BMJ Open

The association between neighbourhood greenspace and type 2 diabetes in a large cross-sectional study

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To cite: Bodicoat DH, O'Donovan G, Dalton AM, *et al*. The association between neighbourhood greenspace and type 2 diabetes in a large cross-sectional study. *BMJ Open* 2014;**4**:e006076. doi:10.1136/bmjopen-2014-006076

▸ Prepublication history for this paper is available online. To view these files please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2014-006076).

Received 9 July 2014
Revised 3 October 2014
Accepted 27 October 2014

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ABSTRACT

Objective: To investigate the relationship between neighbourhood greenspace and type 2 diabetes.

Design: Cross-sectional.

Setting: 3 diabetes screening studies conducted in Leicestershire, UK in 2004–2011. The percentage of greenspace in the participant's home neighbourhood (3 km radius around home postcode) was obtained from a Land Cover Map. Demographic and biomedical variables were measured at screening.

Participants: 10 476 individuals (6200 from general population; 4276 from high-risk population) aged 20–75 years (mean 59 years); 47% female; 21% non-white ethnicity.

Main outcome measure: Screen-detected type 2 diabetes (WHO 2011 criteria).

Results: Increased neighbourhood greenspace was associated with significantly lower levels of screen-detected type 2 diabetes. The ORs (95% CI) for screen-detected type 2 diabetes were 0.97 (0.80 to 1.17), 0.78 (0.62 to 0.98) and 0.67 (0.49 to 0.93) for increasing quartiles of neighbourhood greenspace compared with the lowest quartile after adjusting for ethnicity, age, sex, area social deprivation score and urban/rural status (P_{trend}=0.01). This association remained on further adjustment for body mass index, physical activity, fasting glucose, 2 h glucose and cholesterol (OR (95% CI) for highest vs lowest quartile: 0.53 (0.35 to 0.82); P_{trend}=0.01).

Conclusions: Neighbourhood greenspace was inversely associated with screen-detected type 2 diabetes, highlighting a potential area for targeted screening as well as a possible public health area for diabetes prevention. However, none of the risk factors that we considered appeared to explain this association, and thus further research is required to elicit underlying mechanisms.

Trial registration number: This study uses data from three studies (NCT00318032, NCT00677937, NCT00941954).

Strengths and limitations of this study

- Evidence regarding the association between greenspace and type 2 diabetes is limited since only two cross-sectional studies have investigated this association, and while they showed an inverse association, both used self-reported measures of diabetes.
- A major strength of this study was that robust measures of type 2 diabetes, greenspace and potential confounders were used.
- Other strengths include the large sample size, robust detailed analysis and the multiethnic population.
- The limitations include the cross-sectional nature of the study, that only screen-detected diabetes was included rather than all prevalent cases, and it is not possible to determine from the available data which areas of greenspace were publicly accessible.
- We found that neighbourhood greenspace was inversely associated with screen-detected type 2 diabetes, with 11% prevalence of undiagnosed type 2 diabetes in the lowest quartile of greenspace compared with 6% prevalence in the highest quartile of greenspace.

INTRODUCTION

Prevalence of type 2 diabetes mellitus, a chronic long-term condition, is rapidly increasing, and it is estimated that there are 175 million cases undiagnosed worldwide.[1] This may be largely due to environmental/behavioural factors.[2 3] Individual-level interventions that encourage healthy lifestyles can lead to increased physical activity and improved diet, which in turn lower glucose levels to reduce type 2 diabetes risk or improve type 2 diabetes control.[4] However, public health solutions, such as changes to local environments, are also required to tackle the type 2 diabetes epidemic.[5] In public health, ecological models describe people's interactions with their physical and sociocultural surroundings.[6] The physical environment (built and natural), social environment and policy environment are regarded as important influences on behaviour that may be changed in order to increase physical activity[7] and reduce

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obesity,[8] which are major modifiable risk factors for type 2 diabetes.[9 10] Accordingly, urban designers and planners have been urged to provide greenspace, such as parks and natural areas, to facilitate physical activity, encourage other healthy behaviours and reduce type 2 diabetes risk.[5 11]

