Current Diabetes Reports (2019) 19: 35
https://doi.org/10.1007/s11892-019-1162-1

ECONOMICS AND POLICY IN DIABETES (AA BAIG AND N LAITEERAPONG, SECTION EDITORS)

# Diabetes and the Built Environment: Evidence and Policies

Aisha T. Amuda[1] · Seth A. Berkowitz[2,3]

Published online: 21 May 2019


## Abstract

**Purpose of Review** To explore the relationship between the built environment and type 2 diabetes, considering both risk factors and policies to reduce risk. The built environment refers to the physical characteristics of the areas in which people live including buildings, streets, open spaces, and infrastructure.

**Recent Findings** A review of current literature suggests an association between the built environment and type 2 diabetes, likely driven by two key pathways—physical activity and the food environment. Other hypothesized mechanisms linking the built environment and type 2 diabetes include housing policy, but evidence in these areas is underdeveloped.

**Summary** Policies designed to enhance the built environment for diabetes risk reduction are mechanistically plausible, but as of yet, little direct evidence supports their effectiveness in reducing in type 2 diabetes risk. Future work should rigorously evaluate policies meant to reduce type 2 diabetes via the built environment.

**Keywords** Type 2 diabetes mellitus · Built environment · Diabetes risk · Health policy

## Introduction

Diabetes mellitus remains one of the most significant chronic medical diseases in the USA. In 2015, an estimated 30.3 million people had diabetes—9.4% of the population [1]. Diabetes was the seventh leading cause of death in the USA in 2015 [2], and the estimated cost of diabetes in 2017 was $327 billion [3]. Major risk factors for type 2 diabetes mellitus (T2DM) include physical inactivity and being overweight or obese. An emerging public health issue that may influence diabetes risk is the built environment [4]. Though the term "built environment" can have many meanings, this paper will focus on the physical characteristics of the areas in which people live such as buildings (and what occupies them), streets, open spaces, and infrastructure, and what role they may play in the risk for T2DM. These characteristics can operate at different scales—macro-, meso-, and micro-levels. These levels might correspond, for example, to a large metropolitan area (macro-), within which is nested a particular municipal area (meso-), and a specific neighborhood (micro-). Further, we consider the way that these physical features may help shape the local social circumstances experienced by individuals living in these areas. We begin by examining the evidence about associations between the built environment and diabetes risk, along with mechanisms whereby various features of the built environment may influence diabetes risk. Finally, we examine how policies could help shape the built environment in order to influence diabetes risk.

This article is part of the Topical Collection on *Economics and Policy in Diabetes*

✉ Seth A. Berkowitz
seth_berkowitz@med.unc.edu

Aisha T. Amuda
aisha_amuda@med.unc.edu

1 University of North Carolina School of Medicine, 1001 Bondurant Hall, CB 9535, Chapel Hill, NC 27599, USA

2 Division of General Medicine and Clinical Epidemiology, Department of Medicine, Chapel Hill School of Medicine, University of North Carolina, 5034 Old Clinic Bldg. CB 7110, Chapel Hill, NC 27599, USA

3 Cecil G. Sheps Center for Health Services Research, Chapel Hill, University of North Carolina, Chapel Hill, NC, USA

## The Built Environment and Diabetes Risk: Evidence and Mechanisms

Evidence has mounted that built environment characteristics are associated with diabetes risk. Further, there is additional evidence regarding mechanisms that may underlie this association [5]. Major modifiable risk factors for T2DM include body mass index (BMI), physical activity, and diet [2]. For this reason, much of the work examining mechanisms that link the built environment to diabetes risk has focused on associations between the built environment and these factors [6–18]. Below, we discuss evidence for an association between built environment factors and diabetes risk itself, along with evidence regarding an association between the built environment and diabetes risk factors. In interpreting this evidence, we point out a major issue in studying the built environment: challenges in distinguishing the role that compositional characteristics (i.e., those individual-level characteristics of the people living in an area, for example, education, income, and race/ethnicity) and contextual characteristics (i.e., the characteristics of the environment itself such as housing inventory, parks) play in diabetes risk, and how these factors may interact. Distinguishing these features requires data on both levels (individual and area) and sometimes sophisticated statistical analysis [19]. Some studies are able to do this well, but many studies are less able to do so, often because they lack data on individual socioeconomic circumstances [20, 21]. Therefore, it can be difficult to determine whether it is specific features of the built environment that drive the association, or individual-level factors. For the field to advance and for policies that affect features of the built environment to lower diabetes risk, we will need more sophisticated understanding of the way in which built environment features causally relate to diabetes.

