

**ORIGINAL ARTICLE**

# A greening theory of change: How neighborhood greening impacts adolescent health disparities

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**Abstract**

Neighborhoods are one of the key determinants of health disparities among young people in the United States. While neighborhood deprivation can exacerbate health disparities, amenities such as quality parks and greenspace can support adolescent health. Existing conceptual frameworks of greening-health largely focus on greenspace exposures, rather than greening interventions. In this paper, we develop and propose a Greening Theory of Change that explains how greening initiatives might affect adolescent health in deprived neighborhoods. The theory situates greening activities and possible mechanisms of change in the context of their ability to modify distal social determinants of health factors, stemming from macrostructural and historical processes that lead to resource inequalities, affecting both the social and built environment in which adolescents live and develop. The framework illustrates both short- and long-term health, economic, and security effects of greening. We also describe how the theory informed the development of Project VITAL (Vacant lot Improvement to Transform Adolescent Lives) in Baltimore, MD, which aims to (1) build a citywide sharable database on vacant lot restoration activities, (2) evaluate the impact of greening initiatives on adolescent health outcomes, (3) conduct cost-effectiveness analyses, and (4) develop best practices for greening programs for improved adolescent health.

**KEYWORDS**

adolescent health, greening interventions, greenspace, vacant lots

**Highlights**

- Current greenspace-health frameworks largely address greenspace instead of greening.
- Greening activities that engage social determinants of health might reduce adolescent health disparities.
- Our Greening Theory of Change informed study design for Project VITAL (Vacant lot Improvement to Transform Adolescent Lives).

**INTRODUCTION**

Over the past four decades, the United States has seen an alarming downturn in the mental and physical health of teens and adolescents. Rates of obesity, anxiety, depression, diabetes, attention deficit hyperactivity disorder

(ADHD), and hypertension have increased (Bell et al., 2019; Centers for Disease Control and Prevention, 2023; Racine et al., 2021; Tsoi et al., 2022). In addition, the COVID-19 pandemic is widely recognized for severely exacerbating existing inequities, resulting in poor physical and mental health outcomes for vulnerable

communities, including children and adolescents, during and after the pandemic (Panchal et al., 2023). In 2021, more than a third of high school students reported experiencing poor mental health during the pandemic, and 44% reported they felt persistently sad and hopeless during the past year (Centers for Disease Control and Prevention, 2021).

Outside of genetic factors, the social determinants of health (SDOH) are key contributors to the health of adolescents, especially for those growing up in low-resourced urban communities (Braveman et al., 2011). These determinants can be structural, such as income inequality, racial discrimination, educational opportunities, and social policies, but they can also be proximal determinants, such as household poverty and living conditions (Viner et al., 2012).

Neighborhood environments have been established as an influential SDOH (Diez Roux & Mair, 2010), and they are included as important determinants in prominent SDOH frameworks such as Healthy People 2020 (Hill-Briggs et al., 2021; U.S. Department of Health and Human Services & Office of Disease Prevention and Health Promotion, 2020). Neighborhoods are highly influential in determining adolescent health outcomes because they often encompass both the social and physical environments in which children develop (Leventhal & Brooks-Gunn, 2000).

A large body of evidence now shows that adolescents living in economically deprived versus affluent neighborhoods face much higher risks to their health, which can have long-lasting negative effects well into adulthood (Chetty et al., 2022). Neighborhood physical and structural disparities—in access to resources and opportunities, and exposure risks—interact in complex ways with individual behaviors, social networks, and social norms. The result is that neighborhoods create unique social and physical exposures and experiences for adolescents during a critical period of development in a way that can affect life chances (e.g., education, income, and wealth) and well-being across the life course (Warner & Settersten, 2017).

In Baltimore City, this is especially true among Black adolescents, who often live in neighborhoods where they are exposed to high levels of deprivation, crime and violence, and poor quality, and vacant housing (Baltimore Neighborhood Indicators Alliance, 2021). Inequitable housing patterns here, such as gentrification and redlining, have been associated with higher levels of depression and anxiety symptoms among youth, with this relationship mediated by social cohesion (Sadler et al., 2022).

In this paper, we describe a form of place-based intervention, neighborhood greening, as a potential way to mitigate adolescent health disparities. We respond to a gap in existing nature-health frameworks by proposing a Greening Theory of Change (ToC), which guided the development of Project VITAL (Vacant lot Improvement

to Transform Adolescent Lives), which in turn aims to examine the relationship between conversion of vacant land to community-cared-for green spaces with adolescent health outcomes in the City of Baltimore, MD.