Only two studies have, however, investigated relationships between neighbourhood greenspace and type 2 diabetes.[12 13] Both used self-reported diabetes, and found that greenspace was inversely related to diabetes.[12 13] The knowledge gap highlighted by this limited evidence base is gaining even more importance with the increasing urbanisation worldwide. Additionally, the underlying factors explaining any relationship between greenspace and type 2 diabetes are unclear. For example, physical activity could explain the purported relationship between greenspace and morbidity,[14] but this has not been clearly shown in all studies.[12] This might be because, to the best of our knowledge, no studies have used objective measures of greenspace in conjunction with objective diagnoses of type 2 diabetes and measures of its risk factors. The use of objective measures in the present study is noteworthy because the measurement error associated with self-reported diabetes[15 16] and self-reported physical activity[17] may bias towards the null.

We therefore investigated whether neighbourhood greenspace was associated with type 2 diabetes in a large multiethnic population characterised using robust, objective measurements. The primary objective was to investigate the relationship between neighbourhood greenspace and screen-detected type 2 diabetes, and the secondary objective was to explore possible explanations underlying this relationship.

MATERIALS AND METHODS

Participants

Three type 2 diabetes screening studies were conducted in Leicestershire, UK, using identical standard operating procedures: ADDITION-Leicester (ClinicalTrials.gov registration number: NCT00318032), Let's Prevent Diabetes ('Let's Prevent'; NCT00677937), and Walking Away from Diabetes ('Walking Away'; NCT00941954). This work only included cross-sectional data from the screening stage of each study. All participants gave written informed consent.

Full study descriptions are available elsewhere.[18–20] Briefly, ADDITION-Leicester (2004–2009) was a population-based study which screened people for type 2 diabetes.[18] Individuals selected at random from participating general practices who met the eligibility criteria were invited. Eligibility criteria included age 40–75 years (white Europeans) or 25–75 years (other ethnicities), and no diabetes diagnosis, thus all type 2 diabetes cases are screen detected. Recruitment methods and inclusion criteria were similar in Let's Prevent (2009–2011)[19] and Walking Away (2010),[20] except that individuals in both Let's Prevent and Walking Away were at high risk of type 2 diabetes based on the Leicester Practice Risk Score,[21] and Walking Away had wider age inclusion criteria (18–74 years). Participants were excluded from the current analyses if their postcode was missing or invalid. If they took part in more than one of the studies then their most recent record was kept. In all three studies, participants attended a clinic visit where they provided a fasting sample, underwent an oral glucose tolerance test, had anthropometric measurement recorded, and completed questionnaires.

Outcome

Type 2 diabetes diagnosis was based on WHO 2011 criteria, using gold-standard oral glucose tolerance tests (fasting glucose ≥7.0 mmol/L or 2 h glucose ≥11.1 mmol/L) or glycated haemoglobin (HbA1c; ≥6.5%; 48 mmol/mol).[22]

Explanatory variables

The main explanatory variable was the percentage of greenspace in the participant's home neighbourhood, and this was categorised into quartiles for the analyses. ArcGIS 9.3, a geographic information system, was used.[23] To delineate neighbourhood boundaries, the postcode of each participant was geolocated using the UK Ordnance Survey Code-Point database (2004–2013),[24] which provides a set of coordinates depicting the average latitude and longitude of all mail delivery locations within each postcode, which contains 15 addresses on average. Neighbourhood was delineated based on distance around these coordinates. Neighbourhoods are typically defined as the area within 800 m (approximating to a 10 min walk) of a home location.[25] However, recent research from studies employing global positioning systems to track movement suggests that this may be overly conservative,[26] and that individuals typically travel greater distances to access resources and be physically active, therefore we used a straight-line distance of 3 km.[27] In sensitivity analyses, we also defined neighbourhood based on radii of 800 m and 5 km, and using road network buffers.