## The Built Environment and Diabetes Prevalence and Incidence

Many studies have examined the relationship between the built environment and diabetes risk. In general, these studies focus on two key aspects of the built environment—features that encourage physical activity, such as walkability and green spaces, and the food environment.

Several cross-sectional studies support an inverse relationship between walkability and T2DM risk. Walkability was associated with a lower risk of T2DM in a systematic review of 60 articles from high-income countries including the USA, Canada, Germany, and Australia by Dendup et al. [11] Among older adults, those who lived in the greenest neighborhood quartile had a lower risk of developing diabetes (HR 0.81, 95% CI 0.67–0.99, $P = 0.04$) with relatively little change in risk after adjusting for age, sex, BMI, family history of diabetes or socioeconomic status, in a United Kingdom study [9]. The risk of T2DM was lower in neighborhoods with more green space, with the strongest association among participants who lived in neighborhoods with 40 to 60% green space (OR 0.87 95% CI 0.83, 0.92) in an Australian cohort study conducted among adult middle-aged and older adults [6]. While there is an inverse association between increased walkability and open spaces and diabetes incidence and prevalence, this association is modified by socioeconomic status and immigration status [22••]. The impact of socioeconomic status on the relationship between the built environment and T2DM was further demonstrated in a cross-sectional study of 512,061 Swedish adults conducted by Sundquist et al. Greater neighborhood walkability was associated with greater T2DM incidence (OR 1.33, 95% CI 1.13–1.55) when not adjusting for individual socioeconomic factors. However, this association was no longer significant once these factors were adjusted for [23••]. This finding highlights the importance of considering both compositional and contextual factors in understanding the relationship between the built environment and diabetes. Specifically, associations that may appear to be driven by contextual (aspects of the environment itself like walkability) factors can turn out to be related to compositional (aspects of those who live in the environment, like low socioeconomic status) factors when consideration is given to both possibilities. Similarly, the relationship between immigration status, built environment, and diabetes was further explored in a retrospective cohort study among recent immigrants (214,882 individuals) and long-term residents (1,024,380 individuals) of Toronto, Canada. Area walkability was inversely related to incidence of diabetes among long-term residents in Toronto in both men (RR 1.32, 95% 1.26–1.38) and women (RR 1.24, 95% CI 1.18–1.31) [24••]. The magnitude of this association was greater among recent immigrants (RR 1.58, 95% CI 1.42–1.75 for men; RR 1.67, 95% CI 1.48–1.88 for women).

The longitudinal relationship between changes in the built environment and incident diabetes and diabetes-related outcomes has also been established. In a systematic review and meta-analysis of 36 studies in the USA, Canada, Sweden, and Australia [8], increased neighborhood walkability was associated with decreased incident hypertension, obesity, T2DM, and cardiovascular disease events. Most studies assessed in this review had a duration of 5 years or longer with data collection at three or more time points. A time series analysis from 2001 to 2012 of 8777 neighborhoods and 32,767 individuals in Southern Ontario [25] found that the prevalence of overweight/obesity increased in the neighborhoods that were least walkable at baseline (absolute change, 5.4% [95% CI, 2.1–8.8%]) but did not increase in the most walkable neighborhoods (absolute change, 2.1% [95% CI, − 1.4 to 5.5%]). In a meta-analysis of six studies, increased walkability was associated with lower T2DM risk (RR 0.79, 95% CI 0.72–0.87) [10]. More green space was non-significantly associated with lower T2DM risk (RR 0.90, 95% 0.79–1.03), though the magnitude of this association is small.

Evidence for the association between the food retail environment and diabetes risks suggests that the availability of healthy food outlets decreases T2DM risk. In a systematic review of 109 articles, the presence of fast food and convenience stores was associated with higher T2DM prevalence and risk [10]. In two studies in the UK, close proximity to fast food outlets was associated with greater T2DM risk. The odds of having T2DM (OR = 1.02, 95% CI 1.00–1.04) and obesity (OR = 1.02, 95% CI 1.00–1.03) were greater in neighborhoods with more fast food outlets in a cohort study of 10,461 participants [7], and the odds of T2DM were greater in those with the highest exposure to restaurants and cafeterias, compared with those who had no exposure (OR 1.13, 95% CI 1.05–1.21), in a cross-sectional study of 502,635 adults [16]. Individuals who lived farther away from fast food outlets had lower odds of T2DM (OR 0.84, 95% CI 0.78–0.91) compared with those who lived closest. Also, in a prospective cohort study of more than 4.5 million individuals in Sweden, health-harming food outlets (fast food outlets, bars, or pubs) were associated with higher odds of prevalent (OR = 1.85, 95% CI 1.51–2.26) and incident (OR = 2.11, 95% CI 1.57–2.82) T2DM [15]. Further, individuals who changed locations during the study had a higher odds of incident T2DM (OR 3.67, 95% CI 2.14–6.30) when they moved to an area with more (vs. fewer) health-harming food outlets.

