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BRIEF REPORT

Neighbourhood walkability is associated with risk of gestational diabetes: A cross-sectional study in New York City

Andrew G. Rundle[1] | Eliza W. Kinsey[2] | Elizabeth M. Widen[3] | James W. Quinn[1] | Mary Huynh[4] | Gina S. Lovasi[5] | Kathryn M. Neckerman[6] | Gretchen Van Wye[7]

[1]Mailman School of Public Health, Columbia University, New York, New York, USA

[2]Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA

[3]College of Natural Sciences, The University of Texas at Austin, Austin, Texas, USA

[4]School of Health Sciences, Human Services, & Nursing, Lehman College, New York, New York, USA

[5]Dornsife School of Public Health, Drexel University, Philadelphia, Pennsylvania, USA

[6]Columbia Population Research Center, Columbia University, New York, New York, USA

[7]Bureau of Vital Statistics, New York City Department of Health and Mental Hygiene, New York, New York, USA

Correspondence
Andrew Rundle, Mailman School of Public Health, Department of Epidemiology, New York, NY USA.
Email: agr3@cumc.columbia.edu

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Abstract

Background: Despite the links between neighbourhood walkability and physical activity, body size and risk of diabetes, there are few studies of neighbourhood walkability and risk of gestational diabetes (GD).

Objectives: Assess whether higher neighbourhood walkability is associated with lower risk of GD in New York City (NYC).

Methods: Cross-sectional analyses of a neighbourhood walkability index (NWI) score and density of walkable destinations (DWD) and risk of GD in 109,863 births recorded in NYC in 2015. NWI and DWD were measured for the land area of 1 km radius circles around the geographic centroid of each Census block of residence. Mixed generalised linear models, with robust standard error estimation and random intercepts for NYC Community Districts, were used to estimate risk ratios for GD for increasing quartiles of each of the neighbourhood walkability measures after adjustment for the pregnant individual's age, race and ethnicity, parity, education, nativity, and marital status and the neighbourhood poverty rate.

Results: Overall, 7.5% of pregnant individuals experienced GD. Risk of GD decreased across increasing quartiles of NWI, with an adjusted risk ratio of 0.81 (95% Confidence Interval (CI) 0.75, 0.87) comparing those living in areas in the 4th quartile of NWI to those in the first quartile. Similarly, for comparisons of the 4th to 1st quartile of DWD, the adjusted risk ratio for GD was 0.77 (95% CI 0.71, 0.84).

Conclusions: These analyses find support for the hypothesis that higher neighbourhood walkability is associated with a lower risk of GD. The analyses provide further health related support for urban design policies to increase walkability.

KEYWORDS
gestational diabetes, neighbourhood walkability, poverty rate, urban design

1 | BACKGROUND

Gestational diabetes (GD) is a form of diabetes that develops during pregnancy and in 2020 was diagnosed in 7.8% of pregnancies in the United States.[1,2] GD increases infants' risk for being large for gestational age, may increase the risk of unhealthy weight gain during childhood, and increases the pregnant individual's risk for future type 2 diabetes.[1] Physical activity prior to and during pregnancy is associated with a lower risk of GD, and data suggest that even light physical activity and walking have protective effects.[1,3–6]

Neighbourhood walkability refers to built environment features that promote pedestrian activity.[7,8] In the urban planning literature higher walkability is defined in terms of higher population density, greater street connectivity, availability of transit, greater land

use mix, and higher destination accessibility.[7–10] Higher residential neighbourhood walkability has been associated with more walking, higher overall physical activity, lower BMI, lower incidence of diabetes, and improved glycemic control among patients with Type II diabetes.[7,11–14] Given these prior findings, here we assess whether higher residential neighbourhood walkability is associated with a lower risk of GD among pregnant individuals in New York City (NYC).

Synopsis

Study question

Is neighbourhood walkability associated with lower risk of gestational diabetes (GD)

What's already known

The sole prior study found no association

What this study adds

Given the long-lasting benefits of healthy pregnancies for the parent and the child, this research motivates the use of urban design to support healthy pregnancies.

