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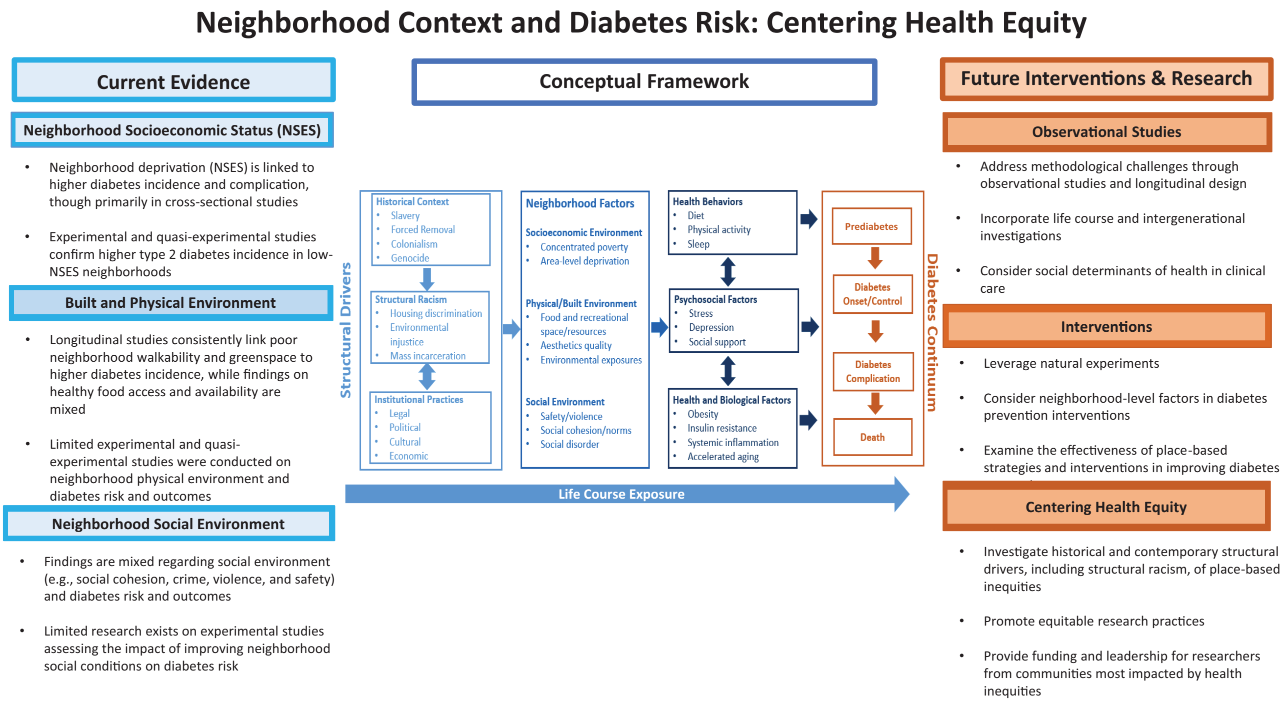

ARTICLE HIGHLIGHTS

- This research was conducted to present current literature on the effect of neighborhood environments on diabetes outcomes and inform the development of place-based interventions.
- Our conceptual framework emphasizes historical context and structural and institutional racism as key drivers of neighborhood environments.
- Observational, longitudinal, quasi-experimental, and experimental studies were included.
- The findings of this review demonstrate a lack of understanding of the complex relationships between neighborhood environments and diabetes and propose future research areas that incorporate health equity principles and place-based interventions.

The Impact of Neighborhoods on Diabetes Risk and Outcomes: Centering Health Equity

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Neighborhood environments significantly influence the development of diabetes risk factors, morbidity, and mortality throughout an individual's life. The social, economic, and physical environments of a neighborhood all affect the health risks of individuals and communities and also affect population health inequities. Factors such as access to healthy food, green spaces, safe housing, and transportation options can impact the health outcomes of residents. Social factors, including social cohesion and neighborhood safety, also play an important role in shaping neighborhood environments and can influence the development of diabetes. Therefore, understanding the complex relationships between neighborhood environments and diabetes is crucial for developing effective strategies to address health disparities and promote health equity. This review presents landmark findings from studies that examined associations between neighborhood socioeconomic, built and physical, and social environmental factors and diabetes-related risk and outcomes. Our framework emphasizes the historical context and structural and institutional racism as the key drivers of neighborhood environments that ultimately shape diabetes risk and outcomes. To address health inequities in diabetes, we propose future research areas that incorporate health equity principles and place-based interventions.

