubMed: 21282191]
43. Mehta SH, et al. HIV incidence among injection drug users in Baltimore, Maryland (1988-2004). *J Acquir Immune Defic Syndr*. 2006; 43(3):368–72. [PubMed: 16980912]
44. Mathers BM, et al. Global epidemiology of injecting drug use and HIV among people who inject drugs: a systematic review. *Lancet*. 2008; 372(9651):1733–45. [PubMed: 18817968]
45. Sievert W, et al. A systematic review of hepatitis C virus epidemiology in Asia, Australia and Egypt. *Liver Int*. 2011; 31(Suppl 2):61–80. [PubMed: 21651703]
46. Ansari A, Jedidi K. Bayesian factor analysis for multilevel binary observations. *Psychometrika*. 2000; 65(4):475–496.
47. Beyrer C, Abdool Karim Q. The changing epidemiology of HIV in 2013. *Curr Opin HIV AIDS*. 2013; 8(4):306–10. [PubMed: 23743721]
48. Pereira LM, et al. Prevalence and risk factors of Hepatitis C virus infection in Brazil, 2005 through 2009: a cross-sectional study. *BMC Infect Dis*. 2013; 13:60. [PubMed: 23374914]
49. Vlahov D, et al. The Alive Study - A Longitudinal-Study of Hiv-1 Infection in Intravenous-Drug-Users - Description of Methods. *Journal of Drug Issues*. 1991; 21(4):759–776.
50. Perkins D, Larsen C, Brown B. Mapping urban revitalization: using GIS spatial analysis to evaluate a new housing policy. *J Prev Interv Community*. 2009; 37(1):48–65. [PubMed: 19197674]
51. Mitchell A. *The ESRI Guide to GIS Analysis Volume 1: Geographic Patterns & Relationships*. 1 edition ed. ESRI Press. 1999:186.
52. Messer L, et al. The development of a standardized neighborhood deprivation index. *J Urban Health*. 2006; 83(6):1041–62. [PubMed: 17031568]
53. Williams ML, et al. A comparison of the reliability of self-reported drug use and sexual behaviors using computer-assisted versus face-to-face interviewing. *AIDS Educ Prev*. 2000; 12(3):199–213. [PubMed: 10926124]
54. Galai N, et al. Longitudinal patterns of drug injection behavior in the ALIVE Study cohort, 1988-2000; description and determinants. *Am J Epidemiol*. 2003; 158:695–704. [PubMed: 14507606]
55. Shah NG, et al. Longitudinal predictors of injection cessation and subsequent relapse among a cohort of injection drug users in Baltimore, MD, 1988-2000. *Drug Alcohol Depend*. 2006; 83(2):147–156. [PubMed: 16364568]