Estimates of greenspace were from the Centre for Ecology and Hydrology Land Cover Map of the UK (2007),[28] which is derived from satellite images and digital cartography, and records the dominant land use type, based on a 23 class typology, per 25 m by 25 m grid cell. Broadleaved and coniferous woodland, arable, improved grassland, seminatural grassland, mountain, heath, bog, and freshwater (including rural lakeland environments) were classed as greenspace. Each participant's exposure was computed by overlaying the mapped greenspace with the neighbourhood boundaries in the geographic information system software to calculate the percentage of each neighbourhood area that contained these land cover types.

Other explanatory variables were treated as confounders, including age, sex, urban/rural location[29] and area

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social deprivation score (The English Indices of Deprivation 2010 provides a relative measure of deprivation at small area level across England, and its measure of multiple deprivation was used in the present study).[30] Ethnicity was self-reported using Census categories and grouped as White European, South Asian and Other due to the small number of participants in some ethnic groups. Trained staff measured weight and height to the nearest 0.1 kg and 0.5 cm, respectively. Body mass index (BMI) was calculated as weight (kg)/height (m) squared. Cholesterol was measured in the fasting blood sample. Self-reported physical activity was obtained using the International Physical Activity Questionnaire (IPAQ). Published standards were used to calculate the number of metabolic equivalents (METS) per day for total activity.[31] Objective physical activity (average number of steps per day) was also available in Let's Prevent (sealed piezoelectric pedometer, NL-800, New Lifestyles, USA) and Walking Away (tri-axial accelerometer, GT3X, ActiGraph, USA). Participants wore the devices during waking hours for seven consecutive days on the right anterior axillary line of their trunks.

Statistical analysis

Participant characteristics were summarised by study and overall as mean (SD) for continuous variables and percentage for categorical variables. The mean (SD) percentage of neighbourhood greenspace was summarised by subgroup of participant demographics and compared using one-way analysis of variance. Generalised estimating equations with a binary outcome were used to investigate whether quartiles of neighbourhood greenspace were associated with type 2 diabetes, with a term for clustering by postcode. Quartiles were defined as ≤30%, 31–59%, 60–77% and ≥78% based on the data. Three models were fitted. Model 1 was adjusted for ethnicity, age, sex, social deprivation score and urban/rural status. Model 2 was adjusted for all variables in model 1 plus BMI and physical activity (total METS). Model 3 was adjusted for all variables in model 2 plus fasting glucose, 2 h glucose, and total cholesterol. Models 2 and 3 were added to allow us to consider the influence of groups of covariates. Model 2 allowed us to consider the influence of lifestyle factors associated with type 2 diabetes.[9 10] Model 3 allowed us to consider the influence of blood borne variables associated with type 2 diabetes.[32–35] Tests for trend were performed by fitting the greenspace quartiles as a continuous variable. Missing data were imputed in all models. Missing type 2 diabetes values were replaced as no type 2 diabetes, and missing ethnicity as white European, as these were overwhelmingly the model values for those variables. All other missing values were replaced using multiple imputation with type 2 diabetes, age, sex and ethnicity as the predictor variables. Model 3 was also fitted using an objective measure of physical activity (average number of steps per day), rather than a subjective one (total METS reported via IPAQ), but this measure was only available in Walking Away and Let's Prevent, so missing data for average number of steps per day were not imputed due to the large quantity of such data. Sensitivity analysis involved fitting the fully adjusted model (model 3) for different neighbourhood definitions. Analyses were performed in Stata V.13. p Values <0.05 were treated as statistically significant.

RESULTS

Participants

The three studies screened 11 032 people (6749 ADDITION-Leicester, 3450 Let's Prevent, 833 Walking Away), of whom 300 were excluded because their postcode was missing (all ADDITION-Leicester), and 12 because it was invalid (6 ADDITION-Leicester, 5 Let's Prevent, 1 Walking Away). There were 244 people who participated in multiple studies; therefore, these analyses included 10 476 participants, whose characteristics are in table 1. The mean age was 59 years, 47% were female, 21% were of non-white ethnicity, and 16% lived in a rural location. There were some differences between the studies, primarily because ADDITION-Leicester screened the general population, whereas the other two screened high-risk populations.