2 | METHODS

The analyses included data from 110,744 births reported in the 2015 NYC Vital Statistics records and the dataset has been described previously.[15] We excluded individuals with a record of pre-pregnancy diabetes (n = 835) and for whom neighbourhood walkability could not be calculated (n = 46), yielding a sample size of 109,863 births. The birth records included self-reported sociodemographic information and pregnancy related data reported in the medical records.[15]

2.1 | Neighbourhood variables

The pregnant individual's residential address was geocoded to the Census block of residence. A 1 km radial buffer was created around the geographic centroid of each 2010 Census block, areas of water were removed, and the radial buffers' land areas were characterised. The 2015 neighbourhood walkability index (NWI) was calculated for these buffers using data on residential density; street intersection density; land use mix; subway stop density; and the ratio of retail building floor area to retail land area, and has been described extensively elsewhere.[7,10] Using the 2014 National Establishment Time Series data a second measure of neighbourhood walkability was created, the density of walkable destinations (DWD), a measure of walkability that is not directly included in the NWI.[7] The proportion of residents with incomes below the poverty line (Poverty Rate) was calculated for each radial buffer using area-weighted interpolation of data from the 2012–2016 American Community Survey.

To preserve the confidentiality of the birth records, the linkage between the Census block of residence and neighbourhood variables was completed at the NYC Department of Health and Mental Hygiene, and the combined individual- and neighbourhood-level data were analysed with neighbourhood-level variables categorised into quartiles. Quartile cut-points were established using the distribution of the neighbourhood-level variables across all Census blocks in NYC.

2.2 | Statistical analysis

Generalised linear mixed models were used to estimate risk ratios and risk differences for GD for increasing quartiles of neighbourhood walkability.[16] Each of the 59 NYC Community Districts is overseen by a Community Board, which is a local representative body that: oversees local land use and zoning issues; assesses the needs of the District; addresses community concerns (e.g., empty storefronts); and makes recommendations for the City budgeting process. Because Community Board activities are likely to cause non-independence of observations of built environment conditions within Districts, random intercepts for Community Districts and robust standard error estimation were used in the mixed models.

Analyses of DWD used negative binomial mixed models, while, due to non-convergence issues with the negative binomial models, analyses of NWI used Poisson mixed models.[16] Risk ratio analyses controlled for pregnant individual's age, education, race/ethnicity, number of prior live births, marital status, nativity and neighbourhood poverty rate. In this population the pregnant individual's age at giving birth is as low as 13 years, and so educational attainment, marital status, and the number of prior live births show some co-linearity with age at giving birth. Models estimating risk differences would not converge when maternal age was included in the models and age at giving birth was removed from these models. Analyses of data on the age at giving birth showed it was a negative confounder of the association between the walkability measures and GD and so not adjusting for this variable resulted in a slight bias to the null.

This study was approved by the Columbia University Irving Medical Center Institutional Review Board as Not Human Research. All analyses were conducted at Columbia University.

3 | RESULTS

Overall, 7.5% of pregnant individuals experienced GD and as shown in Table 1 risk of GD varied across sociodemographic characteristics, notably across categories of race and ethnicity categories and educational attainment. After adjustment for individual-level sociodemographic characteristics and neighbourhood poverty rate, the prevalence of GD declined across increasing quartiles of NWI and DWD (see Table 2). Comparing those living in areas in the 4th

TABLE 1 Sociodemographic characteristics of the pregnant individuals by gestational diabetes status and walkability metrics