## Quality parks and greenspace may improve adolescent health and reduce adolescent health disparities

Publicly accessible parks and greenspaces, whether publicly or privately owned, are important neighborhood elements that can promote good public health alongside quality housing, schools, transportation, food, and safe spaces for recreation (Browning et al., 2022; Lyons et al., 2022). These spaces are important neighborhood infrastructure as they promote mental, physical, and social well-being, as well as community building (Kondo, Fluehr, et al., 2018). The importance of access to safe, outdoor green spaces became especially apparent during the COVID-19 pandemic (Larson et al., 2022). However, parks and green spaces are frequently spatially clustered reflecting racial and economic segregation.

Studies show that urban areas with the highest levels of deprivation generally have less tree canopy than their high-income counterparts (Gerrish & Watkins, 2018), and communities of color tend to have less tree canopy than predominantly white neighborhoods (Watkins & Gerrish, 2018). In part, this is a result of historic “redlining” policies and other discriminatory practices that segregated people of color within specific neighborhoods and disinvested in these areas, resulting in less tree canopy and greenspaces (Locke et al., 2021; Nardone et al., 2021). The disparity in access has been found in many cities, including Baltimore, and can be considered an environmental justice issue (Boone et al., 2009).

In addition to the lack of greenspace, many deprived neighborhoods in cities throughout the United States have an abundance of vacant and dilapidated homes or properties (Mallach, 2018). Vacant buildings and properties have proven negative impacts on public health, and their presence is a consistent predictor of violence (Sivak et al., 2021).

Mitigation and reuse of vacant buildings and spaces, which often involves greening, is one type of place-based intervention associated with health benefits. Vacant building removal was associated with ~5% reduction in violent crime in Baltimore, MD, from 2014 to 2019 (Locke et al., 2023). However, the sustained maintenance of such interventions is likely critical for long-term benefits (Branas & Macdonald, 2014).

The greening and maintenance of vacant lots (transforming a vacant space to a maintained, vegetated space) has been linked to lower levels of violence and depression in Philadelphia (Branas et al., 2018; South et al., 2018). Some evidence suggests that other greening interventions such as

park improvements and promotion, and provisions of greenways and trails might improve public health and safety outcomes (Hunter et al., 2019).

### Gaps in current greenspace-health research and theory

Existing theory about how greenspace affects health tends to conceptualize green space as a static feature, rather than as a socially embedded intervention or change. The Nature and Health framework posed by Hartig et al. (2014) suggests that exposure to nature can affect health and well-being by modifying exposure to air pollution, social contacts, stress, and physical activity. Markevych et al. (2017) provided a widely used framework that reclassifies the pathways by which nature exposure affects health, namely, that nature can reduce harm, restore capacities, and build capacities. Other frameworks elucidate the biological elements in nature that might affect human physiological and psychological states (Kuo, 2015). However, existing greenspace-health conceptual frameworks largely treat SDOH as factors external to greenspace. Area-level social and cultural factors, and individual-level socioeconomic characteristics, have been conceptualized (Hartig et al., 2014) and largely modeled as effect modifiers in existing nature-health research.

In addition, existing frameworks have been primarily developed from research conducted among adults, not adolescents. Adolescents have been found to have different levels of exposure to their neighborhoods and may also have different levels of sensitivity to neighborhood-associated factors compared to adults, and consequently, have different experiences and perceptions about their neighborhoods compared to adults (Allison et al., 1999; Witherspoon & Ennett, 2011). Their bodies are different from adults (e.g., per pound of body weight they breathe more air, drink more water, and their developing bodies create new neural connections); this makes them more sensitive to physical and social environmental exposures than adults.

Promising new lines of theory focus on the mechanisms behind impacts of neighborhood greening. The Busy Streets Theory (Aiyer et al., 2015) suggests ways that resident-led neighborhood transformation can improve safety, specifically. Namely, social capacity, positive relationships, and behaviors are key ingredients to neighborhoods less susceptible to violence. Below, we introduce Project VITAL, which, in addition to gaps in current greenspace-health theory, motivated the development of a Greening ToC that is explicit about multilevel structural influences on health inequalities, and the pathways by which multiple forms of greening activities might affect adolescent health and well-being.