56. Rasbash, J. Cross-classified and multiple membership models. In: Everitt, B.; Howell, D., editors. *Encyclopedia of Statistics in Behavioral Sciences*. London: Wiley; 2005.
57. Goldstein H. Multilevel Cross-Classified Models. *Sociological Methods & Research*, February. 1994; 22(3):364–375.
58. Genberg BL, et al. Trajectories of injection drug use over 20 years (1988–2008) in Baltimore, Maryland. *Am J Epidemiol*. 2011; 173(7):829–36. [PubMed: 21320867]
59. Mehta SH, et al. Factors associated with injection cessation, relapse and initiation in a community-based cohort of injection drug users in Chennai, India. *Addiction*. 2012; 107(2):349–58. [PubMed: 21815960]
60. Linton SL, et al. The longitudinal association between homelessness, injection drug use, and injection-related risk behavior among persons with a history of injection drug use in Baltimore, MD. *Drug Alcohol Depend*. 2013; 132(3):457–65. [PubMed: 23578590]
61. Linton SL, et al. “Everything that looks good ain’t good!”: Perspectives on urban redevelopment among persons with a history of injection drug use in Baltimore, Maryland. *Int J Drug Policy*. 2013
62. Cooper HLF, et al. Public housing relocations in Atlanta, Georgia, and declines in spatial access to safety net primary care. *Health & Place*. 2012; 18(6):1255–1260. [PubMed: 23060002]
63. Mirabal N. Geographies of displacement: Latina/os, oral history, and the politics of gentrification in San Francisco’s Mission District. *Public Hist*. 2009; 31(2):7–31. [PubMed: 19824231]
64. Grieb SM, et al. Understanding housing and health through the lens of transitional housing members in a high-incarceration Baltimore City neighborhood: the GROUP Ministries Photovoice Project to promote community redevelopment. *Health Place*. 2013; 21:20–8. [PubMed: 23399886]
65. Roylance FD. A testy reception for new East Baltimore plans, in *The Baltimore Sun*. 2011
66. Sherman S, et al. Acceptability of a Microenterprise Intervention Among Female Sex Workers in Chennai, India. *Aids and Behavior*. 2010; 14(3):649–657. [PubMed: 20352320]
67. Sherman SG, et al. The evaluation of the JEWEL project: An innovative economic enhancement and HIV prevention intervention study targeting drug using women involved in prostitution. *Aids Care-Psychological and Socio-Medical Aspects of Aids/Hiv*. 2006; 18(1):1–11.
68. Leslie HH, et al. Social participation and drug use in a cohort of Brazilian sex workers. *J Epidemiol Community Health*. 2013; 67(6):491–7. [PubMed: 23505308]
69. Sherman SG, Hua W, Latkin CA. Individual and environmental factors related to quitting heroin injection. *Subst Use Misuse*. 2004; 39(8):1199–214. [PubMed: 15461018]
70. Wooditch A, Lawton B, Taxman FS. The Geography of Drug Abuse Epidemiology Among Probationers in Baltimore. *Journal of Drug Issues*. 2013

Table 1
Characteristics of participants by level of residential rehabilitation in neighborhood of residence at the first available follow-up visit, among 1,818 ALIVE participants

	Total		Low Residential Rehabilitation		Moderate Residential Rehabilitation		High Residential Rehabilitation		P-value
	N	%	N	%	N	%	N	%	
Individual level covariates									
Age									
< 45 years	923	50.8	747	51.7	120	45.1	56	52.3	
45 years	895	49.2	698	48.3	146	54.9	51	47.7	0.14
Male	1215	66.8	964	66.7	177	66.5	74	69.2	0.87
African American	1653	90.9	1350	93.4	227	85.3	76	71.0	<0.01
Income \$5000 USD	360	19.8	284	19.7	58	21.8	18	16.8	0.53
Current Legal Employment	421	23.2	360	24.9	36	13.5	25	23.4	<0.01
Homelessness	357	19.6	240	16.6	73	27.4	44	41.1	<0.01
Incarceration	338	18.6	272	18.8	43	16.2	23	21.5	0.43
Sex with an IDU partner	523	28.8	398	27.6	88	33.1	37	34.6	0.07
Methadone Maintenance	342	18.8	257	17.8	59	22.2	26	24.3	0.08
Detoxification	134	7.4	85	5.9	33	12.4	16	15.0	<0.01
Non-Injection Drug Use	856	47.1	653	45.2	145	54.5	58	54.2	<0.01
Frequency of Injection									
None	731	40.2	601	41.6	92	34.6	38	35.5	
< Daily	474	26.1	371	25.7	73	27.4	30	28.0	
Daily	613	33.7	473	32.7	101	38.0	39	36.5	0.21
HIV Positive	630	34.7	480	33.2	108	40.6	42	39.3	0.04
Neighborhood level covariates									
Economic Deprivation									
1 st Tertile	121	6.6	90	6.2	27	10.2	4	3.7	
2 nd Tertile	417	22.9	349	24.2	51	19.2	17	15.9	
3 rd Tertile	1280	70.4	1006	69.6	188	70.7	86	80.4	0.01

IDU: injection drug user. Non-injection drug use: crack use, snorted cocaine, snorted heroin or marijuana use