## The Built Environment and Diabetes Risk Factors

Aside from examining diabetes risk directly, a number of studies have found that features of the built environment are associated with risk factors for developing diabetes. Major risk factors examined have been physical activity, overweight/obesity, and insulin resistance.

Increased physical activity has been associated with increased walkability. In a systematic review of 44 studies conducted in Australia, Canada, and Belgium, Durand et al. explored the relationship between the physical environment and degree of physical activity [26] and found that open space preservation was associated with increased physical activity and higher rates of walking was associated with range of housing choices, mixed land use, development towards existing communities, and compact building design. Walkability and street connectivity have been related to transportation-related physical activity, and leisure activity has been most frequently associated with road and sidewalk conditions, as well as safety [27]. Across 103 articles concerning children and adolescents, the most consistent correlations in children were between level of physical activity and walkability, traffic speed, volume, land use mix, residential density, and access or proximity to recreational facilities. Among adolescents, land-use mix and residential density were the strongest correlates for physical activity.

Street connectivity and availability of recreational equipment has a positive association with physical activity. Higher street connectivity was significantly related to lower sedentary time ($b = 1.93$, 95% CI 1.11–4.96), in a cross-sectional study of 5712 participants in 17 urban areas across 12 countries [28]. The availability of recreational equipment was associated with various types of physical activity in a systematic review of 47 observational studies [29]. Residential density ($b = 1.01$, 95% CI 1.00–1.01), intersection density ($b = 1.07$, 95% CI 1.01–1.13), public transport density ($b = 1.04$, 95% CI 1.02–1.06), and number of parks ($b = 1.15$, 95% CI 1.03–1.27) were positively associated with physical activity in a cross-sectional study of 6822 adults in 14 cities from 10 countries though these effects were all modest [30]. This suggests that zoning and urban planning may play a role in increasing physical activity in urban areas. Finally, federal housing assistance has been associated with greater physical activity [31].

Changes to the built environment that increase walkability of neighborhoods, improve recreational spaces, and enhance transportation infrastructure could increase physical activity in both children and adults [32]. Examples of these changes are construction of new sidewalks and crosswalks, installation of raised platforms and "zebra" crossings to improve pedestrian safety, development of new greenways, installation of fitness and playground equipment, and park renovations. This evidence suggests that interventions to enhance the physical infrastructure of neighborhoods may promote both transport (i.e., getting to and from locations such as work or school) and recreational physical activity.

Several studies have also examined the relationship between the built environment and overweight/obesity. One way of understanding the relationship between the built environment and overweight/obesity is via neighborhood deprivation. Neighborhood deprivation is a measure that accounts for income, poverty, housing, education, employment, and occupation [33]. A greater degree of neighborhood deprivation was modestly associated with higher BMI (greater than 35) (RR 1.22, 95% CI 1.12–1.31) and hemoglobin A1c of 9% or greater (RRR 1.33, 95% CI 1.16–1.52) even after adjusting for individual factors in a cross-sectional study of 20,188 adults with chronic diseases in 19 Northern California counties.

Another way to conceptualize the relationship between the built environment and overweight/obesity is to consider features of the environments at different scales: the macro-, meso-, and micro-levels [34]. At the macro-level, the built environment is classified by degrees of urban sprawl and compactness using density, mix, centered-ness, and street connectivity. Areas with greater sprawl were associated with higher rates of obesity than more compact ones. Additionally, residents living in more compact areas had lower BMI values and rates of chronic cardiometabolic conditions like hypertension, coronary artery disease, and diabetes. The meso-level described areas within a 1-km distance of individuals, characterizing them by land use mix, residential density, and street connectivity. The investigators found that of these three measures, land use mix was the most strongly associated with obesity and that each quartile increase in land use mix was associated with a 12.2% reduction in likelihood of obesity accounting for gender and ethnicity. They also found that walkability of neighborhoods and proximity to parks and recreational spaces were of significance. Finally, proximity to supermarkets and grocery stores was associated with lower rates of obesity, while proximity to, or presence of, convenience stores and fast food were associated with higher rates of obesity. Highlighting the importance that area planning can play, for each additional kilometer walked, there was a 4.8% decrease in odds of obesity and for each hour spent in a car per day, there was a 6% increase in odds of obesity, in a cross-sectional study including 10,878 participants in the metro Atlanta area [35]. Therefore, planning decisions that influence how much one walks vs. spends time in a car may have a powerful effect on area obesity prevalence. By contrast, commercial density (measured as number of commercial facilities per hectare where commercial facilities are non-residential buildings used to conduct business) was associated with a 0.75-kg/m$^2$ increase in BMI for each additional commercial facility per hectare in a cross-sectional study conducted in rural Vermont [36]. This was surprising, as most prior studies found that lower BMIs were associated with compactness and increased density. This suggests that the relationship between density and obesity may vary in urban versus rural contexts.