Amount of neighbourhood greenspace

Percentage of greenspace varied by neighbourhood definition, however, all measures were strongly correlated (table 2). The remainder of the manuscript pertains to the circular 3 km buffer unless otherwise stated.

Neighbourhoods comprised 57% (SD 26%) greenspace on average (table 3). The amount of neighbourhood greenspace was higher for participants who were older (p<0.001), male (p<0.001), of White European ethnicity (p<0.001), lived in rural locations (p<0.001), and had low area social deprivation (p<0.001).

Associations with type 2 diabetes

Increased neighbourhood greenspace was associated with significantly lower levels of screen-detected type 2 diabetes. In the lowest greenspace quartile, 281 (10.7%) of people had type 2 diabetes; the analogous figures were 236 (9%), 159 (6.1%) and 161 (6.1%) for the second, third and fourth quartile, respectively. ORs suggested that inverse relationship was significant (figure 1). The OR (95% CI) for screen-detected type 2 diabetes was 0.67 (0.49 to 0.93) in the highest compared with the lowest quartile after adjusting for ethnicity, age, sex, area social deprivation score and urban/rural status (P_{trend}=0.01). This pattern remained on further adjustment for BMI and physical activity (figure 1). After further adjustment for fasting glucose, 2 h glucose and cholesterol, the dose–response relationship weakened, but the inverse association between greenspace and type 2 diabetes remained (P_{trend}=0.01; figure 1).

The effect sizes were similar in analyses stratified by recruitment type (fully adjusted OR (95% CI) for highest vs lowest quartile: population-based 0.48 (0.23,

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Table 1 Participant characteristics by study and for the entire sample combined

Variable	Addition-Leicester	Let's prevent diabetes	Walking away from diabetes	All
Age, years	56.2 (10.8)	63.2 (8.2)	63.1 (8.2)	59.0 (10.4)
Area social deprivation score	19.7 (14.1)	17.3 (15.0)	20.2 (16.3)	19.0 (14.6)
Total METS	3376.2 (3579.6)	2293.5 (3038.0)	3380.0 (3949.8)	3007.3 (3475.3)
Average steps per day*	–	6544.1 (3100.0)	6610.3 (3210.9)	6557.6 (3122.7)
Body mass index, kg/m^2	28.0 (5.0)	32.4 (5.7)	32.5 (5.6)	29.8 (5.7)
Waist, cm	93.7 (13.2)	108.8 (12.9)	101.8 (12.4)	99.4 (14.8)
Fasting glucose, mmol/L	5.2 (0.9)	5.3 (0.8)	5.3 (0.8)	5.2 (0.9)
2 h glucose, mmol/L	6.0 (2.4)	6.6 (2.5)	6.5 (2.4)	6.3 (2.5)
HbA1c, %	5.7 (0.6)	5.9 (0.5)	5.9 (0.6)	5.8 (0.6)
Total cholesterol, mmol/L	5.5 (1.1)	5.1 (1.0)	5.1 (1.1)	5.4 (1.1)
Female	53.1	39.1	36.5	47.2
South Asian	23.5	10.7	8.1	18.0
Other ethnicity	2.6	2.6	3.5	2.6
Rural location	11.7	24.5	17.5	16.3
Type 2 diabetes mellitus	6.2	10.9	9.4	8.0
Total	6200	3444	832	10 476

Data are mean (SD) or percentage.
Missing data: 0 age and sex, 21 Social deprivation score, 1481 total METS, 208 body mass index, 33 fasting glucose, 81 2 h glucose, 149 HbA1c, 108 total cholesterol, 190 ethnicity, 21 rural location, 13 type 2 diabetes.
*Measured using pedometers in Let's Prevent Diabetes and using accelerometers in Walking Away from Diabetes (735 missing values).
METS, metabolic equivalents; HbA1c, glycated haemoglobin.

1.01); high-risk studies 0.47 (0.27, 0.81); data not shown). When objectively-measured physical activity was included in model 3, rather than subjectively-measured physical activity, the inverse association between greenspace and type 2 diabetes remained (fully adjusted OR (95% CI) for highest vs lowest quartile: 0.45 (0.24, 0.82); $P_{trend}<0.01$; N=3541; data not shown).

