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Neighbourhood greenspace and physical activity and sedentary behaviour among older adults with a recent diagnosis of type 2 diabetes: A Prospective analysis

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Full title: Neighbourhood greenspace and physical activity and sedentary behaviour among older adults with a recent diagnosis of type 2 diabetes: A Prospective analysis

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Abstract

Objectives:

Regular physical activity can reduce the risk of complications and mortality among people with type 2 diabetes. Greenspace is one of the important factors that can promote an active lifestyle. The aim of this study was to investigate the association between access to greenspace and changes in physical activity and sedentary behaviour among people with newly diagnosed T2D.

Design: Prospective cohort.

Setting: New South Wales, Australia

Methods:

We used self-reported information from the New South Wales 45 and Up Study (baseline) and a follow-up study. Information on sitting, walking and moderate to vigorous physical activity was used as outcomes. The proportion of greenspace within 500m, 1km and 2km road network buffers around participant's residential address was generated as a proxy measure for access to greenspace. The association between the access to greenspace and the outcomes were explored among the newly diagnosed T2D group and those without T2D.

Results:

Of the 18,094 participants, 1.4% reported type 2 diabetes in the follow-up survey but not in the baseline survey (New type 2 diabetes) whereas 98.6% participants did not report type 2 diabetes at both baseline and follow-up. Among New type 2 diabetes, although no significant changes were found in the amount of walking with the percentage of greenspace, increasing trends were apparent. There was a significant association between the percentage of greenspace within 2km buffer and changes in

amount of MVPA. Among No type 2 diabetes, the changes in amount of MVPA and walking remained fairly stable with increasing percentage of greenspace. For changes in sitting time, there were no significant associations with percentage of greenspace regardless of buffer size.

Conclusions:

This study indicates that neighbourhood greenspace is related to active lifestyles only to a very limited extent among people with newly diagnosed type 2 diabetes.

Strengths and Limitations of this study

- This is the first study to explore environmental influences on the behaviours of people who transition into living with type 2 diabetes.
- Other strength of this study include a prospective design and a large population-based cohort study.
- Change in duration of physical activity and sitting were calculated from self-reported survey, at two time points.

Introduction

Type 2 diabetes is a lifelong condition and is associated with increased risk for cardiovascular, renal disease[1] and mortality.[2,3] A healthy lifestyle that includes, for example regular physical activity, can help maintain healthy blood glucose levels and reduce the risk of complications of type 2 diabetes.[4-7] However, only about half of Australians with diabetes achieve adequate control of their blood glucose level.[3]

It is recommended that adults, including those diagnosed with type 2 diabetes engage in at least 30 minutes of physical activity every day.[8] In a population-based study in Australia, participants with incident type 2 diabetes reported lack of changes in their walking and moderate to vigorous physical activity (MVPA) after their diagnosis. Studies reported that 60% of people aged 35-64 years with diabetes (types 1 and 2) were not achieving the recommended level of physical activity,[9] one third of adults with type 2 diabetes were completely inactive[10] and only a third exercised on regular basis.[10] Physical activity behaviour is determined by a range of biological, psychosocial and environmental factors.[11] Built environment attributes are frequently found to be associated with physical activity,[12] and activity-unfriendly environments may be associated with higher type 2 diabetes incidence.[13] For example, a study reported that one of the barriers among inactive patients with diabetes (both type 1 and 2) was lack of local facilities.[14]

One environmental attribute that plays an important role in physical activity is greenspace.[15-17] Greenspace is defined as any vegetated land adjoining an urban area which includes bushland, nature reserves, national parks, outdoor sports fields, school playgrounds and rural or semi-rural areas immediately adjoining an urban area.[18] Several studies have found that people who have better access to parks and green spaces are more likely to report that they engage in physical activity.[19 20] The potential mechanism for these associations may be that greenspace prompts, facilitates, and reinforces location-specific physical activity, [21] while simultaneously discouraging sedentary lifestyles . Thus, greener surroundings may be a motivating factor among people with newly diagnosed diabetes to engage in more physical activity. Given that diagnosis of type 2 diabetes may serve as a window opportunity for behavioural modification,[22 23] we hypothesise that the association between neighbourhood greens pace and physical activity among people with newly diagnosed type 2 diabetes may be greater than those never diagnosed with type 2 diabetes.

Using data from a large cohort study in New South Wales (NSW), Australia, we aimed to 1) investigate the associations between the access to neighbourhood greenspace and changes in physical activity and sitting time in this large population-based sample; and 2) examine whether the associations differed by type 2 diabetes diagnosis status.

Materials and Method

Study population

The study area was the Sydney Statistical Division which has a population of approximately 4.12 million people and covers an area of 12,428 square kilometres. It is the largest urban agglomeration in Australia, with a wide range of environmental features and diverse sociodemographic characteristics.