There have been few longitudinal studies examining changes in the food environment and its effects on diabetes outcomes. Improvements in the food environment, such as increases in supermarkets, grocery stores, and produce venues supplying healthful foods in a person's neighborhood, was associated with weight loss among adults with diabetes who maintained the same residence over 5 years, in a longitudinal cohort study of 194,652 individuals in Northern California conducted by Laraia et al. [37]. However, magnitude of the association (1 pound lost for each standard deviation improvement in food environment) was small and unlikely to be clinically meaningful.

The majority of studies assessing the built food environment address the location and types of food vendors, but a study from Kern et al. reveals an intriguing finding related to food cost. Residents who lived in areas with larger cost differentials between healthy and non-healthy foods had greater insulin resistance, in their longitudinal cohort study of 3408 individuals in six US cities [14].

## Evidence from Policies

Overall, there is little direct evidence linking particular policies to changes in diabetes outcomes. However, based on the understanding of the relationship between the built environment and diabetes risk, there are several policy levers that might be used to influence risk factors. This has formed the basis of emerging policy evidence regarding the built environment and diabetes.

Development policies can increase physical activity [34]. At the macro-level, this has focused on mixed-use zoning and transit-based development. At the micro-level, a promising strategy has been reforms to improve street connectivity and transit changes to promote more walkable neighborhoods. Municipalities have also worked towards providing bonuses, waivers, and streamlined permits for developers who build communities with increased walkability, recreational spaces, and active travel. A recent study provides an example of how such an approach may play out. Arnason et al. used modeling to estimate the number of diabetes cases that could be prevented after a municipal policy was passed to increase physical activity through active transportation for work commutes in Ottawa, Ontario [38••]. This policy required pedestrian areas on all existing, new, and reconstructed roads; increased pedestrian crossings at high traffic transit corridors; reduced pedestrian crossing distances; created infrastructure supportive of cycling by building or renovating cycling pathways; and developing cycling connections to transit, and public bicycle parking [39]. Model estimates predicted that, over a 10-year timeframe, such policies could substantially reduce diabetes incidence, preventing up to 1620 cases of diabetes among 17,300 physically inactive individuals or 12,300 inactive adults greater than 45 years old [38••].

Two factors strongly influenced by public policy, a high degree of "urban sprawl" and low "land use mix", consistently showed an association with overweight/obesity in a systematic review of 92 studies [40]. Urban sprawl, or uncontrolled growth and development in the outskirts of a city, is a phenomenon that heavily affects the built environment given its impact on street connectivity, availability of green spaces, neighborhood walkability, and locations of retail outlets [41]. Land use mix is a measure that assesses the diversity of function within a building, set of buildings, or area [42]. Areas with high mixed-use development may include residential, office, retail, and personal services, as well as parks and open green spaces. Both urban sprawl and land use mix are potential areas for intervention at the policy level where zoning regulations and controlled urban planning can support health-promoting urban development [40]. Purnell et al. presented a review of policy recommendations to address diabetes, but acknowledged that evidence for the effectiveness of these policies is scant [43]. Recommendations that particularly focused on built environment issues were local zoning regulations to promote active transportation, which in turn would increase physical activity, and urban planning to promote connectivity, safety, and public transportation.

Local, grassroots level policy changes can be effective at improving the built environment to reduce diabetes risk as well. Using community-based participatory methods, community stakeholders and researchers in an indigenous community of Kahnawake, Quebec, developed a process to improve the safety of travel to and from school for grade school children over 19 months [44•]. The safety initiative shaped policies regarding transport and pedestrian routes that encouraged transport physical activity. Healthy food retail policies, as exemplified by a recent San Francisco initiative, also have potential to affect diabetes risk [45]. The program offers redesigns to stores (including storage and display areas for perishable items) and provides support for store owners who increase capacity for produce sales and limit availability of tobacco and alcohol. Evidence on outcomes was not yet available at the time of this article. The South Side Diabetes Collaborative is a multicomponent intervention that integrates a quality-improved collaborative, patient activation educational program, clinician training, and partners with community organizations to improve diabetes outcomes on the South Side of Chicago [46]. Early results showed improved diabetes care and control. Finally, the Healthy Communities Study, which focused on local community policy and programs that targeted childhood obesity and behavioral change around diet and physical activity, found that a larger number of approaches, without regard to the specific types of policies, was associated with lower BMI in children, suggesting that multiple policy approaches in combination may be effective in reducing diabetes risk [47].