Sensitivity analysis

Table 4 shows the fully adjusted analyses (model 3) for different neighbourhood definitions. When a distance of 800 m was used to define the neighbourhood, there was not a significant association between type 2 diabetes and greenspace, regardless of whether a circular or road network buffer was used. Conversely, when a distance of 3 or 5 km was used, there was a significant inverse association between greenspace and type 2 diabetes regardless of the type of buffer used.

DISCUSSION

In this large cross-sectional study, older age, male sex, White European ethnicity, higher socioeconomic status and rural locations were associated with having more neighbourhood greenspace. After adjustment for these and other factors, increasing amounts of greenspace were associated with lower prevalence of screen-detected type 2 diabetes. Sensitivity analyses suggested that this inverse association was somewhat dependent on neighbourhood definition.

Our study has major strengths. Notably, the objective measures of greenspace, type 2 diabetes and potential confounders, the large sample size, robust detailed analysis and the multiethnic population, mean that we are able to add novel, robust information to an emerging area of type 2 diabetes prevention. Furthermore, the diverse ethnic, socioeconomic and geographical distribution of this population means that our results are

Table 2 Average percentage of greenspace and correlations between percentage of greenspace according to neighbourhood definition

	Mean (SD) % of greenspace	Correlations					
		Circular buffer			Road network buffer		
		800 m	3 km	5 km	800 m	3 km	5 km
Circular buffer							
800 m	38 (27)	1					
3 km	57 (26)	0.81	1				
5 km	65 (22)	0.74	0.97	1			
Road network buffer							
800 m	33 (28)	0.94	0.72	0.65	1		
3 km	50 (27)	0.85	0.97	0.92	0.77	1	
5 km	58 (24)	0.77	0.98	0.98	0.69	0.96	1

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Table 3 The percentage of neighbourhood greenspace by participant characteristics

Variable	Category	N	Mean (SD) percentage of greenspace	p Value
Age, years	<55	3208	51 (26)	
	55–64	3548	58 (25)	
	≥65	3720	60 (25)	<0.001
Sex	Male	5534	58 (26)	
	Female	4942	55 (25)	<0.001
Ethnicity	White European	8167	62 (24)	
	South Asian	1847	35 (17)	
	Other	272	33 (20)	<0.001
Urban/rural location	Urban	8749	50 (22)	
	Rural	1706	91 (06)	<0.001
Area social deprivation score	Low	5872	68 (21)	
	High	4583	41 (23)	<0.001
Total		10 476	57 (26)	

p Values test for a difference in the percentage of greenspace across the categories and were estimated using one-way analysis of variance.

generalisable to other populations. This study also has limitations. The most important is that the cross-sectional nature of the study means that we are unable to infer causality from our findings. Other limitations are likely to have weakened the association between greenspace and type 2 diabetes, and so it may be stronger than observed. These limitations are that only screen-detected diabetes was included rather than all prevalent cases, and it is not possible to determine from the available data which areas of greenspace were publicly accessible. We only had information on area deprivation and, while individual and area deprivation are known to be strongly associated, not all residents of deprived areas will be deprived themselves.

There is some evidence that better quality greenspaces are more health promoting, such as those free from vandalism and with better accessibility.[36] Indeed, some research has suggested that objective measures of greenspace availability may differ from how such spaces are perceived and actually used.[37 38] In the absence of such