	Gestational diabetes		Neighbourhood walkability index quartiles				Density of walkable destinations quartiles			
	No	Yes	1	2	3	4	1	2	3	4
	N (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)
Total population of pregnant individuals	101,658 (92.5)	8205 (7.5)	10,830 (9.9)	20,310 (18.5)	36,206 (33)	42,517 (38.7)	7918 (7.2)	15,102 (13.7)	32,722 (29.8)	54,121 (49.3)
Age at giving birth										
<20	3843 (97.8)	88 (2.2)	325 (8.3)	717 (18.2)	1174 (29.9)	1715 (43.6)	211 (5.4)	595 (15.1)	1374 (35)	1751 (44.5)
20–24	17,675 (96.1)	721 (3.9)	1537 (8.4)	3116 (16.9)	6206 (33.7)	7537 (41)	1004 (5.5)	2579 (14)	6016 (32.7)	8797 (47.8)
25–29	26,834 (93.4)	1892 (6.6)	2974 (10.4)	5455 (19)	9960 (34.7)	10,337 (36)	2135 (7.4)	4315 (15)	9254 (32.2)	13,022 (45.3)
30–34	29,904 (91.8)	2661 (8.2)	3452 (10.6)	6190 (19)	10,466 (32.1)	12,457 (38.3)	2684 (8.2)	4377 (13.4)	9231 (28.3)	16,273 (50)
35–40	18,272 (89.9)	2043 (10.1)	2046 (10.1)	3713 (18.3)	6452 (31.8)	8104 (39.9)	1514 (7.5)	2539 (12.5)	5281 (26)	10,981 (54.1)
40+	5130 (86.5)	800 (13.5)	496 (8.4)	1119 (18.9)	1948 (32.8)	2367 (39.9)	370 (6.2)	697 (11.8)	1566 (26.4)	3297 (55.6)
Race and ethnicity of the pregnant individual										
Non-Hispanic White	33,129 (95.8)	1455 (4.2)	3474 (10)	5979 (17.3)	11,089 (32.1)	14,042 (40.6)	2990 (8.6)	3109 (9)	7214 (20.9)	21,271 (61.5)
Hispanic	31,151 (92.9)	2385 (7.1)	2445 (7.3)	5942 (17.7)	10,382 (31)	14,767 (44)	1705 (5.1)	4318 (12.9)	12,398 (37)	15,115 (45.1)
Non-Hispanic Asian	15,850 (85.6)	2667 (14.4)	1861 (10.1)	3303 (17.8)	6946 (37.5)	6407 (34.6)	1364 (7.4)	2473 (13.4)	5880 (31.8)	8800 (47.5)
Non-Hispanic Black	20,019 (92.8)	1559 (7.2)	2860 (13.3)	4740 (22)	7218 (33.5)	6760 (31.3)	1701 (7.9)	4932 (22.9)	6763 (31.3)	8182 (37.9)
Non-Hispanic Other	1447 (91.6)	133 (8.4)	189 (12)	337 (21.3)	547 (34.6)	507 (32.1)	156 (9.9)	262 (16.6)	450 (28.5)	712 (45.1)
Missing	62 (91.2)	6 (8.8)	1 (1.5)	9 (13.2)	24 (35.3)	34 (50)	2 (2.9)	8 (11.8)	17 (25)	41 (60.3)
Educational attainment of the pregnant individual										
Less than high school	19,274 (91.1)	1890 (8.9)	1319 (6.2)	3282 (15.5)	7140 (33.7)	9423 (44.5)	814 (3.8)	2528 (11.9)	7240 (34.2)	10,582 (50)
High School	23,139 (92.6)	1858 (7.4)	2126 (8.5)	4067 (16.3)	8502 (34)	10,302 (41.2)	1510 (6)	3480 (13.9)	7502 (30)	12,505 (50)
Some college	16,262 (92.7)	1286 (7.3)	2133 (12.2)	3701 (21.1)	5954 (33.9)	5760 (32.8)	1595 (9.1)	3014 (17.2)	5771 (32.9)	7168 (40.8)
Associates	6644 (91.1)	652 (8.9)	1000 (13.7)	1580 (21.7)	2488 (34.1)	2228 (30.5)	747 (10.2)	1341 (18.4)	2469 (33.8)	2739 (37.5)
Bachelors	20,094 (93.0)	1523 (7.0)	2518 (11.6)	4387 (20.3)	6811 (31.5)	7901 (36.5)	1923 (8.9)	2949 (13.6)	5970 (27.6)	10,775 (49.8)
Grad degree	15,936 (94.2)	974 (5.8)	1709 (10.1)	3244 (19.2)	5206 (30.8)	6751 (39.9)	1313 (7.8)	1744 (10.3)	3677 (21.7)	10,176 (60.2)
Missing	309 (93.4)	22 (6.6)	25 (7.6)	49 (14.8)	105 (31.7)	152 (45.9)	16 (4.8)	46 (13.9)	93 (28.1)	176 (53.2)
Number of prior live births										
0	45,024 (93.6)	3094 (6.4)	4650 (9.7)	9032 (18.8)	15,681 (32.6)	18,755 (39)	3335 (6.9)	6406 (13.3)	13,991 (29.1)	24,386 (50.7)
1	31,224 (92.1)	2679 (7.9)	3631 (10.7)	6453 (19)	11,398 (33.6)	12,421 (36.6)	2740 (8.1)	4918 (14.5)	10,262 (30.3)	15,983 (47.1)
2	14,330 (91.1)	1398 (8.9)	1695 (10.8)	2952 (18.8)	5238 (33.3)	5843 (37.2)	1204 (7.7)	2345 (14.9)	5071 (32.2)	7108 (45.2)
3	5546 (90.4)	586 (9.6)	535 (8.7)	1071 (17.5)	2042 (33.3)	2484 (40.5)	416 (6.8)	848 (13.8)	1967 (32.1)	2901 (47.3)