Diabetes, a complex chronic metabolic disease, remains a major public health problem as a leading cause of death and disability in the U.S. (1). The prevalence of diabetes has more than doubled over several decades, and in 2019, an estimated 37.3 million Americans had diabetes ($\sim$11.7% of the population) (1,2). There are also significant racial and ethnic disparities in diabetes. Indigenous Americans (i.e., American Indian/Alaska Native) and Black Americans are particularly burdened with a higher prevalence, incidence, complications (e.g., blindness, amputation, and kidney and other organ damage), and death from diabetes, and these inequities are increasing over time (1,3). It is well established that behavioral and biological factors alone are insufficient to understand population-level inequities in diabetes and that social factors may be key drivers of these inequities (4,5).

In acknowledgment of the pervasive inequities in diabetes and to underscore the critical importance of the social determinants of health (SDOH), the American Diabetes Association (6) developed the "Health Equity Bill of Rights." This bill aims to eliminate unjust health disparities and ensure equal access to basic human rights for Americans at risk for or living with diabetes, irrespective of race, income, zip code, age, education, or gender. It recognizes the influence of location on health, with two rights explicitly focusing on access to healthy foods nearby and a safe environment free from diabetes risk hazards. The bill highlights the geographic variation in diabetes risk and outcomes as supported by evidence that links neighborhoods to diabetes risk

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See accompanying articles, pp. 1587, 1590, and 1599.

and emphasizes how unequal distribution of resources, services, and health risks contribute to diabetes disparities (6).

This article builds on prior reviews on SDOH and diabetes (7) to focus specifically on neighborhood environments. We begin with a conceptual framework that links neighborhoods and diabetes across the continuum of risk to mortality. We then provide a brief overview of the literature on neighborhood environments and diabetes risk and outcomes. We conclude by discussing areas for future research and avenues for interventions to address place-based health inequities in diabetes.

CONCEPTUAL AND THEORETICAL FRAMEWORK

In our conceptual framework (Fig. 1), diabetes risk and outcomes represent a continuum of events over the life course that are shaped by neighborhood socioeconomic, physical, and social environmental factors. There are several pathways through which neighborhood environments can affect this diabetes risk continuum. First, neighborhood factors may influence the development of prediabetes by limiting access to healthy food, green spaces, safe housing, and transportation options and by constraining healthy choices, which can increase the risk of poor diet, insufficient physical activity, obesity, and other major risk factors for diabetes (8). Often referred to as obesogenic environments, these environments may also make individuals with diabetes more susceptible to poor diabetes control and micro- and macro-level complications (9). Second, neighborhood environments may affect psychosocial factors, including stress, depression, and social support, which in turn may affect physiological processes. These effects can subsequently lead to accelerated aging, and the premature breakdown of biological systems, which can lead to the early onset of diabetes, aggressive acceleration of diabetes complications, and premature death (8). Finally, neighborhood environments may affect access to health care and diabetes prevention and management services (8).

Critical to our framework is the acknowledgment that neighborhood environments are shaped by a historical context and ongoing structural processes that reinforce social hierarchies and inequitable distributions of goods and services across people and places. Beginning with the enslavement of Black people and genocide of Indigenous people, these historical insults provided a blueprint for legal systems of racial oppression and racial terror (12). Enslaved Black people represented only 3/5 of a person by law until the adoption of the 13th Amendment abolishing slavery in 1865. Thereafter, the government sanctioned new practices such as the Jim Crow laws institutionalized separate and unequal conditions, Black Codes restricted the freedom of Black families so that White employers could extract cheap labor from them, and the Ku Klux Klan unleashed racial violence and lynching on Black families (13,14). Other minoritized groups were also affected by legal policies such as the Indian Removal Act of 1830, which led to genocide and forced removal of Indigenous groups, and the Chinese Exclusion Act of 1882, which launched a series of racialized immigration policies that unfairly targeted Asian American people (15). In our framework, we explicitly refer to structural racism as the normalization and legitimization of a set of inequitable policies and practices across a wide range of intrinsically linked and mutually reinforcing systems that routinely advantage White people while unfairly disadvantaging Black and other people of color (12,16–18). The creation and reinforcement of these oppressive systems produce racial/ethnic and geospatial marginalization. Although we emphasize the U.S. context, we acknowledge that comparable systems, such as colonialism and racial capitalism, exist globally (19).

Several theories shed light on how neighborhood environments are influenced by structural racism. The political economy of health theory explains how health inequalities are shaped by the political economy's production, distribution, and consumption of goods, services, and generational wealth and, in turn, affect disease risk (20). The ecosocial theory helps us understand health inequities by considering the cumulative interplay between exposure, susceptibility,