## INTRODUCING PROJECT VITAL

Project VITAL is a study that seeks to advance our knowledge of whether and how vacant lot restoration can reduce adolescent health disparities in Baltimore City. The study was created to address the research gaps mentioned above and to better understand how Baltimore City's increased greening and vacant lot restoration activities are impacting the health of young people who live near vacant lots.

Currently, Baltimore has over 25,000 vacant lots and an additional 17,000 vacant buildings (Baltimore Green Network, 2023). The City of Baltimore runs programs that engage communities in the care of vacant lots, for example: (1) the Care-A-Lot and BMORE Beautiful program which provides funding for cleaning and beautification projects in communities, and (2) Adopt-A-Lot program, which is a temporary land-use agreement allowing for community-led greening projects on vacant lots, often with various sources of funding secured through grassroots efforts. Members of these programs are contributors to Project VITAL. While a variety of groups and programs have restored close to 1000 lots, their efforts vary widely in the type and quality of restoration. Some of the restoration efforts include mowing and trash pick-up, while others involve creating art murals, planting community gardens, and hosting community programs and events.

Participation by a wide variety of stakeholders in care of vacant lots in Baltimore provides an opportunity for a multidisciplinary team of researchers, practitioners, and policymakers to implement a study with a highly collaborative and multifaceted comprehensive approach. Results can inform the development of long-term strategies for investing not only in neighborhood improvements but also in the health equity of adolescents living in the most deprived neighborhoods.

Project VITAL has four key objectives: (1) build a sharable database containing key characteristics of “greened” and “ungreened” vacant lots by public, private and community actors; (2) examine the relationships between adolescent health and exposure to various types of vacant lot restoration using a mixed methods study design that includes adolescent surveys, observations, and in-depth interviews; (3) estimate the cost-effectiveness of different restoration programs on adolescent experiences of crime and violence, mental health, and food insecurity; and (4) develop and disseminate a blueprint for reducing adolescent health disparities through lot restoration strategies that can be adapted for different US municipalities.

In looking for a framework to guide the study, existing frameworks did not adequately elucidate potential pathways for how greening influences the health of adolescents. In addition, existing frameworks did not illustrate how greening vacant lots could be used as a strategy for reducing adolescent health disparities. Based

on prior evidence, as well as input from a facilitated brainstorming session with a diverse set of stakeholders, we propose a Greening Theory of Change. This served as a guide to Project VITAL and can serve other projects that examine the impacts of greening activities on reducing disparities in adolescent health and improving community safety for adolescents.

## A GREENING THEORY OF CHANGE

Project VITAL commenced in 2020, with a workshop to brainstorm the various factors at play in greening work for adolescent health in Baltimore. The workshop was attended by representatives from community organizations engaging young people in greening, Baltimore City agencies, and researchers in adolescent health, urban forestry, environmental health, violence, mental health, and neighborhood effects. Together, we developed a Greening Theory of Change that depicts the processes by which neighborhood greening initiatives might affect adolescent health and health disparities, informed by a combination of research and lived experiences as reported by those involved in vacant lot care and community-led transformation work (see Figure 1).

This ToC is unique in several important ways. First, it situates greening activities and the possible mechanisms of change in relation to distal SDOH factors stemming from historical and macrostructural policies and processes, which have led to resource inequalities that affect neighborhood-built environment and social context. Second, given that mechanisms of change can occur at different scales, we included potential mechanisms at the individual-, interpersonal-, and environmental levels. Finally, the framework illustrates potential short- and long-term outcomes of greening, including health as well as economic and security outcomes, which greening can influence—both positively and negatively. Where possible, we cite evidence from greening intervention studies; however because the extent of this research is limited, especially among adolescents (Hunter et al., 2019), we also draw from studies that have examined the association of greenspace and health. Each layer of the theory is described in more detail below.

## Factors

### Societal factors

Historical development and policy processes have shaped current societal factors that drive increasing health inequalities for young people. Early urban development in the United States was driven by advances in, and expansion of, the manufacturing sectors and industry. Urban populations, with the largest being New York

City, Chicago, and Philadelphia, grew rapidly and without time to install adequate housing and infrastructure. Jacob Riis's ethnographic account, *Where the Other Half Lives* (Riis, 1890), brought attention to the squalid living conditions and the subsequent threats to health, with tuberculosis, pneumonia, and diarrhea being the leading causes of death, affecting children disproportionately (Centers for Disease Control and Prevention, 1999).