Despite evidence that housing support can increase physical activity [31] and that moving from a high poverty to lower poverty neighborhood via a housing assistance program reduces diabetes incidence [48], we found no evidence regarding changes in housing policy and diabetes risk.

Some work has focused on how best to facilitate and study policy change for the built environment. In a qualitative analysis of data collected from public health, urban planning, transportation, and governmental stakeholders in Southern Ontario, Canada, Fazli et al. established a framework for defining the built environment, standardized measurement, and monitoring of the built environment, and actionable steps for developing health promoting solutions [49•]. Beyond establishing consistent measures for the built environment, Giles-Corti et al. have developed strategies for prioritizing research to inform policy and practice changes for chronic disease management [50]. Two of the strategies related to the physical environment include encouraging more policy-relevant research around active living and changes to the built environment that may reduce chronic disease burden. They also recommend incentivizing academics through partnerships with policymakers and practitioners to solve population health problems.

The most effective way to implement programs that encourage healthy built environments may be initiatives prioritizing maximum stakeholder engagement. Suggested stakeholders include community members and organizations, public health experts, legislators, and consultants with experience in transportation, land use, and urban planning [51–53]. For example, Miro et al. evaluated a capacity-building project for public health professionals in British Columbia [54]. Health authorities in this province were paired with a consultant to gain an understanding of land use and transportation planning in order to integrate public health principles with physical environment changes. This initiative allowed health professionals to participate in planning processes and hold influence in decisions around the built environment. While this effort is promising, there are not yet data to evaluate the public health effect of this effort.

## Recommendations for Future Work

While the role for policy in shaping the built environment to reduce diabetes risk is clear, much work remains to be done. Rigorous evaluation of policies aimed at increasing physical activity, improving diet quality, and reducing obesity needs to occur. High quality public health surveillance of diabetes is available for many municipalities, enabling tracking of area-level changes in diabetes incidence. However, attributing effects to any given policy out of a multitude of ongoing efforts will be tricky. Ideally, policies will be guided by evidence on mechanisms of diabetes risk, and be accompanied by robust, prospective evaluation in order to determine their effects. When experimental designs are not possible, use of quasi-experimental analysis strategies, such as interrupted time series analyses, regression discontinuity designs, or instrumental variable approaches, may be useful.

Another key area that has been neglected in current work is examining ways to use built environment policy to reduce diabetes disparities. It is well-established that there are disparities in diabetes risk and incidence based on race/ethnicity, socioeconomic status, and immigration status [55–58]. One potential mechanism for these disparities is the differences in the built environment. Those with lower socioeconomic status and racial/ethnic minorities are often exposed to built environments that impede physical activity, and constrain healthy food choice. Because disease burden disproportionately affects populations by race/ethnicity, socioeconomic status, and immigrant status, efforts to improve built environment characteristics should be sensitive to the unique needs of these communities. Prioritizing research and evaluation that can mitigate T2DM risk factors may be an additional avenue to reduce disparities in diabetes risk, and other chronic diseases. Further, because these populations are at heighted diabetes risk, reducing their risk may not only reduce disparities but help drive down overall incidence of diabetes.

## Conclusions

There is a large body of research describing the relationship between diabetes risk and physical activity, overweight/

obesity, and the food environment [2, 59, 60]. Current evidence suggests a relationship between the built environment and these risk factors. Given this relationship, policies that enhance the physical environment, particularly by encouraging more physical activity and exposure to healthy food retail options may reduce risk of diabetes. But despite increasing consideration of the built environment as a mechanism for improving health of communities and reducing risk of chronic disease, the evidence base is still under development. At the present time, policy approaches to reduce diabetes risk are promising, but we do not yet know what public health impact they can truly offer.

**Funding** Seth A. Berkowitz's role in the research reported in this publication was supported by the National Institute Of Diabetes And Digestive And Kidney Diseases of the National Institutes of Health under Award Number K23DK109200.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflicts of interest.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