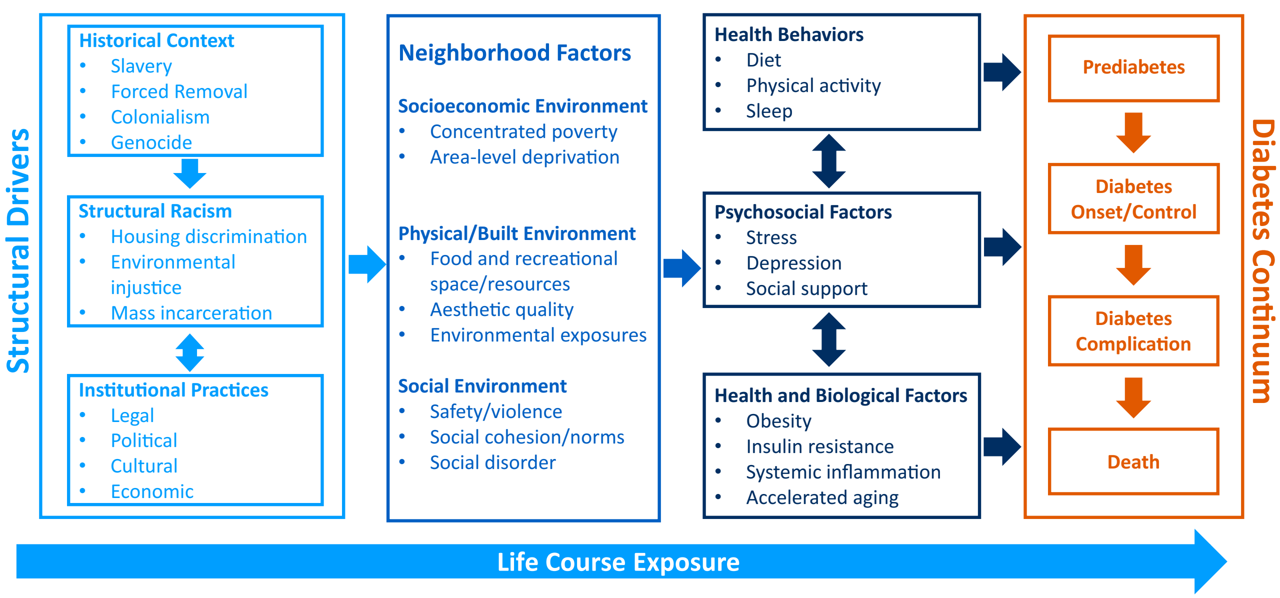

Figure 1—Conceptual framework of diabetes risk and outcomes over the life course that are shaped by neighborhood socioeconomic, built and physical, and social environmental factors. The framework was adapted from Williams and Mohammed (10) and Hailu (11).

and resistance at multiple levels (21). This theory posits that factors that lead to the distribution of disease and related outcomes result from the cumulative interplay among exposure (social or biological), susceptibility, and resistance (of the population or the individual). Fundamental cause theory further links structural forces like structural racism to health outcomes, as they affect multiple outcomes through various pathways, which are reproduced over time and involve access to flexible resources (22,23). Lastly, life course theory emphasizes that neighborhood environments may be more critical to the development of diabetes during sensitive periods or due to the accumulation of these exposures over the life span (24,25). These theories provide a foundation for understanding how resources and neighborhood environments are constructed by historical and contemporary processes that disadvantage some racial/ethnic groups while privileging others.

Overview, Definitions, and Key Concepts

Below we provide a brief overview of studies on neighborhood environments and diabetes risk and outcomes. Neighborhoods are broadly defined as geographical areas that are subdivisions of larger places (e.g., cities and states) and have both social and cultural meanings for those who reside within and outside them (8,26). In the literature, there is substantial variation in how neighborhoods have been operationalized for use in studies. Census tracts and block groups are most frequently used in the U.S. because they are systematically defined boundaries that allow for the linkage of U.S. Census indicators and other administrative data sets. When data are limited because of confidentiality or other constraints due to granularity, larger and unspecified boundaries are used (e.g., zip codes), but researchers should be mindful of using boundaries not created for data collection purposes, such as zip codes, because these boundaries typically do not delineate neighborhoods with shared cultural, social, or economic features. Studies also consider spatial (e.g., 1-mile buffer zone), local (e.g., community districts), political (e.g., voting districts), and cultural (e.g., Chinatown) definitions of neighborhoods. Other methodological considerations are beyond the scope of this review but are covered elsewhere (26,27).

This section summarizes the neighborhood socioeconomic environment, physical and built environment, and social environment. Our summary refers to both compositional (i.e., the characteristics of the people who reside in the neighborhood) and contextual (i.e., the features of the neighborhoods themselves) neighborhood factors, as both have been extensively investigated. However, we acknowledge that contextual factors are more amenable to change and are best suited to place-based interventions (26). We also address the contribution of neighborhoods and the structural drivers of neighborhoods to racial/ethnic inequities in diabetes risk and outcomes. Consistent with other reviews on diabetes, we use type 1 diabetes (T1D), type 2 diabetes (T2D), and diabetes when a type is unspecified. This is not meant to be an exhaustive review, and we do not review the extensive literature on neighborhood environments and obesity (28,29), a major etiologic factor in the development and progression of diabetes. Instead, we build on prior reviews (7,30) and focus on recent findings, emphasize longitudinal and experimental studies, and highlight areas of emerging research.

