Is Neighborhood Green Space Associated With a Lower Risk of Type 2 Diabetes? Evidence From 267,072 Australians

Thomas Astell-Burt,[1,2] Xiaoqi Feng,[3] and Gregory S. Kolt[1]

EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

OBJECTIVE

Lifestyle interventions for type 2 diabetes mellitus (T2DM) are best positioned for success if participants live in supportive neighborhood environments. Deprived neighborhoods increase T2DM risk. Parks and other "green spaces" promote active lifestyles and therefore may reduce T2DM risk. We investigated association between neighborhood green space and the risk of T2DM in a large group of adult Australians.

RESEARCH DESIGN AND METHODS

Multilevel logit regression was used to fit associations between medically diagnosed T2DM and green space exposure among 267,072 participants in the 45 and Up Study. Green space data were obtained from the Australian Bureau of Statistics, and exposure was calculated using a 1-km buffer from a participant's place of residence. Odds ratios (ORs) were controlled for measures of demographic, cultural, health, diet, active lifestyles, socioeconomic status, and neighborhood circumstances.

RESULTS

The rate of T2DM was 9.1% among participants in neighborhoods with 0–20% green space, but this rate dropped to approximately 8% for participants with over 40% green space within their residential neighborhoods. The risk of T2DM was significantly lower in greener neighborhoods, controlling for demographic and cultural factors, especially among participants residing in neighborhoods with 41–60% green space land use (OR 0.87; 95% CI 0.83–0.92). This association was consistent after controlling for other explanatory variables and did not vary according to neighborhood circumstances.

CONCLUSIONS

People in greener surroundings have a lower risk of T2DM. Planning, promoting, and maintaining local green spaces is important in multisector initiatives for addressing the T2DM epidemic.

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[1]School of Science and Health, University of Western Sydney, Sydney, Australia
[2]School of Geography and Geosciences, University of St. Andrews, St. Andrews, U.K.
[3]Centre for Health Research, School of Medicine, University of Western Sydney, Sydney, Australia

Corresponding author: Thomas Astell-Burt, t.astell-burt@uws.edu.au.

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Type 2 diabetes mellitus (T2DM) is preventable, yet the rising burden of disease poses daunting human costs and an unsustainable future for health care systems worldwide (1). Multiple lifestyle interventions are known to reduce the risk of developing T2DM (2), but their success in real-world settings can be affected by the circumstances in which people live. Recent work in Australia, for example, has reported that people living in deprived neighborhoods are at a higher risk of incident T2DM (3) and many of the lifestyle-related risk factors (4).

To address the impact of location on health outcomes, especially within disadvantaged communities, parks and other "green spaces" are increasingly viewed by policymakers and planners as a lever for promoting healthier, more active lifestyles (5). Adults living near parks exercise harder and more often (6) and some groups (women, in particular) have lower BMI (7). This manifests in a reduced risk of mortality even among people living in deprived neighborhoods (8). Active lifestyles and favorable weight status are important determinants of T2DM (2), though the relationship between green space and T2DM has been rarely examined (9).

In this study, we used a large data set of Australian adults in middle-to-older age to investigate association between T2DM and exposure to green space within the residential environment. In particular, we were interested in whether T2DM was less common among people living in greener environs and to what extent green space reduced the risk of T2DM among people living in more deprived neighborhoods.

RESEARCH DESIGN AND METHODS

The 45 and Up Study (10) contains health, behavioral, socioeconomic, and geographic information on 267,072 people aged 45 years and older living in New South Wales (NSW). Participants were randomly sampled from the Medicare Australia database (the provider of universal health insurance in Australia). Oversampling in remote and rural areas helped to ensure a geographic spread of participants from virtually all areas of NSW. A self-completed survey was administered between 2006 and 2009, with a response rate of approximately 18%. The University of New South Wales Human Research Ethics Committee approved the 45 and Up Study.