**Disclaimer** The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

## References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. National Center for Chronic Disease Prevention and Health Promotion. National Diabetes Statistics Report, 2017. Centers for disease control and prevent. US Department of Health and Human Service; 2017.
2. Risk Factors for Type 2 Diabetes. NIDDK. 2016. https://www.niddk.nih.gov/health-information/diabetes/overview/risk-factors-type-2-diabetes. Accessed 1 Mar 2019.
3. American Diabetes Association. Economic costs of diabetes in the U.S. in 2017. Diabetes Care. 2018;41(5):917–28.
4. Nathan A, Villanueva K, Rozek J, Davern M, Gunn L, Trapp G, et al. The role of the built environment on health across the life course: a call for CollaborACTION. Am J Health Promot. 2018;32(6):1460–8.
5. Singh GK, Siahpush M, Kogan MD. Neighborhood socioeconomic conditions, built environments, and childhood obesity. Health Aff (Millwood). 2010;29(3):503–12.
6. Astell-Burt T, Feng X, Kolt GS. Is neighborhood green space associated with a lower risk of type 2 diabetes? Evidence from 267,072 Australians. Diabetes Care. 2014;37(1):197–201.
7. Bodicoat DH, Carter P, Comber A, Edwardson C, Gray LJ, Hill S, et al. Is the number of fast-food outlets in the neighbourhood related to screen-detected type 2 diabetes mellitus and associated risk factors? Public Health Nutr. 2015;18(9):1698–705.
8. Chandrabose M, Rachele JN, Gunn L, Kavanagh A, Owen N, Turrell G, et al. Built environment and cardio-metabolic health: systematic review and meta-analysis of longitudinal studies. Obes Rev. 2019;20(1):41–54.
9. Dalton AM, Jones AP, Sharp SJ, Cooper AJM, Griffin S, Wareham NJ. Residential neighbourhood greenspace is associated with reduced risk of incident diabetes in older people: a prospective cohort study. BMC Public Health. 2016;16(1):1171.
10. den Braver NR, Lakerveld J, Rutters F, Schoonmade LJ, Brug J, Beulens JWJ. Built environmental characteristics and diabetes: a systematic review and meta-analysis. BMC Med. 2018;16(1):12.
11. Dendup T, Feng X, Clingan S, Astell-Burt T. Environmental risk factors for developing type 2 diabetes mellitus: a systematic review. Int J Environ Res Public Health. 2018;15(1). https://doi.org/10.3390/ijerph15010078.
12. Garcia L, Lee A, Zeki Al Hazzouri A, Neuhaus JM, Moyce S, Aiello A, et al. Influence of neighbourhood socioeconomic position on the transition to type II diabetes in older Mexican Americans: the Sacramento Area Longitudinal Study on Aging. BMJ Open. 2016;6(8):e010905.
13. Herrick CJ, Yount BW, Eyler AA. Implications of supermarket access, neighbourhood walkability and poverty rates for diabetes risk in an employee population. Public Health Nutr. 2016;19(11):2040–8.
14. Kern DM, Auchincloss AH, Stehr MF, Diez Roux AV, Moore KA, Kanter GP, et al. Neighborhood price of healthier food relative to unhealthy food and its association with type 2 diabetes and insulin resistance: the multi-ethnic study of atherosclerosis. Prev Med. 2018;106:122–9.
15. Mezuk B, Li X, Cederin K, Rice K, Sundquist J, Sundquist K. Beyond access: characteristics of the food environment and risk of diabetes. Am J Epidemiol. 2016;183(12):1129–37.
16. Sarkar C, Webster C, Gallacher J. Are exposures to ready-to-eat food environments associated with type 2 diabetes? A cross-sectional study of 347 551 UK Biobank adult participants. Lancet Planet Health. 2018;2(10):e438–50.
17. Smalls BL, Gregory CM, Zoller JS, Egede LE. Assessing the relationship between neighborhood factors and diabetes related health outcomes and self-care behaviors. BMC Health Serv Res. 2015;15(1):445.
18. Tait CA, L'Abbé MR, Smith PM, Rosella LC. The association between food insecurity and incident type 2 diabetes in Canada: a population-based cohort study. PLoS One. 2018;13(5):e0195962.
19. Black JL, Macinko J. Neighborhoods and obesity. Nutr Rev. 2008;66(1):2–20.
20. Kivimäki M, Vahtera J, Tabák AG, Halonen JI, Vineis P, Pentti J, et al. Neighbourhood socioeconomic disadvantage, risk factors, and diabetes from childhood to middle age in the Young Finns Study: a cohort study. Lancet Public Health. 2018;3(8):e365–73.
21. Kivimäki M, Virtanen M, Kawachi I, Nyberg ST, Alfredsson L, Batty GD, et al. Long working hours, socioeconomic status, and the risk of incident type 2 diabetes: a meta-analysis of published and unpublished data from 222 120 individuals. Lancet Diabetes Endocrinol. 2015;3(1):27–34.
22.•• Bilal U, Auchincloss AH, Diez-Roux AV. Neighborhood environments and diabetes risk and control. Curr Diab Rep. 2018;18(9):62. **Extremely thorough and well conducted overview of the evidence regarding the association between neighborhood environment and diabetes.**
23.•• Sundquist K, Eriksson U, Mezuk B, Ohlsson H. Neighborhood walkability, deprivation and incidence of type 2 diabetes: a population-based study on 512,061 Swedish adults. Health Place. 2015;31:24–30. **This study describes the association between**