Neighborhood Socioeconomic Status

Neighborhood socioeconomic environment, or neighborhood socioeconomic status (NSES), is a construct that captures how socioeconomic resources vary across places. Studies consider multidimensional indicators meant to capture broad disinvestment or deprivation and examine those indicators on a scale. NSES seeks to measure area-level exposures of socioeconomic status (SES) and is typically operationalized at the level of the NSES measures, including median neighborhood income and educational attainment, unemployment rate, and concentrated poverty measures (if >20% of the area is below the federal poverty level). Often, NSES is converted into a composite score or made into an index to simplify multiple relevant factors. Commonly used scales or composite scores include the area deprivation index (ADI) (31), neighborhood deprivation index (NDI) (32), and neighborhood social and environment indicator (NSEE) (33). Most studies of NSES include extensive adjustment for individual-level SES (i.e., individual educational attainment and family income) to highlight that NSES captures more than the characteristics of neighborhood residents (26).

The negative association between NSES and diabetes is well-established in the literature through individual studies and numerous reviews (7,30). In a recent review, Bilal et al. (30) identified 24 articles on NSES and diabetes published between 2010 and 2017. Most of the studies were cross-sectional and documented that increased neighborhood deprivation (i.e., lower neighborhood socioeconomic resources) was associated with a higher prevalence of diabetes (34–38), a lower prevalence of diabetes control (based on HbA_{1c} levels) (39–41), and a higher prevalence of micro- and macro-level complications. Findings appear to be robust in geography. For example, Uddin et al. (42) used data from the Reasons for Geographic and Racial Differences in Stroke (REGARDS) study to examine associations between NSES and diabetes prevalence and to determine if associations varied across the urban and rural continuum. Although the magnitude of association was strongest in lower-density urban areas and suburban/small-town areas, associations were found in other settings (e.g., higher-density urban areas and rural areas).

Longitudinal Observational Studies

Fewer studies have prospectively examined NSES in relation to diabetes risk and outcomes. Among these studies, NSES (i.e., increased deprivation) is associated with a higher incidence of diabetes, independent of individual-level confounders (30,43,44). A recent study by Schmittdiel et al. (45) used data from integrated electronic health records (EHR) within Kaiser Permanente Northern California to document that members >18 years old with laboratory-defined prediabetes (fasting plasma glucose 100–125 mg/dL and/or HbA_{1c} 5.7–6.4) were more likely to progress to diabetes if they resided in neighborhoods with lower NSES (assessed via median income, percentage of adults with bachelor degree or higher, and >10% of household receiving Supplemental Nutrition Assistance Program benefits) compared with their counterparts residing in higher-NSES neighborhood. Additional longitudinal studies examined associations in racial/ethnic and/or sex-specific cohorts. For example, Krishnan et al. (46) found, in the Black Women's Health Study, a higher incidence of T2D among African American women residing in low-NSES neighborhoods compared with those in high-NSES neighborhoods, independent of individual-level factors. Gallo et al. (47) documented that NSES was associated with higher HbA_{1c} and a higher incidence of diabetes in the Hispanic Community Health Study/Study of Latinos (HCS/SOL). Taken together, these studies suggest that NSES associations are salient in minoritized groups.

Recent work has also begun to emphasize the importance of examining the pathways that link NSES to diabetes risk. For example, it is hypothesized that lower-NSES neighborhoods have fewer health-promoting resources, including healthy food access. However, a study by Richardson et al. (48) found that although areas with declining NSES had fewer non–fast-food restaurants and more convenience stores over 20 years, they had the same number of supermarkets. Thorpe et al. (49) found that robust associations between low NSES and higher incidence of diabetes across three cohorts persisted and had minimal attenuation after adjusting for the food environment. A final study by Moon et al. (50) used a similar methodology to document that NSES also was not mediated by the physical activity environment. Thus, more research is needed to examine other mechanisms that link NSES and diabetes risk.

Experimental and Quasi-Experimental Studies

Key experimental studies of NSES and diabetes use Moving to Opportunity for Fair Housing (MTO) data. MTO was a housing voucher program that randomly assigned low-income families to move from a high-poverty neighborhood to a low-poverty neighborhood or to stay in their current high-poverty neighborhood. A 10- to 15-year evaluation of MTO found lower diabetes prevalence for the experimental group compared with the Section 8 group and the control group (51). Similar work has been conducted in Sweden and Denmark, each with a national registry of refugees and their quasi-randomized assignment to neighborhoods with various levels of NSES. Results of these studies showed that those assigned to low-NSES neighborhoods had a higher incidence of T2D (52,53).