Table 2
Crude longitudinal association between multi-level factors and injection drug use among 1,818 ALIVE participants in follow-up 2000-2011

	Crude odds ratio (95% confidence interval)
<i>Individual Level Covariates</i>	
Age	
< 45 years old	<i>Ref</i>
45 years old	0.38 (0.33, 0.45)
Gender	
Male	<i>Ref</i>
Female	0.76 (0.58, 0.98)
Race	
Other	<i>Ref</i>
Black	0.36 (0.23, 0.57)
Income	
< \$5000 USD	<i>Ref</i>
\$5000 USD	0.67 (0.59, 0.78)
Current Legal Employment	0.81 (0.70, 0.92)
Homelessness	1.82 (1.56, 2.13)
Incarceration	1.91 (1.61, 2.25)
Sex with an IDU partner	1.69 (1.47, 1.94)
Methadone Maintenance	0.57 (0.48, 0.66)
Detoxification	1.60 (1.30, 1.96)
Frequency of Injection	
None	<i>Ref</i>
Less than daily	7.17 (6.31, 8.14)
Daily	15.61 (13.62, 17.89)
Non-injection drug use	2.16 (1.91, 2.44)
HIV Positive	0.62 (0.49, 0.80)
<i>Neighborhood Level Covariates</i>	
Residential Rehabilitation	
Low	<i>Ref</i>
Moderate	0.53 (0.46, 0.61)
High	0.48 (0.39, 0.60)
Economic Deprivation	
1 st Tertile	<i>Ref</i>
2 nd Tertile	1.20 (0.83, 1.72)
3 rd Tertile	1.32 (0.94, 1.86)

IDU: injection drug user. Non-injection drug use: crack use, snorted cocaine, snorted heroin, or marijuana use. All covariates were time-varying and lagged one visit prior to when injection drug use was measured, excluding gender and race. All time-varying covariates were measured in the last six months, unless otherwise stated.

Table 3
Adjusted longitudinal association between residential rehabilitation and injection drug use among 1,818 ALIVE participants in follow-up 2000-2011

	Adjusted odds ratio (95% confidence interval)
Residential Rehabilitation	
Low	<i>Ref</i>
Moderate	0.77 (0.67, 0.87)
High	0.74 (0.61, 0.91)

Model adjusted for baseline gender and race, and the following time-varying covariates lagged one visit prior to when injection drug use was measured: age, income, employment, homelessness, incarceration, sex with an injection drug user, methadone maintenance, frequency of injection drug use, non-injection drug use, HIV, neighborhood deprivation, and recruitment wave.

Table 4
Unadjusted and adjusted longitudinal association between relocation and injection drug use among 1,758 ALIVE participants in follow-up 2000-2011

	Unadjusted odds ratio (95% confidence interval)	Adjusted odds ratio (95% confidence interval)
Relocation		
Continued Residence in Low RR	<i>Ref</i>	<i>Ref</i>
Continued Residence in Moderate/High RR	0.49 (0.41, 0.57)	0.72 (0.61, 0.83)
Relocation Between Low RR	1.30 (1.09, 1.53)	1.12 (0.95, 1.33)
Relocation Between Moderate/High RR	0.54 (0.40, 0.72)	0.68 (0.51, 0.90)
Relocation from Low to Moderate/High RR	0.66 (0.53, 0.83)	0.65 (0.52, 0.81)
Relocation from Moderate/High to Low RR	0.87 (0.66, 1.14)	0.90 (0.70, 1.17)

RR: Residential Rehabilitation. Relocation was measured across visit pairs for which location of residence was available at the current and lagged visit (n=13707 observations). Model adjusted for baseline gender and race, and the following time-varying covariates lagged one visit prior to when injection drug use was measured: age, income, employment, homelessness, incarceration, sex with an injection drug user, methadone maintenance, frequency of injection drug use, non-injection drug use, neighborhood deprivation, and recruitment wave.