TABLE 1 (Continued)

	Gestational diabetes		Neighbourhood walkability index quartiles				Density of walkable destinations quartiles			
	No	Yes	1	2	3	4	1	2	3	4
	N (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)
4 or more	5513 (92.5)	447 (7.5)	318 (5.3)	798 (13.4)	1837 (30.8)	3007 (50.5)	222 (3.7)	582 (9.8)	1426 (23.9)	3730 (62.6)
Missing	21 (95.5)	1 (4.5)	1 (4.5)	4 (18.2)	10 (45.5)	7 (31.8)	1 (4.5)	3 (13.6)	5 (22.7)	13 (59.1)
Nativity of the pregnant individual										
Foreign Born	52,632 (90.2)	5703 (9.8)	5288 (9.1)	11,068 (19)	20,944 (35.9)	21,035 (36.1)	3605 (6.2)	8284 (14.2)	19,891 (34.1)	26,555 (45.5)
U.S. Born	48,994 (95.1)	2498 (4.9)	5541 (10.8)	9241 (17.9)	15,248 (29.6)	21,462 (41.7)	4312 (8.4)	6813 (13.2)	12,821 (24.9)	27,546 (53.5)
Missing	32 (88.9)	4 (11.1)	1 (2.8)	1 (2.8)	14 (38.9)	20 (55.6)	1 (2.8)	5 (13.9)	10 (27.8)	20 (55.6)
Neighbourhood poverty rate quartiles										
1	12,893 (94.1)	807 (5.9)	3594 (26.2)	3240 (23.6)	2552 (18.6)	4314 (31.5)	3278 (23.9)	2415 (17.6)	1000 (7.3)	7007 (51.1)
2	17,040 (92.7)	1349 (7.3)	3280 (17.8)	5443 (29.6)	4883 (26.6)	4783 (26)	2489 (13.5)	5291 (28.8)	4589 (25)	6020 (32.7)
3	27,510 (91.2)	2638 (8.8)	2144 (7.1)	6408 (21.3)	12,265 (40.7)	9331 (31)	1200 (4)	4445 (14.7)	12,635 (41.9)	11,868 (39.4)
4	44,215 (92.8)	3411 (7.2)	1812 (3.8)	5219 (11)	16,506 (34.7)	24,089 (50.6)	951 (2)	2951 (6.2)	14,498 (30.4)	29,226 (61.4)