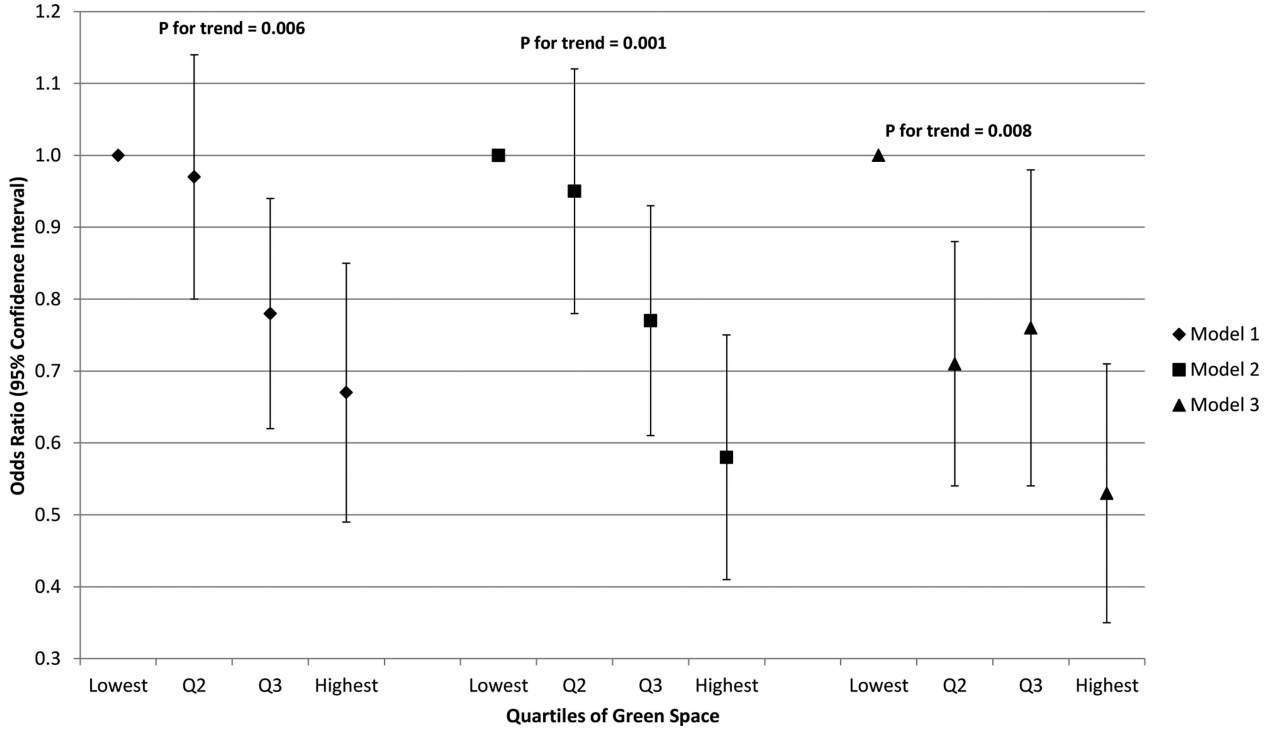

Figure 1 ORs of screen-detected type 2 diabetes mellitus in relation to quartiles of neighbourhood greenspace in 10 476 participants. Missing data were imputed so analyses included all participants. Lowest quartile is referent category. Q2, Quartile 2; Q3, Quartile 3. Model 1 was adjusted for ethnicity, age, sex, area social deprivation score, and urban/rural status. Model 2 was adjusted for all variables in model 1 plus body mass index and physical activity (total metabolic equivalents (METS)). Model 3 was adjusted for all variables in model 2 plus fasting glucose, 2 h glucose, and total cholesterol.

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Table 4 Sensitivity analyses considering different definitions of neighbourhood for the risk of type 2 diabetes mellitus in relation to quartiles of neighbourhood green space in 10 476 participants*

Greenspace definition	Adjusted† OR (95% CI) of outcome			p For trend
	Quartile 2	Quartile 3	Highest quartile	
Circular 800 m	0.96 (0.73 to 1.27)	0.98 (0.72 to 1.32)	1.00 (0.68 to 1.47)	0.990
Circular 3 km	0.71 (0.54 to 0.93)	0.76 (0.54 to 1.05)	0.53 (0.35 to 0.82)	0.008
Circular 5 km	0.65 (0.50 to 0.85)	0.79 (0.56 to 1.09)	0.65 (0.44 to 0.95)	0.041
Road network 800 m	1.07 (0.82 to 1.40)	0.92 (0.69 to 1.24)	1.03 (0.73 to 1.45)	0.888
Road network 3 km	0.71 (0.55 to 0.93)	0.67 (0.49 to 0.93)	0.48 (0.30 to 0.77)	0.001
Road network 5 km	0.67 (0.51 to 0.88)	0.75 (0.54 to 1.05)	0.58 (0.39 to 0.86)	0.013