A municipal response sought to use the law, via city codes and ordinances, to improve living conditions and the health of urban workers and their families (Lopez, 2012). Early park movements set aside large parcels of land, centrally located, to provide “lungs” to the city, and natural retreats within an urban context. At the same time, planning efforts such as the Garden City Movement began the development of leafy suburban communities that were highly controlled in terms of both physical and social features. Subsequent local, state, and federal policies, beginning in the 1930s, aided an exodus of urban populations and jobs to suburban areas, except that they largely aided only those racialized as white (Katznelson, 2005). These policies also subsidized a new phenomenon of home ownership, as well as college education, also excluding people of color.

Meanwhile, planning initiatives in the 1950s–1970s used racist policies and programs such as redlining, urban renewal, and public housing to concentrate people of color and deprivation in cities (Swope et al., 2022). These historical, macrosocial factors still influence neighborhood social and physical environment and may determine what resources are made available for greening activities.

### Local factors

The resulting race- and class-based segregation and unequal distribution of subsidies and wealth that exist today are local factors that lead to ongoing, and exacerbated, social and health inequalities. Cities lost residents, jobs, and sources of healthy food, while investment in housing stock, infrastructure, and schools declined. Industrial, commercial, and residential properties became vacant, and communities became disenfranchised from political and economic systems. These factors affect the social fabric and the capacity within communities for dealing with disinvestment and for implementing solutions such as greening.

### Greenspaces and greening activities

Access and exposure to urban parks and other greenspaces combined with community-led reclamation of vacant land through greening activities have been a vital resource to the urban communities left behind.