Participants were asked to report whether they had been diagnosed with diabetes by a doctor (yes or no). The survey did not differentiate between the various types of diabetes, though the majority of cases among middle-to-older aged adults are known to be T2DM (1).

Objective data on green space land use was extracted using a geographic information system (ArcGIS V.10) from the Australian Bureau of Statistics Meshblock 2006 classification (11). Meshblocks are very small geographic areas that are classified by the Australian Bureau of Statistics according to their majority land use. We used those Meshblocks that were classified as representing green space (e.g., parks). Meshblocks that were classified as agricultural land were not used, as these areas are not usually available for recreational and physical activities. In line with previous work (6,7,9), we calculated the percentage of green space land use available within a catchment area of 1-km radius around the residential location of each participant (proxied by the centroid of each Census Collection District of residence).

A range of explanatory variables were taken into account. These variables included demographic and cultural (age-group, sex, couple status, ancestry, country of birth, language spoken at home); health status (weight status, risk of psychological distress, smoking status, medically diagnosed hypertension); diet and active lifestyle (the number of weekly portions of red meat, processed meat, and cheese, the number of daily portions of fruit and vegetables, the number of 10-min sessions spent walking or in moderate-to-vigorous physical activity [MVPA], the number of hours spent sitting in a day); and socioeconomic circumstances (employment status, annual income, educational qualifications). Recognized ecological measures were used to differentiate between urban and remote, affluent and deprived neighborhoods. The Accessibility Remoteness Index of Australia (12) was used to measure geographic remoteness. Neighborhood affluence was measured using the Socio-Economic Index For Areas scale of advantage and disadvantage (13).

Descriptive statistics were used to assess the broad patterning of T2DM and all other explanatory variables across different levels of exposure to green space. Association between T2DM (as the binary outcome variable) and green space exposure was then explored using multilevel logit regression. A null (or "empty") model was fitted with participant identifiers at level 1 (n = 267,072) and Census Collection Districts at level 2 (i.e., the random intercept; n = 11,722). A significant variance of 0.107 (SE = 0.008) in the risk of reporting T2DM was reported between level 2 units. A significant ($P < 0.001$) curvilinear association between diabetes risk and linear, square, and cubic functions of the green space measure were detected. To simplify the reporting of this nonlinearity, we substituted the polynomial functions of green space for equal-interval categories of exposure defined as follows: *1*) 0–20, *2*) 21–40, *3*) 41–60, *4*) 61–80, and *5*) >80% green space. Odds ratios (ORs) with 95% CI were calculated by exponentiating the coefficients. These ORs were then adjusted sequentially for the other explanatory variables. Interaction terms were fitted between green space and neighborhood affluence to investigate for effect modification. Statistically significant associations were identified using the log-likelihood ratio test ($P < 0.05$). All analyses were conducted in 2013 using STATA 12 (StataCorp, TX).

RESULTS

Table 1 reports the descriptive statistics of the sample across different levels of green space exposure. The rate of T2DM was 9.1% among participants in neighborhoods with 0–20 and 21–40% green space land use. This rate dropped to approximately 8% for participants with over 40% green space within their residential neighborhoods. Greener