Lowest quartile is referent category.
*Missing data were imputed so analyses included all participants.
†ORs were adjusted for ethnicity, age, sex, social deprivation score, urban/rural status, body mass index, physical activity (total metabolic equivalents (METS)), fasting glucose, 2 h glucose, and total cholesterol.
Q2, Quartile 2; Q3, Quartile 3.

information, we used a measure of neighbourhood greenness based on detailed land cover information, using circular buffers to indicate the maximum potential accessible greenspace. The use of such buffers is consistent with the work of others.[39] The buffer size we used (3 km) is inevitably somewhat arbitrary, but it was based on evidence of mobility patterns from the literature and we tested the sensitivity of our findings to this definition by examining larger and smaller buffers. Road network buffers have been used in some studies, but we deemed them inappropriate in the present study because greenspaces are not necessarily accessed by road. While other measures of greenspace have been used in other studies, such as distance to nearest greenspace or number and size of greenspaces around a home location,[11] these are based on a range of assumptions around greenspace use. In the absence of clear, causal mechanisms linking greenspace use with diabetes risk we did not test them. A clear limitation of our work was that we had no information about actual use of greenspaces among study participants. Studies utilising wearable tracking devices such as global positioning systems will help to reveal patterns of use, and thus provide more robust evidence to inform understanding of potential causal mechanisms.

Our finding that neighbourhood greenspace might be associated with lower screen-detected type 2 diabetes prevalence can be interpreted in two ways due to the cross-sectional nature of our study. First, it could suggest that areas with a low amount of greenspace would benefit from targeted screening programmes since these areas tend to have a higher number of undiagnosed type 2 diabetes cases. This could have important implications in terms of resource allocation, and might suggest that a general population screening programme is the best suited to urban areas with low greenspace availability, whereas in areas with more greenspace then only those at high-risk of type 2 diabetes would need to be screened. It also suggests that areas with a low density of greenspace might benefit from community interventions, such as mass media campaigns, to raise awareness of type 2 diabetes and its prevention.

Second, it could suggest that greenspace might be protective for type 2 diabetes if the association between undiagnosed type 2 diabetes and greenspace is the same as that between overall type 2 diabetes and greenspace, which seems likely to be the case particularly after adjustment for socioeconomic status, ethnicity and other demographic factors that are likely to lead to earlier diagnosis. The idea that greenspace might be protective for type 2 diabetes supports the findings of two other large cross-sectional studies, both of which used self-reported measures of type 2 diabetes,[12 13] as well as emerging evidence that more walkable neighbourhoods are associated with fewer diabetes cases.[40] Maas *et al*[13] used similar methods to ours to quantify greenspace in a Dutch population, and found that greenspace was inversely associated with diabetes in a 1 km, but not a 3 km, radius. Conversely, our results tended towards a stronger association when a larger radius was used. Differences depending on the neighbourhood definition used may occur for a number of reasons. For example, people living on the edge of urban developments may be linked with a small percentage of greenspace based on a road network buffer, and with a much larger percentage based on a circular buffer. Therefore, some neighbourhood definitions may better capture the amount of greenspace that people access than others. Astell-Burt *et al*[12] also recently reported that greater access to greenspace was associated with lower diabetes risk in Australian adults aged 45 years and older. Our work extends the limited evidence in this area by demonstrating that the association between greenspace and screen-detected type 2 diabetes appears also to be present in multiethnic populations and when robust type 2 diabetes diagnoses are used. We estimated that people living in neighbourhoods with the highest quartiles of greenspace had a 47% lower OR of type 2 diabetes compared with those in the lowest quartile. These quartiles relate to ≥78% and ≤30% neighbourhood greenspace, respectively, suggesting that those with the lowest prevalence of type 2 diabetes have access to approximately three times as much greenspace as those