# GREENING THEORY OF CHANGE

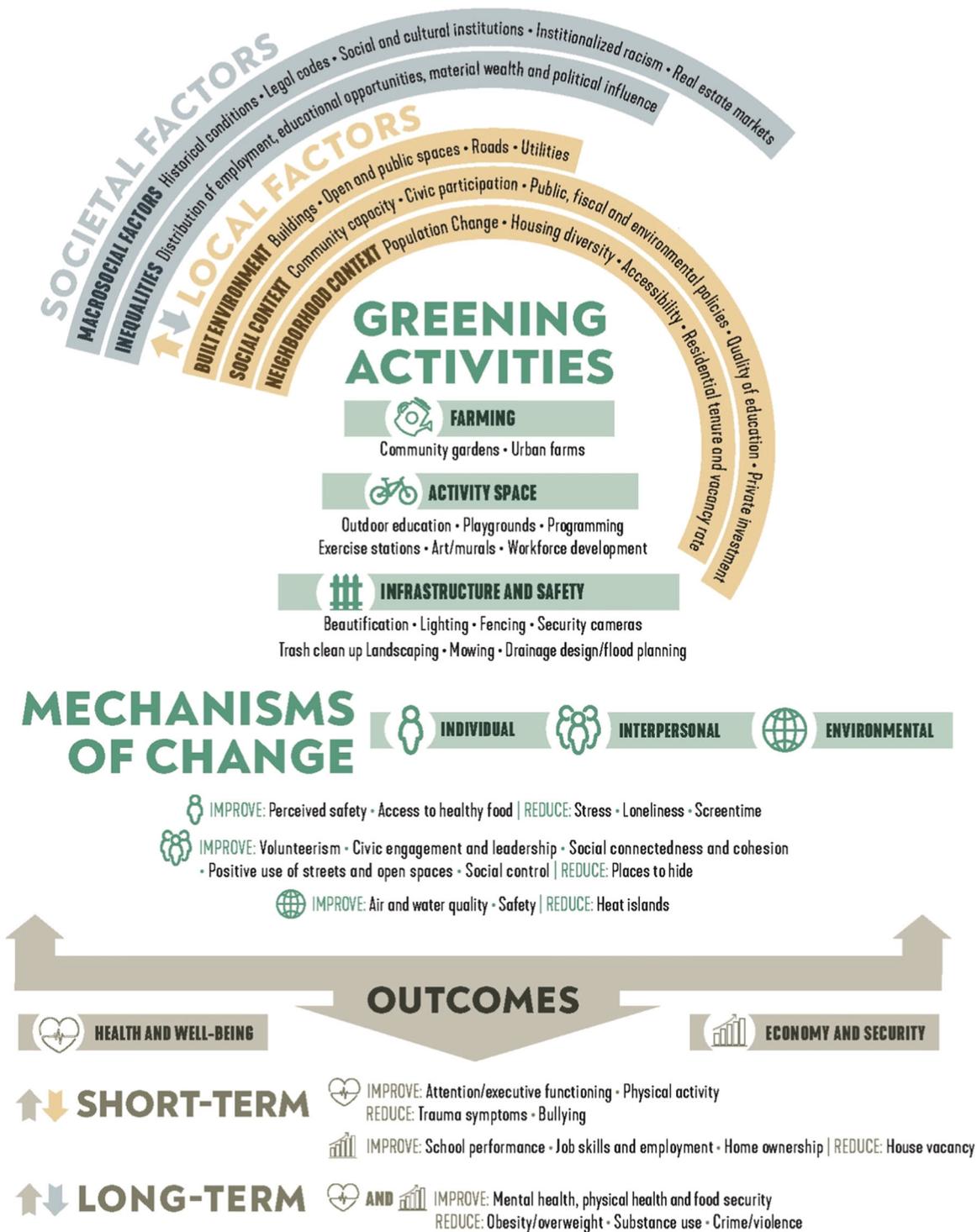


FIGURE 1 The Greening Theory of Change.

Both installation and vacant lot reclamation through greening activities present an opportunity to provide jobs to local residents and even to reduce recidivism if paired with appropriate programming and other support. Very often, community-led greening activities make use of vacant parcels or lots that would otherwise contribute to a cycle of neighborhood neglect and decline. Greening activities often specifically seek to counteract detrimental factors associated with vacant lots and improve neighborhood conditions, clean up areas, and show signs of care and maintenance, all to improve safety. Greening activities can also be a method to help communities heal from trauma. Planting and gardening activities have been used as therapeutic practices in communities impacted by persistent poverty, natural disasters, war, displacement, and loss (Tidball & Krasny, 2013).

Greening activities are often designed to meet the needs of children and families specifically, for example by providing safe places for play and recreation. The “vest” pocket park movement of the mid- to late-1960s in New York City and other large cities sought to make use of vacant lots to provide local recreation opportunities. Pocket parks can also provide healthy food grown in community gardens; these sites can promote healthy learning and development (Kuo & Jordan, 2019) and can pass on cultural traditions and history. Paying young people for greening work or engaging them via school programs or after-school programs are common ways to engage them in greening activities. This can also lead to marketable skill sets and resume-building experiences.

## Mechanisms of change

### Reducing pollution and heat exposures

Well-established pathways by which greenspace exposure and greening activities affect health are based largely on research with adult populations. Some mechanisms are universal; for example, creating or maintaining access to greenspace can reduce harm to adults and adolescents alike by reducing exposures to harmful pollutants and heat. Greenspace has been found to partially mitigate negative effects of traffic-related air pollution and noise on stress levels among children (Franklin et al., 2020). In addition, children, in general, are less heat tolerant than adult populations. Tree canopy has been found to lower urban temperatures by up to 10° (F) (Hoffman et al., 2020), and lower temperatures from tree shade have been associated with higher levels of moderate to vigorous physical activity (Lanza et al., 2022).

### Stress

The Stress Recovery Theory posits that humans evolved primarily in natural settings and therefore are

physiologically and psychologically better adapted to natural rather than urban settings (Ulrich et al., 1991). The benefits of nature for stress reduction, measured as a psychological or physiological state, have been well-established (Kondo, Jacoby, et al., 2018). Prior studies have shown that nature or greenspace can buffer against stressful life events, or improve stress regulation (Van den Berg et al., 2010), especially among children (Wells & Evans, 2003). For young people in particular, neighborhood green space helps to cope with stress via opportunities to be social and physically active (Roe et al., 2017).

Residents of economically deprived communities have often experienced trauma that may result from, and also compound, negative effects of social disparities. Trauma may result from interpersonal- or family-level occurrences such as domestic violence, loss of family or friends, or experiences of assault. Trauma can also be triggered by neighborhood or community-level experiences, such as discrimination and oppression, high incarceration rates, and witnessing violence (Conching & Thayer, 2019).

Neglected places with physical characteristics that signal distrust and disinvestment (e.g., litter or trash, unmaintained playground equipment, sick or dead trees and shrubs, and chain-link fences with razor wire), may cause or exacerbate stress and trauma (Ross & Mirowsky, 2001). Children are at relatively higher risk of developing trauma-related disorders such as post-traumatic stress disorder (PTSD) (Herringa, 2017). On the other hand, parks and greenspace, and greening activities, could be part of what Schroeder et al. (2021) refer to as “trauma-informed neighborhoods.” Park spaces, and sometimes planting of individual trees, have frequently been part of a healing process in traumatized communities (Svendsen & Campbell, 2010).