A few studies have examined whether NSES modifies the effectiveness of lifestyle interventions to reduce diabetes risk. For example, Jiang et al. (54) examined the relationship between neighborhood characteristics and outcomes of lifestyle interventions for diabetes prevention among Indigenous groups in America. They leveraged data from the Special Diabetes Program for Indians Diabetes Prevention Program, an evidence-based lifestyle intervention implemented in 36 American Indian/Alaska Native grantee sites across the U.S. They found that living in neighborhoods with higher levels of social disadvantage was associated with poorer outcomes, including a higher risk of developing diabetes, and that the intervention was less effective in increasing physical activity and lowering BMI among participants in more disinvested neighborhoods.

Neighborhood Built and Physical Environments

Neighborhood built and physical environments include environmental exposures to natural physical features and manufactured features in which people live, work, play, learn, worship, and age. These features are often interconnected. To date, cross-sectional studies have generated a large body of evidence that documents the relationships between neighborhood physical characteristics, such as green space, walkability, and food environment, and diabetes prevalence (55–57). These studies lay a strong foundation for longitudinal studies to strengthen causal inference and examine these aspects of the neighborhood environment.

Longitudinal Observational Studies

Walkability is a complex construct that typically consists of several factors that determine the suitability of the built and physical environment for walking. These components include street condition, safety, accessibility of walkable destinations, land use, population density, and connectivity. Walkability can be conceptualized as an important feature of the neighborhood environment that promotes physical activity, affecting diabetes risk and management. Studies have more frequently relied on the assessment of walkability using a walkability index constructed from secondary data (58,59). Perceived walkability, however, may have a different relationship with diabetes incidence. Longitudinal observational studies found that increased walkability was associated with a lower risk of developing diabetes (58,59) and a greater likelihood of glycemic control in one (60), but not all, studies (61).

Another important feature of the neighborhood built and physical environment documented in longitudinal observational studies is the food environment, which consists of the availability, affordability, and accessibility of healthier food options. The food environment matters for dietary quality, a key factor in diabetes prevention and control. Objective assessments of the food environment, measured and visualized through geographic information systems (GIS), include distance to healthy food retailers such as supermarkets. It also includes the ratio between healthful and unhealthful food retailers and the count or density of a specific type of food retailer (e.g., fast food stores) within a buffer region (e.g., a certain distance from home) or an administrative boundary (e.g., census tract) (59,62–64). Overall, these studies have documented that a better food environment was associated with lower diabetes risk across multiple exposure assessment methods. On the other hand, studies that assessed diabetes management found mixed results, as some documented that a better food environment was associated with positive glycemic control and self-care behavior (60) and others found null associations (61,65).

Neighborhood green space, or naturally occurring and manufactured areas of land covered in vegetation, such as forests, parks, and botanical gardens, provide several health-promoting benefits, including cleaner air, reduced exposure to heat, and opportunities for physical activity and community connections. Green space has been measured using GIS-based methods, such as the normalized difference vegetation index and landcover typology, tree canopy, and distance to parks and other green recreational spaces, and the survey-based measurement of participants' satisfaction with the greenness of their neighborhoods (55). Generally, longitudinal studies have relied on GIS-assessed measures of green space and documented that more availability of green space in the neighborhood was associated with a lower risk of diabetes (66–68). Studies have generally not examined diabetes management and the influence of green space.

Broadly, longitudinal studies have examined environmental hazards, often common in urban settings, such as noise and traffic-related pollution (69–71). Overall, evidence has demonstrated that greater exposure to air and chemical pollutants, such as particulate matter that is 2.5 μm or less in diameter (PM2.5), and traffic-related noise is associated with a greater incidence of diabetes (69–71). Other environmental hazards, such as light pollution and extreme heat, have not been extensively evaluated in terms of diabetes incidence and management, which may be a gap for future studies to assess (72).

Studies have also used composite measures to assess the effects of the built and physical environment on diabetes. These composite measures typically combine several aspects of the neighborhood physical environment or different approaches for measuring the physical environment to assess the overall quality of the environment. Christine et al. (62) used data from the Multi-Ethnic Study of Atherosclerosis (MESA) to show that summary measures of physical activity and the food environment (e.g., a combination of survey-based and GIS indicators) were mainly driven by survey-based measures, with results being weaker and often null for the GIS-based measures of the food and physical activity environment. Hirsch et al. (33) used a composite measure of community factors, including socioeconomic deprivation, fitness assets, food environment, and physical activity favorability, to assess the influence of community domains on diabetes control using data from the Geisinger EHR system. They documented that neighborhoods with worse composite score environments had lower 6-month declines in HbA_{1c} than neighborhoods with better composite scores. This approach, when supported by a strong theoretical framework and conceptualization, enables a comprehensive characterization of the physical environment. However, the inability to isolate specific aspects of the environment may affect the design of interventions.