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with the highest prevalence. It is also notable that those with the lowest neighbourhood greenspace had demographic patterns congruent with those of people at highest risk of type 2 diabetes, for example those of south Asian ethnicity, suggesting that public health guidance to increase greenspace access to prevent or delay type 2 diabetes would potentially be of greatest benefit to those at highest risk if it were to be implemented.[5 11]

Intuitively, the most likely reason that greenspace might be associated with type 2 diabetes prevalence seems to be that increased greenspace might encourage healthy behaviours, particularly physical activity, which is known to decrease type 2 diabetes risk.[41] However, we found little evidence to support this; adjusting for subjectively and objectively measured physical activity did not attenuate the association between greenspace and type 2 diabetes. This supports another observational study in England, which found that greenspace was not significantly related to the types of physical activity normally associated with greenspace.[42] Possible explanations of this are that 7 days of measurement may not reflect seasonal variation in physical activity and might bias towards the null any relationship between physical activity and greenspace,[43 44] and that we were only able to measure participation in physical activity without reference to where it occurs, such as in greenspace, the gym or at home. Astell-Burt *et al*[12] also found that physical activity did not appear to explain the inverse relationship between greenspace and diabetes.[12] Indeed, the association between greenspace and type 2 diabetes was not explained by any of the type 2 diabetes risk factors that we accounted for in the analyses. This could mean that they are not causally associated, or that these associations are due to confounding with an unmeasured factor. Similarly, other studies have found that the potential mediators that they examined did not explain the association between health and greenspace.[12] They therefore concluded that other unmeasured pathways might explain the association, such as air pollution,[12] quality of sleep, or psychosocial factors,[45] which seems highly plausible.

In conclusion, these data support the hypothesis that access to greenspace is inversely associated with screen-detected type 2 diabetes, thus highlighting a potential area to be considered for targeted screening programmes and type 2 diabetes prevention. While these data are in keeping with calls for urban designers and planners to provide more greenspace, more research is required to explain the inverse association between greenspace and type 2 diabetes.

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Acknowledgements The research was supported by The National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care—East Midlands (NIHR CLAHRC—EM), the Leicester Clinical Trials Unit and the NIHR Leicester-Loughborough Diet, Lifestyle and Physical Activity Biomedical Research Unit which is a partnership between University Hospitals of Leicester NHS Trust, Loughborough University and the University of Leicester. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health. The work of AD and APJ was supported by the Centre for Diet and Activity Research (CEDAR), a UKCRC Public Health Research: Centre of Excellence. Funding from the British Heart Foundation, Economic and Social Research Council, Medical Research Council, the National Institute for Health Research, and the Wellcome Trust, under the auspices of the UK Clinical Research Collaboration, is gratefully acknowledged (RES-590–28-0002). The researchers are independent from the funders.

Contributors KK, MJD, LJG, TY and SH designed and conducted the Let's Prevent Diabetes study. KK, MJD, DRW, and LJG designed and conducted the ADDITION-Leicester study. KK, MJD, TY, CE and LJG designed and conducted the Walking Away from Diabetes study. DHB, GOD, AMD and APJ conceived and designed the current analyses. DHB conducted and is responsible for the data analysis. DHB wrote the first draft of the manuscript with GOD. All authors contributed to interpreting the data, revising the manuscript, and approved the final version. DHB is the guarantor for the study. DHB affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted, and that any discrepancies from the study as planned have been explained. All authors had full access to all the data in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

Funding There was no funding sought specifically for the analysis presented here. The ADDITION-Leicester was funded for support and treatment costs by NHS Department of Health Support for Science and project grants. Let's Prevent Diabetes was funded by a National Institute for Health Research Programme Grant (RP-PG-0606-1272). Walking Away from Diabetes was supported by funding from the National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care for Leicestershire, Northamptonshire and Rutland. The funders of these studies had no role in the collection, analysis or interpretation of the data, in the writing of the report, or in the decision to submit the article for publication.

Competing interests None.

Ethics approval Ethical approval was from the University Hospitals of Leicester and Leicestershire Primary Care Research Alliance (ADDITION-Leicester) or the Nottingham (Walking Away/Let's Prevent) Research Ethics Committees.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing sharing statement No additional data are available.

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