### Social connectedness

Both greenspace and involvement in greening activities may help adolescents connect with peers and caring adults. For example, pre/post studies of schoolyard greening have found improved positive social interactions among students (Bates et al., 2018). Improved social connections associated with greenspace have been directly linked to better mental health among young people (Dzhambov et al., 2018). Improved social connections can also reduce isolation and loneliness, which have been linked to poor mental health outcomes (Wang et al., 2017).

### Community engagement

Residents of under-resourced communities, young people in particular, are not often included in decisions

regarding their neighborhoods and public spaces (Silverman et al., 2020). Meaningful engagement of all people, especially in high-risk environments, is a key tenet of environmental justice initiatives (Hilmers et al., 2012). Participation and leadership in greening activities and environmental stewardship might instill ownership over neighborhood space and improve civic engagement (Fisher et al., 2015), which among young people in urban communities of color has been shown to improve life satisfaction and educational attainment, and reduce arrest rates into adulthood (Chan et al., 2014). Adolescent community engagement also predicts decreased depressive symptoms later in life (Wray-Lake et al., 2019). Greening activities also often involve volunteering. Among adolescents, volunteering has been found to improve various dimensions of competence, improve leadership, attitudes and relationships, as well as reduce risk-taking behaviors (Hernantes et al., 2020).

### Less screentime

Proximity to greenspace has been found to be associated with less noneducational screen time among children (Aggio et al., 2015). Research has established a number of negative effects of screen time in its various forms, including reduced sleep (Hale & Guan, 2015) and adverse psychological outcomes (Oswald et al., 2020).

### Positive use of outdoor spaces and social control

Greening activities themselves, and the improved vacant and public spaces that result, might promote *busy streets*, in which neighbors are engaging in positive interactions as they go about their daily activities (Aiyer et al., 2015). Greening activities can signal social control (Rupp et al., 2020) and have been found to be associated with increased use of outdoor spaces for socializing, reduced fear, and reduced gun violence (Branas et al., 2018).

At the same time, it has been argued that social policing, or informal social control, in public settings can reduce young people's feeling of welcome (Littman, 2022). Young people are often socially marginalized or excluded from public spaces, but there have been some efforts to engage marginalized youth in neighborhood planning exercises, and to design social and physical spaces that explicitly cater to youth (Loebach et al., 2020).

### Perceived safety

Adolescents' perceptions of the safety in their neighborhoods may be an indicator of the quality of greened vacant lots and the frequency with which they use

greened lots. Adolescents who perceive their neighborhoods as safe may spend more time in the greened vacant lots compared to adolescents who do not. While there have not been any studies conducted on whether greening can improve adolescents' sense of safety, studies among adults have shown that living next to greenspace improves perceptions of neighborhood safety (Maas et al., 2009). Maintenance of greened spaces may also play a critical role in actual and perceived safety; so condition, quality, and long-term maintenance of greened spaces is important.

### Food access/availability

When greenspace is utilized for community gardens and urban farms, there is some research to show that it can improve fruit and vegetable intake and reduce food insecurity among participants (Alaimo et al., 2023), as well as residents who live nearby (Hume et al., 2022). To date, however, very little has been published on this topic in relation to adolescents and whether living next to a greened vacant lot can improve their access to healthier food choices.

### Short-term outcomes

In our Greening ToC, we divide the outcomes into health/well-being and economy/security to reflect the myriad and inter-related impacts of greening among individuals and communities. While there is generally insufficient quantity and quality of investigation into health impacts of greenspace specifically for adolescent populations (Ye et al., 2022), some patterns are beginning to emerge. Below we describe the literature to date on the impact of greening on selected outcomes among adolescents and where there may be gaps to explore further.

### Cognitive functioning and behaviors

Among adolescents, greenspace exposure has been found to correlate with improved selective attention, sustained attention and working memory, cognitive performance, and white and gray matter volume in several regions of the brain, including regions associated with cognitive development and working memory (Sprague et al., 2022; Vella-Brodrick & Gilowska, 2022). Another study found greenspace exposure to be associated with improved self-determination, self-regulation, lower frequency of peer and conduct problems, and decreased odds of an ADHD diagnosis (Sakhvidi et al., 2022). Exposure to greenspace is associated with reduced ADHD symptoms and behavioral difficulties, as well as improved prosocial behavior and emotions for adolescents (Sakhvidi

et al., 2023). In addition, schoolyard greening has reduced bullying (Bates et al., 2018).