quartile of NWI to those in the 1st quartile, the adjusted risk ratio for GD was 0.81 with a 95% confidence interval (CI) of 0.75 to 0.87. Similarly, for comparisons of the 4th to 1st quartile of DWD, the adjusted risk ratio for GD was 0.77 (95% CI 0.71, 0.84). Among individuals for whom this was the first live birth, the inverse association between the neighbourhood walkability measures and GD was slightly stronger; the risk ratio comparing the 4th quartile of NWI to the 1st was 0.68 (95% CI 0.61, 0.77) and the risk difference was −2.30 percentage points (95% CI −3.13, −1.47). Similarly, the risk ratio comparing the 4th quartile of DWD to the 1st was 0.70 (95% CI 0.61, 0.80) and the risk difference was −1.83 percentage points (95% CI −2.72, −0.95).

4 | COMMENT

These analyses find that in NYC risk of GD is inversely associated with increasing levels of neighbourhood walkability. The association appears modest, with a reduction in the risk of GD between 1.30 and 1.44 percentage points comparing those who lived in the lowest and highest quartiles of the walkability metrics. However overall, 7.5% of pregnant individuals were diagnosed with GD, 39% of the pregnant individuals lived in the highest citywide quartile of NWI and 49% lived in the highest citywide quartile of DWD. Thus, this risk reduction may be experienced by a large number of pregnant individuals.

To our knowledge, only one prior study has assessed neighbourhood walkability as a risk factor for GD and did not find an association.[17] That study used Walk Score as the metric of walkability, a measure that is comparable in conceptual design to the NWI and is similarly linked to variation in residents' physical activity and body mass index.[7,10,18] However, Walk Score includes neighbourhood features within an assumed 30-minute walk (roughly 2 miles at a moderate pace walk) from an address, which might be a longer distance than is relevant for walking behaviours among pregnant individuals.[18] Simulation analyses show that when the neighbourhood scale used in data analyses is larger than that actually utilised by study participants bias to the null occurs.[19,20] Thus the difference in findings for the present study compared to the prior study may relate to differences in the area defined as the residential neighbourhood.

The strengths and weaknesses of this data set have been described previously.[15] One weakness is that data on GD in prior pregnancies were not available and a prior GD diagnosis is a risk factor for GD in subsequent pregnancies. It is unlikely that prior GD would cause a woman to experience lower neighbourhood walkability during a subsequent pregnancy and create a confounding effect and spurious results in the current data. In addition, a significant inverse association was observed between NWI and GD risk and between DWD and GD risk among individuals for whom this was the first live birth. However, the absence of these data does preclude analyses of effect modification between prior GD and neighbourhood walkability on the risk of GD in the pregnancies studied here.

TABLE 2 Associations between the risk of gestational diabetes and neighbourhood walkability index score and density of walkable destinations

	Gestational Diabetes		Unadjusted Risk Ratio (95% CI)	Adjusted[a] Risk Ratio (95% CI)	Unadjusted Risk Difference[b] (95% CI)	Adjusted Risk Difference[c] (95% CI)
	No *N* (%)	Yes *N* (%)				
NWI quartiles						
1 (low walkability)	9933 (91.7)	897 (8.3)	1.00 (Reference)	1.00 (Reference)	0.00 (Reference)	0.00 (Reference)
2	18,730 (92.2)	1580 (7.8)	0.94 (0.87, 1.02)	0.90 (0.83, 0.97)	−0.50 (−1.14, 0.13)	−0.75 (−1.34, −0.16)
3	33,404 (92.3)	2802 (7.7)	0.93 (0.87, 1.00)	0.84 (0.78, 0.91)	−0.54 (−1.13, 0.04)	−1.12 (−1.68, −0.56)
4 (high walkability)	39,591 (93.1)	2926 (6.9)	0.83 (0.77, 0.89)	0.81 (0.75, 0.87)	−1.40 (−1.97, −0.80)	−1.30 (−1.85, −0.76)
DWD Quartiles						
1 (low walkability)	7298 (92.2)	620 (7.9)	1.00 (Reference)	1.00 (Reference)	0.00 (Reference)	0.00 (Reference)
2	13,802 (91.4)	1300 (8.6)	1.10 (1.003, 1.21)	1.00 (0.91, 1.09)	0.78 (0.04, 1.52)	−0.11 (−0.81, 0.59)
3	29,992 (91.7)	2730 (8.3)	1.07 (0.98, 1.16)	0.90 (0.83, 0.98)	0.51 (−0.15, 1.18)	−0.73 (−1.38, −0.09)
4 (high walkability)	50,566 (93.4)	3555 (6.6)	0.84 (0.77, 0.91)	0.77 (0.71, 0.84)	−1.26 (−1.89, −0.63)	−1.44 (−2.04, −0.84)