**built environment feature of neighborhood walkability and type 2 diabetes, but highlights the importance of considering compositional and contextual characteristics in future studies.**

24. Booth GL, Creatore MI, Moineddin R, Gozdyra P, Weyman JT, Matheson FI, et al. Unwalkable neighborhoods, poverty, and the risk of diabetes among recent immigrants to Canada compared with long-term residents. Diabetes Care. 2013;36(2):302–8.
25. Creatore MI, Glazier RH, Moineddin R, Fazli GS, Johns A, Gozdyra P, et al. Association of neighborhood walkability with change in overweight, obesity, and diabetes. JAMA. 2016;315(20):2211–20.
26. Durand CP, Andalib M, Dunton GF, Wolch J, Pentz MA. A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning. Obes Rev. 2011;12(501):e173–82.
27. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJF, Martin BW, et al. Correlates of physical activity: why are some people physically active and others not? Lancet. 2012;380(9838):258–71.
28. Owen N, Sugiyama T, Koohsari MJ, De Bourdeaudhuij I, Hadgraft N, Oyeyemi A, et al. Associations of neighborhood environmental attributes with adults' objectively-assessed sedentary time: IPEN adult multi-country study. Prev Med. 2018;115:126–33.
29. Wendel-Vos W, Droomers M, Kremers S, Brug J, van Lenthe F. Potential environmental determinants of physical activity in adults: a systematic review. Obes Rev. 2007;8(5):425–40.
30. Sallis JF, Cerin E, Conway TL, Adams MA, Frank LD, Pratt M, et al. Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. Lancet. 2016;387(10034):2207–17.
31. Wong MS, Roberts ET, Arnold CM, Pollack CE. HUD housing assistance and levels of physical activity among low-income adults. Prev Chronic Dis. 2018;15. https://doi.org/10.5888/pcd15.170517.
32. Smith M, Hosking J, Woodward A, Witten K, MacMillan A, Field Aet al. Systematic literature review of built environment effects on physical activity and active transport – an update and new findings on health equity. Int J Behav Nutr Phys Act [Internet]. 2017 Nov 16 [cited 2019 Jan 7];14:158. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5693449/.
33. Laraia BA, Karter AJ, Warton EM, Schillinger D, Moffet HH, Adler N. Place matters: neighborhood deprivation and cardiometabolic risk factors in the Diabetes Study of Northern California (DISTANCE). Soc Sci Med. 2012;74:1082–90.
34.•• Garfinkel-Castro A, Kim K, Hamidi S, Ewing R. Obesity and the built environment at different urban scales: examining the literature. Nutr Rev. 2017;75:51–61. **Key review of the evidence to date on built environment policies and obesity, and provides a useful framework for understanding levels at which policies may act.**
35. Frank LD, Andresen MA, Schmid TL. Obesity relationships with community design, physical activity, and time spent in cars. Am J Prev Med. 2004;27(2):87–96.
36. Troy AR, Bonnell LN, Littenberg B. Relationship between the built environment and body mass index in a rural context: a cross-sectional study from Vermont. Cureus. 2018;10(7):e3040.
37. Laraia BA, Downing JM, Zhang YT, Dow WH, Kelly M, Blanchard SD, et al. Food environment and weight change: does residential mobility matter? Am J Epidemiol. 2017;185(9):743–50.
38.•• Arnason T, Tanuseputro P, Tuna M, Manuel D. Municipal transportation policy as a population health intervention: estimating the impact of the City of Ottawa Transportation Master Plan on diabetes incidence. Can J Public Health. 2019. https://doi.org/10.17269/s41997-018-0168-9. **This study is one of few that attempts to quantify the potential impact on diabetes of municipal policy aimed at increasing active transport.**
39. Transportation master plan. Ottawa City Services. 2013.
40. Mackenbach JD, Rutter H, Compernolle S, Glonti K, Oppert J-M, Charreire H, et al. Obesogenic environments: a systematic review of the association between the physical environment and adult weight status, the SPOTLIGHT project. BMC Public Health. 2014;14:233.
41. Resnik DB. Urban sprawl, smart growth, and deliberative democracy. Am J Public Health. 2010;100(10):1852–6.
42. Spears S, Boarnet MG, Handy S, Rodier C. Impacts of land-use mix on passenger vehicle use and greenhouse gas emissions, vol. 6; 2014.