Table 1—Descriptive statistics of the sample, by level of green space exposure

	Green space					
	0–20%	21–40%	41–60%	61–80%	81%+	*P* value (trend)
N	182,557	50,822	18,519	8,439	6,735	
Diabetes (yes)	9.1	9.1	8.0***	7.9***	7.9***	<0.001
Demographics						
Age (years)						
45–54	28.1	27.3***	26.9***	28.1	27.9	<0.001
55–64	32.4	31.5***	32.4	34.2***	36.1***	<0.001
65–74	22.1	21.9	23.2***	23.1*	23.8***	<0.001
75+	17.4	19.3***	17.6	14.5***	12.2***	<0.001
Sex (female)	53.8	53.4	53.4	52.8	52.7	0.085
Couple status (in a couple)	74.2	74.1	77.0***	79.6***	79.7***	<0.001
Ancestry (Australian)	24.4	23.7***	25.0	24.9	24.8	0.001
Country of birth (Australia)	74.9	74.1***	75.6*	76.6***	77.7***	<0.001
Speak language other than English at home (yes)	10.1	9.4***	7.4***	6.0***	5.2***	<0.001
Health status						
Weight status						
Overweight	44.1	43.8	44.4	44.0	44.0	0.594
Obese	20.9	20.4*	19.2***	20.3	19.8*	<0.001
Psychological distress (high risk)	11.8	11.4**	10.2***	9.7***	10.1***	<0.001
Smoking status (current)	7.5	6.9***	6.3***	6.1***	7.3	<0.001
Hypertension (yes)	38.3	38.6	37.5*	38.4	36.7**	0.008
Diet and active lifestyle						
Diet (high fat)	24.9	23.4***	23.8***	23.5**	25.4	<0.001
Less than 5 daily portions of fruit and vegetables	39.4	39.0	38.4*	38.2*	37.8**	0.003
Highest quintile of walking	14.4	14.1	13.6**	14.6	17.4***	<0.001
Highest quintile of MVPA	24.5	23.8**	24.6	26.0***	30.5***	<0.001
Highest quintile of sitting time	22.7	24.2***	23.1	23.9**	19.3***	<0.001
Socioeconomic circumstances						
Economic status (unemployed)	2.2	2.0***	2	1.9*	1.9	<0.001
Annual income (<$20,000)	20.2	19.0***	18.5***	17.4***	18.8**	<0.001
Qualifications (no school certificate)	12.2	11.2***	10.0***	9.9***	9.7***	<0.001
Neighborhood circumstances						
Living in major cities	42.7	56.9***	45.3***	43.3	21.3***	<0.001
Living in the most affluent neighborhoods	18.6	23.8***	24.4***	24.8***	10.5***	<0.001

***$P < 0.001$. *$P < 0.05$ (from 0–20% green space). **$P < 0.01$.

neighborhoods tended to have middle-aged populations but fewer adults over 75 years old. People with access to more green space tended to be born in Australia, were more likely to speak English at home, were more likely to eat at least five daily portions of fruit and vegetables, and participated in more walking and MVPA. Higher levels of green space exposure were related to a lower prevalence of high-fat diets, lower rates of obesity and psychological distress, fewer people of Australian ancestry, fewer current smokers, lower rates of annual incomes below $20,000, and school leavers without educational qualifications. Access to a large amount of green space was rarer among participants living in major cities and in more deprived neighborhoods, except for neighborhoods where green space accounted for over 80% of the local land use. Sex and overweight status did not vary by green space exposure.

Table 2 illustrates the results of the multilevel logit regression models in abbreviated format. The risk of T2DM in model 1 was significantly lower in greener neighborhoods, controlling for demographic and cultural factors. The strongest effect size was found among participants residing in neighborhoods with 41–60% green space land use (OR 0.87; 95% CI 0.83–0.92). Weaker effects were observed for participants in greener environs and also those with access to 21–40% green space. The protective effect of green space on T2DM risk was consistent in model 2 after controlling for indicators of health status (weight status, psychological distress, and smoking status). Only for participants living in areas with over 80% green space land use was the association with T2DM rendered not statistically significant. The negative association between T2DM with higher levels of green space exposure persisted after adjusting for diet and active lifestyles (model 3), socioeconomic status, and neighborhood circumstances (model 4).

Interaction terms fitted between green space exposure and neighborhood affluence (extending model 4) were not statistically significant. This suggested that the protective influence of green space on T2DM risk was independent of the local socioeconomic circumstances in which people were living at the time of the study.