Experimental and Quasi-Experimental Studies

Few natural experiments have focused on diabetes-related outcomes, and findings have been mixed. Laraia et al. (73) used the Diabetes Study of Northern California (DISTANCE) to perform a natural experiment that compared diabetes outcomes of residents from two neighborhoods in Oakland, CA: West Oakland and Fruitvale. The former neighborhood underwent significant redevelopment, including new housing, retail, and recreational facilities. The study revealed that residents of the redeveloped neighborhood had lower rates of diabetes-related complications, such as kidney disease, eye disease, and cardiovascular disease, as well as better diabetes management outcomes, including lower average HbA_{1c} levels and a greater likelihood of achieving recommended blood pressure and lipid level targets, compared with residents of the other neighborhood (73). A study by Zhang et al. (74) also leveraged the DISTANCE study to assess whether a reduction in distance to the nearest supermarket affects BMI among T2D patients within Kaiser Permanente Northern California and found that these reductions in travel time did not lead to meaningful changes in study outcomes. Several systematic reviews have assessed the effect of natural experiments that target the built environment and the effects on obesity, diet, and physical activity (75). Evidence has been robust and consistently effective for built environment improvements that support active lifestyles and physical activity. However, findings concerning the food environment are mixed, which may be due to insufficient follow-up length or the inability to capture the aspects of the food environment most salient to the development of diabetes.

Neighborhood Social Environment

Neighborhood social environment captures the interactions between and within neighborhoods, including interpersonal relationships and cultural and social norms that influence daily life (76). Few studies have examined specific features of the social environment outside of socioeconomic status, which was covered in an earlier section of this review, and findings have been mixed. Gebreab et al. (77) used data from the Jackson Heart Study (JHS) to document that neighborhood social cohesion, measured by the social connectedness among neighbors, was associated with a lower risk of T2D among Black adults. However, a study by Christine et al. (62) found no association between a similar measure of social cohesion and incident T2D in a multiethnic cohort. Neighborhood social cohesion has also been linked to glycemic control, as well as other self-care behaviors, among individuals living with diabetes in cross-sectional studies (65).

Crime, neighborhood problems, violence, and safety make up another group of factors that represent neighborhood social hazards. Akinboboye et al. (78) examined the association between neighborhood crime and violence and glycemic control in a sample of adults with T2D in the southeastern U.S. They found a significant association between neighborhood crime and violence and glycemic control among White adults but not Black adults. However, findings by Smalls et al. (65) found mixed results, as neighborhood violence was not associated with diabetes self-care behaviors. In a study by de Vries McClintock et al. (79), which examined social environment as composed of social affluence, residential stability, and neighborhood advantage, patients with T2D who resided in neighborhoods that scored high on each of the components were found to have greater adherence to oral hypoglycemic agents and increasing adherence patterns than residents from neighborhoods with low scores. Finally, several studies have explored the relationship between other neighborhood social processes and the risk of diabetes. For instance, in the MESA study, Christine et al. (80) observed that individuals residing in neighborhoods with higher housing foreclosure rates exhibited higher fasting HbA_{1c} levels. Additionally, Bilal et al. (81) investigated the impact of neighborhood social and economic changes, serving as a proxy for gentrification, on incident diabetes using data from the Heart Healthy Hoods study in Spain. They found a lower incidence of diabetes among residents living in neighborhoods of declining SES and areas with an infusion of new housing and higher-SES individuals compared with those residing in stable areas. These results highlight the pressing need for more studies that investigate these dynamic processes.

We are unaware of any experimental studies that assess the impact of improving neighborhood social conditions and diabetes risk. However, a recent study by South et al. (82) investigated whether structural repairs to homes of low-income owners were associated with a reduction in nearby crime in Black urban neighborhoods in Philadelphia. The results showed that the addition of a property that received the repair program was associated with a decrease in expected crime, including homicide, assault, burglary, theft, robbery, disorderly conduct, and public drunkenness.

Neighborhoods and Racial/Ethnic Health Inequities

Given the disproportionate burden of diabetes in racially minoritized groups and their disproportionate exposure to disinvested neighborhoods with poorer access to health-promoting resources, a growing body of literature has investigated the contribution of neighborhood environments to these health inequities

(83). The historical and contemporary structural factors that shape the differential distribution of resources and opportunities across race and place may be critical drivers of diabetes health inequities. Residential segregation, the systematic separation of racial and ethnic groups into different social and economic environments, is the most widely studied indicator of structural racism in relation to diabetes and health more broadly (84,85). A review by Kershaw and Pender (86) identified four studies that had investigated residential segregation and diabetes prevalence within non-Hispanic Black, Hispanic, and Asian American populations. Although none of these studies documented significant associations with diabetes prevalence, two ecologic studies discussed in this review found higher age-adjusted mortality in areas with a higher percentage of Black individuals. Since this review was published, additional evidence has emerged that provides longitudinal evidence supporting the link between residential segregation and diabetes incidence (87). Bravo et al. (88) used data from the Duke Medicine Enterprise Data Warehouse to document that increases in racial isolation were associated with a higher risk of diabetes in both White and Black adults in Durham, NC. Mayne et al. (87) examined associations between racial residential segregation and incident diabetes among Black adults in the Coronary Artery Risk Development Study in Young Adults (CARDIA). Although individual covariates and other neighborhood-level covariates attenuated this association, unadjusted models produced much higher hazard ratios for incident diabetes among participants who resided in neighborhoods with high racial segregation than for incident diabetes among participants with low to medium racial segregation.