43. Purnell JQ, Herrick C, Moreland-Russell S, Eyler AA. Outside the exam room: policies for connecting clinic to community in diabetes prevention and treatment. Prev Chronic Dis. 2015;12. https://doi.org/10.5888/pcd12.140403.
44.• Macridis S, Garcia Bengoechea E, McComber AM, Jacobs J, Macaulay AC, Members of the Kahnawake Schools Diabetes Prevention Project-School Travel Planning Committee. Active transportation to support diabetes prevention: expanding school health promotion programming in an indigenous community. Eval Program Plann. 2016;56:99–108. **Key description of a collaborative effort to enact policy changes to enhance the built environment for health promotion.**
45. Minkler M, Estrada J, Dyer S, Hennessey-Lavery S, Wakimoto P, Falbe J. Healthy retail as a strategy for improving food security and the built environment in San Francisco. Am J Public Health. 2019;109(S2):S137–40.
46. Peek ME, Wilkes AE, Roberson TS, Goddu AP, Nocon RS, Tang H, et al. Early lessons from an initiative on Chicago's south side to reduce disparities in diabetes care and outcomes. Health Aff. 2012;31(1):177–87.
47. Strauss WJ, Nagaraja J, Landgraf AJ, Arteaga SS, Fawcett SB, Ritchie LD, et al. The longitudinal relationship between community programmes and policies to prevent childhood obesity and BMI in children: the Healthy Communities Study. Pediatr Obes. 2018;13(Suppl 1):82–92.
48. Ludwig J, Sanbonmatsu L, Gennetian L, Adam E, Duncan GJ, Katz LF, et al. Neighborhoods, obesity, and diabetes–a randomized social experiment. N Engl J Med. 2011;365(16):1509–19.
49.• Fazli GS, Creatore MI, Matheson FI, Guilcher S, Kaufman-Shriqui V, Manson H, et al. Identifying mechanisms for facilitating knowledge to action strategies targeting the built environment. BMC Public Health. 2017;17 Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5210277/. **This paper highlights the need for consensus on built environment measures and monitoring.**
50. Giles-Corti B, Sallis JF, Sugiyama T, Frank LD, Lowe M, Owen N. Translating active living research into policy and practice: one important pathway to chronic disease prevention. J Public Health Policy. 2015;36(2):231–43.
51. Cheadle A, Cromp D, Krieger JW, Chan N, McNees M, Ross-Viles S, et al. Promoting policy, systems, and environment change to prevent chronic disease: lessons learned from the king county communities putting prevention to work initiative. J Public Health Manag Pract. 2016;22(4):348–59.
52. Coghill C-L, Valaitis RK, Eyles JD. Built environment interventions aimed at improving physical activity levels in rural Ontario health units: a descriptive qualitative study. BMC Public Health. 2015;15:464.
53. Politis CE, Mowat DL, Keen D. Pathways to policy: lessons learned in multisectoral collaboration for physical activity and built environment policy development from the Coalitions Linking Action and Science for Prevention (CLASP) initiative. Can J Public Health. 2017;108(2):e192–8.
54. Miro A, Perrotta K, Evans H, Kishchuk NA, Gram C, Stanwick RS, et al. Building the capacity of health authorities to influence land use and transportation planning: Lessons learned from the Healthy Canada by Design CLASP Project in British Columbia. Can J Public Health. 2014;106(1 Suppl 1):eS40–52.

55. Campbell JA, Walker RJ, Smalls BL, Egede LE. Glucose control in diabetes: the impact of racial differences on monitoring and outcomes. Endocrine. 2012;42(3):471–82.
56. Heidemann DL, Joseph NA, Kuchipudi A, Perkins DW, Drake S. Racial and economic disparities in diabetes in a large primary care patient population. Ethn Dis. 2016;6(1):85–90.
57. Saydah S, Lochner K. Socioeconomic status and risk of diabetes-related mortality in the U.S. Public Health Rep. 2010;125(3):377–88.
58. Spanakis EK, Golden SH. Race/ethnic difference in diabetes and diabetic complications. Curr Diab Rep. 2013;13(6):814–23.
59. Seligman HK, Bindman AB, Vittinghoff E, Kanaya AM, Kushel MB. Food insecurity is associated with diabetes mellitus: results from the National Health Examination and Nutrition Examination Survey (NHANES) 1999-2002. J Gen Intern Med. 2007;22(7):1018–23.
60. Seligman HK, Jacobs EA, López A, Tschann J, Fernandez A. Food insecurity and glycemic control among low-income patients with type 2 diabetes. Diabetes Care. 2012;35(2):233–8.