CONCLUSIONS

Strong evidence exists that T2DM can be prevented by multiple lifestyle interventions targeting weight loss and

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Table 2—Association between level of green space exposure and medically diagnosed T2DM status (multilevel logit regression)

	Green space				
Model	21–40%	41–60%	61–80%	81%+	*P* value (trend)
1	0.98 (0.95–1.02)	0.87 (0.83–0.92)***	0.90 (0.83–0.97)**	0.90 (0.82–0.99)*	<0.001
2	0.99 (0.95–1.02)	0.89 (0.84–0.95)***	0.90 (0.83–0.99)*	0.92 (0.84–1.02)	<0.001
3	0.98 (0.95–1.02)	0.89 (0.84–0.95)***	0.90 (0.82–0.98)*	0.94 (0.85–1.04)	<0.001
4	0.99 (0.96–1.03)	0.90 (0.85–0.96)***	0.91 (0.84–0.99)*	0.94 (0.85–1.03)	0.002

Data are OR (95% CI) unless otherwise indicated. Model 1: adjusted for age-group, sex, couple status, ancestry, country of birth, and language spoken at home. Model 2: as model 1, adjusted for weight status, risk of psychological distress, smoking status, and hypertension. Model 3: as model 2, adjusted for diet, walking, MVPA, and sitting time. Model 4: as model 3, adjusted for economic status, annual income, qualifications, neighborhood affluence, and geographic remoteness. ***$P < 0.001$. **$P < 0.01$. *$P < 0.05$.

an increase in physical activity (2). Sustainable lifestyle modification is more likely to be achieved if people's circumstances are supportive of those changes. Belief among policymakers is growing rapidly that parks and other forms of green space (e.g., woodlands) are a key part of neighborhoods that support healthy and active lifestyles (5). As green spaces are attractive settings for physical activity and recreational walking (6) and are also associated with lower weight status (7), it is plausible that similar association could be found for T2DM risk. Our study is among the first to explore this hypothesis, finding participants in greener surroundings had a lower risk of T2DM. This association was not specific only to people in wealthier areas, and it was not peculiar in more deprived neighborhoods. Promoting access to nature is an important preventive health tool for addressing the T2DM epidemic regardless of a person's socioeconomic circumstances. Investments in green-space planning policy and practice are, therefore, investments in health.

Only one study, based in the Netherlands, has previously examined the relationship between green space exposure and T2DM risk (9). A similar negative association was found. Both studies controlled for socioeconomic (income, employment, education) and demographic (e.g., couple status) factors that influence whether people can choose to live in greener neighborhoods. Our study provides even more robust findings than that in the Netherlands in that we were able to control for important variables such as physical activity, sedentary behavior, and weight status.

One limitation, however, is that it is well known that a nontrivial proportion of the population is thought to be living with undiagnosed T2DM. We acknowledge that the number of participants self-reporting with a medically diagnosed case of T2DM in our study is likely to be conservative. Though previous work has shown that the relative risk estimates from the 45 and Up Study are similar to those calculated from a "representative" population survey (14), a further limitation of our data was the 18% response rate and that participants self-selected into the study. Self-selection often skews participation in favor of more affluent populations, and sampling from the Medicare Australia database covers Australian citizens and migrants on permanent visas but omits some migrants on temporary visas who are not entitled to this scheme. Future studies aiming to replicate our findings with nationally representative data are warranted.

To some extent, the basis of our hypothesis was that green space promotes active lifestyles and healthier BMIs, which then have an influence on T2DM risk. Since association between green space and T2DM was independent of these lifestyle variables, this is an important finding, as it could point to a direct health benefit, though it is likely that other pathways that we have been unable to directly control for are also important, such as restoration, air pollution, and quality of sleep (15). Quality of green space may play a role in this observation, though our study was restricted to examining quantity only. It was also notable that 41–60% green space availability remained highly significant after controlling for all confounding variables, which raises the policy-relevant question of the optimum amount of green space for promoting healthy outcomes. Further exploration of this and other important questions will be possible as the next wave of the 45 and Up Study becomes available, pushing past the well-known limitations of cross-sectional study design with prospective research using longitudinal data analysis.

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the manuscript. All authors read and approved the final version of the manuscript. T.A.-B. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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