[a]Adjusted for race/ethnicity, education, age at birth, marital status, previous number of births and nativity of the pregnant individual and neighbourhood poverty rate.

[b]Percentage point difference in risk of gestational diabetes.

[c]Percentage point difference in risk of gestational diabetes, adjusted for race/ethnicity, education, marital status, previous number of births, and nativity of the pregnant individual and neighbourhood poverty rate.

5 | CONCLUSIONS

These analyses find that in NYC higher neighbourhood walkability is associated with a lower risk of GD, which, along with our prior findings that higher walkability is associated with lower odds of excessive gestational weight gain, suggest that urban design can contribute to healthy pregnancies.[15] By 2030, it is projected that 14% of the world's population (1.2 billion people) will live in cities like NYC that have populations of 5 million or more.[21] As such, the findings reported here may be applicable to a very large population. Multiple design and planning guidelines to support planners and architects designing for health have been published by cities, professional organisations, and for-profit entities.[8,22–25] However, because of limited research on active design and health during pregnancy, these guides do not explicitly consider pregnant individuals and their infants. Given the long-lasting benefits of healthy pregnancies for the parent and the child, this research motivates the use of urban design to support healthy pregnancies. If further research replicates the findings presented here, supporting healthy pregnancies should be factored into cost–benefit analyses of built environment interventions to create walkable neighbourhoods.

AUTHOR CONTRIBUTIONS

Andrew G. Rundle: Conceptualised the study, conducted data analyses and wrote the first draft of the manuscript. Eliza W. Kinsey: Helped conceptualise the study, processed, cleaned and coded the Vital Statistics data, contributed to writing the manuscript. Elizabeth M. Widen: Helped conceptualise the study, consulted on statistical analyses and contributed to writing the manuscript. James W. Quinn: Conducted all of the geoprocessing of the neighbourhood data. Mary Huynh: Curated the Vital Statistics data, conducted data linkage of the neighbourhood-level and Vital Statistics data, contributed to writing and editing the manuscript. Gina S. Lovasi: Contributed to developing the neighbourhood-level data set, consulted on statistical analyses and interpreting the results, and contributed to writing and editing the manuscript. Kathryn M. Neckerman: Contributed to developing the neighbourhood-level data set, developed the neighbourhood walkability index, and contributed to writing and editing the manuscript. Gretchen Van Wye: Helped conceptualise the study, responsible for the collection and integrity of the Vital Statistics data and contributed to writing and editing the manuscript.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

New York City Birth Record data are available to qualified investigators through Data Use Agreements with the Bureau of Vital Statistics, the New York City Department of Health and Mental Hygiene. New York City Neighbourhood Walkability Index data are available from the Built Environment and Health Research Group at Columbia University, contact Andrew Rundle at agr3@cumc.columbia.edu.

ORCID

Andrew G. Rundle https://orcid.org/0000-0003-0211-7707
Elizabeth M. Widen https://orcid.org/0000-0002-9574-6109
Gina S. Lovasi https://orcid.org/0000-0003-2613-9599

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