## Physical activity

For children and adolescents, greenspaces can provide outlets for physical activity and energy expenditure (Chawla, 2015). Physical activity has been measured and reported in different ways, including the percentage of time spent in moderate to vigorous physical activity, time spent in sedentary and light physical activity, physical activity frequency and distance, and the percentage or number of children and adolescents observed in different activities in green spaces (Klinker et al., 2014; Lachowycz et al., 2012). In general, studies have shown a positive association between greenspace and physical activity, with one review concluding greenspace confers stronger benefits for boys than girls and for older versus younger adolescents. Similarly, schoolyard greening has been found to increase students' physical activity (Raney et al., 2019). While findings are mixed, some intervention studies of park improvements have reported positive impacts on physical activity including among adolescents (Hunter et al., 2019).

## Job skills and employment

An emerging body of research is examining the association between engaging young people in urban greenspace projects and job creation. For example, the Bronx Environmental Stewardship (BEST) Academy trained young people in low-income neighborhoods to restore urban green spaces. Over 85% of the graduates of the academy have obtained employment after graduation, with more than 90% employed in environmental-sector jobs (Pacific Institute, 2013). Similarly, in Atlanta, the Greening Youth Foundation organized a year-and-a-half paid training and work experience for young adults, where trainees gain skills in construction, gardening, and landscaping to be employable with the City's Green Infrastructure Strategic Plan (City of Atlanta, 2017). Another avenue for job training and creation tied to vacant land reclamation includes programs aimed at deconstructing vacant buildings, such as Baltimore's Deconstruction Training Program (City of Baltimore, 2014).

However, the value of job creation in terms of addressing health equity is tied to more than just job provision, but also job quality, stability, opportunities for long-term economic mobility, and whether or not the most vulnerable have access to these opportunities (Tsui, 2010). These outcomes are far less frequently measured than less significant, but more immediate, measures like initial job placement (Martinson et al., 2016) as more job training programs that involve

greening continue to emerge, research is needed on the extent to which such programs lead to long-term employment opportunities among young people.

## Long-term outcomes

### Mental health and well-being

Transforming vacant spaces to cared-for greenspaces can increase the likelihood that teens will access greenspace in their communities, thereby increasing exposure to greenspace, while decreasing exposure to vacant buildings. The Attention Restoration Theory posits that greenspace exposure reduces stress and the burden of mental fatigue which promotes positive mental well-being (Kaplan, 1995). A prior study of vacant lot greening in Philadelphia found that residents living near cleaned-and-greened lots reported reduced symptoms of depression and worthlessness compared to residents living near control vacant lots (South et al., 2018). A randomized controlled trial of a community gardening intervention found that participants who received a garden plot reported greater reductions in stress and anxiety than did control participants (Litt et al., 2023). It has not been established whether these benefits extend to adolescents.

### Food security

The association between food security and greenspace has been examined primarily via community gardens. While there have not been any studies to date that have examined the impact of urban community gardens and adolescent food security, there have been several conducted among adults. Overall, while studies are mixed, most suggest that community gardens can improve food security, especially for those living in low-income neighborhoods (Cyzman et al., 2009; Egli et al., 2016).

### Physical health

A growing number of studies have used experimental and quasi-experimental techniques to evaluate the impact of greening interventions on physical health and health behaviors such as physical activity. These interventions are diverse in nature, and studies have demonstrated positive effects of planting street trees on reducing nonaccidental and cardiovascular mortality (Donovan et al., 2022), and mixed or null results for building greenways (Hunter et al., 2019; Xie et al., 2022) and upgrading urban greenspace in deprived neighborhoods and self-reported health status (Droomers et al., 2016). Kondo et al. (2015) found null results for impacts of

green stormwater infrastructure installation on the incidence of high cholesterol, blood pressure, and stress. The inconsistent results from a small number of very different interventions highlight the need for careful research to understand what kinds of greening interventions may be expected to have what kinds of health effects on which populations.