It is important to note that residential segregation was shaped by discriminatory policies, including redlining, deed restrictions, discriminatory zoning, mortgage lending, and racial covenants, that led to significant disinvestment in neighborhoods where predominately minoritized and immigrant populations resided (89). Recently, studies have examined historical redlining in relation to health outcomes by leveraging Home Owner's Loan Corporation (HOLC) residential security maps, which were used to guide decisions regarding investment in the 1930s with the following grading system: A, best; B, still desirable; C, declining; D, hazardous (e.g., redlined). An ecological study by Linde et al. (90) determined that a neighborhood's redlining explains 45% and 56% of the variation in age-adjusted diabetes mortality rates in Seattle, WA, between 1990 and 2014 at the census tract level. Mujahid et al. (91) assessed HOLC grades in the MESA study and documented that Black adults who resided in neighborhoods that were historically redlined had poorer cardiometabolic health, especially concerning BMI and systolic blood pressure. However, findings were not statistically significant for HbA_{1c}.

A few studies have explicitly examined the contribution of neighborhood environments to racial/ethnic inequities in diabetes. The Exploring Health Disparities in Integrated Communities (EHDIC) study compared racial/ethnic differences in a range of cardiometabolic outcomes in "integrated census tracts," representing the 1% of census tracts with at least 35% Black and 35% White participants living in the tract, with comparable socioeconomic status between the racial groups (92). Within those areas, differences in diabetes prevalence between Black and White participants were lower and not statistically significant compared with data from the National Health Interview Survey national sample. Several other studies provide marginal support for the idea that racial/ethnic inequities in diabetes are partly explained by neighborhood conditions. Mujahid et al. (93) used data from MESA to show that neighborhood factors accounted for 16.2% and 26% of differences in optimal HbA_{1c} between Black and White individuals and Hispanic and White individuals, respectively. Piccolo et al. (94) used data from the Boston Area Community Health Study to show that neighborhood poverty explained 1% of the excess odds of T2D among Black adults and 6% among Hispanic/Latino adults. In both studies, racial disparities persisted after adjustment, suggesting that other factors are at play. Gaskin et al. (95) point to the complexity of disentangling racial disparities from the systemic factors that shape these inequities. Using data from the National Health and Nutrition Examination Survey (NHANES), they documented the highest predicted probability of diabetes prevalence for low-income White individuals living in low-income neighborhoods and the lowest predicted probability for White individuals who are not low-income and do not live in low-income neighborhoods. Interestingly, the predicted probability for Black people who are not low-income and do not live in low-income neighborhoods was only slightly lower than that of the highest-risk group, low-income White individuals living in low-income neighborhoods. These studies underscore the need for more research on the structural drivers of diabetes risk.

CONCLUSIONS

This review highlights the significant evidence that links neighborhood environments to diabetes risk and identifies critical gaps in knowledge. Three key areas for future research are identified (Table 1). Although there is a strong push for place-based interventions, observational studies are still needed to address the methodological challenges to better inform evidence-based inputs for these interventions. For example, the National Institutes of Health is spearheading efforts to establish standardized measures through the PhenX Toolkit, which encompasses various research domains, including SDOH (96). Furthermore, the Centers for Disease Control and Prevention–funded Diabetes Location, Environmental Attributes, and Disparities (LEAD) Network aims to investigate neighborhood environment and diabetes disparities through harmonized measures, which enables comparisons across observational studies (49,50). These initiatives improve the consistency and quality of data collection in diabetes research and ultimately inform evidence-based interventions. Another limitation of existing studies on neighborhoods and diabetes is the high prevalence of cross-sectional designs, which offer insufficient insights into this complex relationship. To achieve a more comprehensive understanding of diabetes risk, observational studies that go beyond cross-sectional data are necessary. Longitudinal studies may provide valuable insights into causal inference, which will allow researchers to minimize bias and explore the effect of neighborhood environments on HbA_{1c} levels over time (97). These studies allow for a more robust investigation of the biological and other mediating pathways underlying these relationships. Longitudinal studies that capture information across the life course can identify critical periods of vulnerability and inform interventions. Additionally, intergenerational cohorts enable exploration of the intergenerational transmission of place-based diabetes risk, aiding in the development of interventions to break