### Substance use

Residential greenness has also been linked with possible patterns of substance use among young people. A cross-sectional analysis of 14,070 adolescents and young adults aged 15–25 years showed that higher levels of vegetation in residential areas were associated with lower odds of frequent binge drinking, tobacco use, and greater odds of marijuana use for adolescents who lived in those neighborhoods (Wiley et al., 2022). Some of these results may be explained by greenspace's ability to alleviate stress that otherwise may encourage individuals to turn to substances for relief. This is especially significant in neighborhoods with abandoned houses/plots, which are conducive to drug use, crime, and a lower perception of neighborhood safety (Rupp et al., 2020).

### Crime and violence

Vacant properties are commonly associated with crime and violence, as they are often used as storefronts for narcotics trade, as hiding places, and places near which to stash weapons (Branas et al., 2018). Greening activities involving vacant lots have been shown to reduce violence, in particular gun violence (Branas et al., 2018), which might have a disproportionately positive impact on adolescents in disadvantaged communities. A recent study of vacant lot greening in Flint, MI, found a significant decrease in gun crimes involving a youth victim (relative to at control lots) between 2015 and 2018, but only on lots where the landbank owners engaged community members in the greening process (Bushman et al., 2023).

## DISCUSSION AND CONCLUSIONS

Neighborhoods are a critical part of the SDOH, and vacancy is a characteristic of neighborhood environments in many cities. Decision makers need to know what types of investments are likely to make a difference in outcomes for residents and adolescents in particular, and the potential pathways and mechanisms that influence those relationships. A comprehensive understanding is critical to being able to leverage policy, planning, and design as an intervention to improve adolescent health.

While greenspace is understood to make positive contributions to adolescent health, existing theory underexplores the role of *greening* in disrupting the effects of social inequalities and their antecedents on health. Urban greening activities that work to counteract various domains within the SDOH have the potential to reduce health disparities and improve safety for adolescents.

Community efforts to improve neighborhood environments, for example through greening activities, are situated within and influenced by broader and historical sociopolitical processes. The Greening Theory of Change makes transparent some of the many avenues by which greening programs might improve greenspace while addressing pressing resource issues, thereby improving adolescent health and safety.

Greening activities and possible mechanisms of change are considered within the context of their ability to modify the effect of distal SDOH factors on health outcomes. These factors, in turn, stem from macro-structural and historical policies and processes that affect both the local built environment and the social context in which adolescents live, work, and develop. It includes potential mechanisms of change such as how the physical transformation of vacant, uncared for spaces may interact with other social factors to influence the health of adolescents in communities dealing with historic and repeated trauma. It also includes short- and long-term outcomes that encompass economic and security-related variables that influence, and should be measured alongside, health outcomes.

Our Greening Theory of Change provides a framework by which to answer questions facing communities of Baltimore and beyond. For Project VITAL, the Greening ToC guided the selection of research methods and measures used to examine the relationship between greening and adolescent health. For example, a mixed methods approach that utilized primary and existing data was chosen to be able to assess the associations of different types of greening activities and mechanisms of change on various adolescent health outcomes.

One of the first major activities of Project VITAL was to create a database of all the greenspace in Baltimore and geocode the spaces that can be filtered by zip code, neighborhood, as well as whether the green space was a previous vacant lot, city park, or forest. Existing data can be further layered on this database which can allow us to explore societal and local factors that surround different types of greened space.

For primary data collection methods, the Project VITAL team designed an adolescent survey to measure mechanisms of change and health outcomes, and city block and vacant lot observation tools, to assess the immediate neighborhood conditions and types of greening activities next to where adolescent survey respondents live. By linking adolescent survey data to the observations, we have the ability to examine how

different types of greening activities are associated with various adolescent health outcomes. These data can also be layered in our database map of greenspace, which we can use to analyze broader neighborhood factors as potential moderators or mediators.

The ToC also guided the selection of measures to include in both the survey and observation tools. Specific variables from our ToC that were selected for the adolescent survey included perceived exposure to greenspace, volunteerism, social engagement and cohesion, trauma symptoms, perceived safety and crime, use and types of activities within green spaces, mental health (depression, anxiety, happiness, and hopefulness), food security, violence victimization, and perpetration.

In addition, we are assessing each of the greening activities from our ToC in our observation tools, and together with our adolescent survey data, this will be used to elucidate not only associations between greening and health but also the potential mechanisms of change. These methods and measures will ultimately provide us with answers about whether greening vacant lots engages and improves the lives of youth in the city. In addition, the information can be used to further refine the ToC and guide additional research and policy work on how greening can potentially provide a structural, sustainable, and scalable intervention (Branas & Macdonald, 2014) to improve young people's health.

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