Table 1—Research priorities for neighborhoods and diabetes risk and outcomes

Area of focus	Recommendation
Observational studies	Conduct observational studies to address methodological challenges in the existing body of literature using standardized measures. Use longitudinal designs to incorporate life course and intergenerational investigations of neighborhoods and diabetes risk. Incorporate SDOH, including neighborhood factors, into clinical care settings.
Interventions	Leverage natural experiments to assess the influence of neighborhood change on the health and well-being of residents. Target diabetes prevention interventions to improve their effectiveness among vulnerable populations by considering neighborhood-level factors. Examine the effectiveness of multilevel interventions that incorporate improvements in neighborhood factors and other place-based strategies for improving diabetes prevention.
Centering health equity	Center health equity, including investigations of historical and contemporary structural drivers of place-based inequities, particularly structural racism, to address persistent health inequities. Promote equitable research practices by prioritizing studies that focus on racially and ethnically minoritized populations without requiring a comparison group. Provide funding and leadership opportunities for researchers who come from the communities most impacted by health inequities.

the cycle of disparities. In summary, longitudinal studies are crucial for advancing knowledge on the neighborhood–diabetes risk relationship and for guiding public health policies and practices.

Another key area for future research is the incorporation of SDOH, including neighborhood factors, into clinical care, which is essential to the improvement of diabetes prevention and management. The Institute of Medicine report (98) emphasizes the importance of including social factors in EHR to improve patient care. This includes geocoding patient addresses and adding measures of median household income to capture neighborhood-level factors that affect diabetes outcomes. By doing so, clinicians can better understand the social and environmental factors that influence their patients' health outcomes and tailor interventions accordingly. As an example, Institute of Medicine used EHR to identify hot spots of high diabetes prevalence and poor control in neighborhoods in the catchment area of the Boston Medical Center (98). Based on these results, the study team developed a community-based intervention program that included tailored diabetes self-management education and outreach to community health workers. The intervention resulted in significant improvements in glycemic control among the targeted patients compared with a control group. Overall, incorporating neighborhood-level and other SDOH factors into clinical care settings can help identify populations with high social needs and develop interventions that may address these needs to improve diabetes outcomes. EHR data provide a powerful tool to identify these high-risk areas and to target interventions accordingly. The inclusion of SDOH in clinical care settings represents a significant step toward achieving health equity and reducing health disparities among vulnerable populations.

Interventions that target diabetes prevention should consider neighborhood-level factors to improve their effectiveness among vulnerable populations. Studies should also continue to leverage natural experiments. Natural experiments may be more beneficial if they bundle a suite of environmental improvements over a longer period. For example, the Pittsburgh Hill/Homewood Research on Neighborhood Change and Health (PHRESH) study is based on a series of projects that use a natural experiment design to assess the effect of neighborhood change on the health and well-being of residents in the Hill District and Homewood neighborhoods of Pittsburgh, PA, two predominately African American and low-income communities in Pittsburgh (99). Examples of the specific improvements made to the neighborhoods included the demolition of vacant housing, new housing construction, infrastructure improvements such as street and sidewalk repairs, and the addition of green space and other community amenities, for a total investment of ∼\$60 million. Findings to date have shown that changes in the built environment, such as the availability of healthy food options and safe spaces for physical activity, were associated with improvements and can positively influence the health behaviors and outcomes of residents (100,101). The PHRESH project and other natural experiments highlight the need for research that continues to examine the effect of neighborhood change on health and well-being and that focuses on how policies and programs can be designed to promote equitable and sustainable development in historically disinvested communities.

Finally, centering health equity will be critical to diabetes prevention efforts (4). To center health equity means to investigate the historical and contemporary structural drivers of place-based inequities, including structural racism. It requires a comprehensive understanding of the challenges faced by communities and funding studies that focus on racially and ethnically minoritized populations without the requirement of a comparison group. It also requires the provision of funding and leadership for researchers from these communities. At the core, to center health equity is to understand that inequalities in diabetes care and management arise from malfunctioning and interconnected systems and to require a systematic approach to address and improve each of these systems. Despite previous efforts by the American Diabetes Association to address racial and ethnic inequities in diabetes, structural racism continues to be a major factor in persistent health disparities, including in diabetes, and it affects Black Americans and other historically disenfranchised groups. Recent events, such as the coronavirus disease 2019 pandemic and police killings of Black Americans, have highlighted the ongoing impact of structural racism on health outcomes. Future research on racism should investigate the joint effects of multiple forms of racism, including structural, interpersonal, cultural, and anti-Black racism, on diabetes outcomes. As part of the Health Equity Bill of Rights, we must take responsibility for dismantling racism and commit to improving conditions for marginalized communities, advocating for policies that promote equity in economic opportunities, education, and health care, and increasing allyship among racial and ethnic groups.

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