Information about physical activity and relevant covariates at the individual level was obtained from the baseline 45 and Up Study and the Social, Economic and Environmental Factors (SEEF) follow-up Study. The 45 and Up Study is a population-based cohort survey of NSW residents aged 45 years and older. Recruitment was undertaken between 2006 and 2009. Potential participants were randomly selected from the Medicare Australia database (Australia's universal public health insurance system). Participants joined the study by completing a mailed self-administered questionnaire and providing consent for long-term follow-up, including linkage to various personal health records. The full study cohort consists of 267,153 people aged 45 years or older at the time of recruitment. The response rate was 18% and participants comprised 11% of the NSW population aged 45 years and over.[24]

In 2010, the SEEF Study questionnaire was distributed to the first 100,000 participants of the 45 and Up Study, of whom 60,404 returned the completed questionnaire. The average follow-up period was 3.3 ± 0.9 years (median=2.8 years, range=1.7-5.1 years, inter-quartile range=2.6 to 4.6 years). Questionnaires for both the 45 and Up and the SEEF Study are available from the Sax Institute website[25]. Of the 60,404 participants, 24,220 resided in the study area at the time of the baseline 45 and Up Study.

The baseline 45 and Up and the SEEF Study were approved by the University of New South Wales Human Research Ethics Committee and the University of Sydney Human Research Ethics Committee respectively.

Measures

Exposure: access to greenspace

We used the percentage of greenspace within 500m, 1km and 2km polygon-based road network (PBRN) buffers around participants' residences (available for the baseline survey only) as proxies for geographic access to greenspace. These buffer sizes were chosen as they are considered as walkable distance.[26]

Greenspace data was obtained from StreetPro (PitneyBowers Inc., USA). In this dataset, greenspace includes national parks, nature reserves, historic sites, state forests, State recreation areas, wildlife refuges, conservation parks, protected areas, wildlife reserves, urban recreation parks and other urban greenspaces. The PBRN buffers were created using the StreetPro Navigation (PitneyBowers Inc., USA) road network file and ArcGIS network analyst to calculate the endpoints of all possible routes up to the specified distance (500m, 1km and 2km) along the road network for each participant's residence. The endpoints were then connected to form irregular polygons. Percentage of greenspace within PBRN buffers were categorised into 0-5%, >5-10%, >10-15%, >15-20% and >20%. We combined >15-20% and >20% for greenspace within 500m buffers due to the small sample sizes.

Outcomes: sitting and physical activity

Information on sitting (hours per week), walking (minutes per week) and MVPA (minutes per week) was collected in both surveys. Duration of sitting was adapted from the International Physical Activity Questionnaire which has acceptable reliability[27] and validity.[27] Physical activity was assessed using the Active Australia Survey[28] which also has acceptable reliability[29] and validity.[30] In this instrument, walking is defined as walking for recreation or exercise or to get to or from places. Vigorous physical activity refers to any activity that causes a participant to breathe harder or puff and pant. Moderate physical activity refers to less intense activities such as gentle swimming, social tennis, vigorous gardening or work around the house. Total weighted minutes of MVPA per week is calculated by the sum of minutes of walking, moderate physical activity and twice the minutes of vigorous physical activity.[29] Reported time spent on walking and MVPA greater than 14 hours per day was considered as an impossible value and recoded to 14 hours. [31] We conceptualised walking and total MVPA as two separate outcomes because walking is expected to be more specifically related to neighbourhood greenspace while total MVPA is commonly used as a measure of overall levels of health-enhancing physical activity.

Moderator: type 2 diabetes diagnosis

New cases of type 2 diabetes were defined as those participants who did not report T2D at the baseline survey but reported type 2 diabetes at the follow-up survey (New type 2 diabetes). The comparator group was participants who did not report type 2 diabetes at both baseline and follow-up surveys (No type 2 diabetes). The questions asked to determine a diagnosis of type 2 diabetes at the baseline survey were "Has a doctor ever told you that you have diabetes" and "Have you taken Diabex, Diaformin, Metformin for most of the last 4 weeks".

Participants who reported that they had been told by a doctor that they had diabetes were then also asked about their age at diagnosis. For participants with newly diagnosed type 2 diabetes, the time lapse since diagnosis to completion of the SEEF Study questionnaire was also calculated (age at time of completion of SEEF Study questionnaire minus age at type 2 diabetes diagnosis). Self-reported diagnosis of type 2 diabetes in the 45 and Up Study has high sensitivity (83.7%) and specificity (97.7%) compared to administrative hospitalisation data [32].

Covariates

Participant reported socio-demographic characteristics, including age, gender, country of birth (English speaking countries, Europe, Middle-East, Asia, Other) and body mass index (BMI) were included as covariates in the regression models. We also included physical functioning (measured using the Medical Outcomes Study (MOS) Physical Functioning Scale; it ranges from 0 to 100 and was categorised into no limitation (100), minor limitation (95-99), moderate limitation (85-94), or severe limitation (0-84)) [33], psychological distress (Kessler-10 (K10); a K10 score of ≥22 reflects high or very high psychological distress[34]) and an area-level deprivation score as covariates in the model. Area-level deprivation was measured by 2006 Index of Relative Socio-Economic Disadvantage (IRSED) quintiles at the postcode level. The IRSED was created by the Australian Bureau of Statistics to compare social and economic disadvantage across geographical areas in Australia. The index is derived from the 2006 Census variables such as income, educational attainment, unemployment, and people working in unskilled occupations[35].

Statistical analysis

The Kruskal-Wallis test was used to compare continuous baseline lifestyle variables between type 2 diabetes groups. Separate multivariate linear regression models were used to examine the association between greenspace access and change in outcome variables (in MVPA, walking, and sitting). Only statistically significant variables from univariate regression analyses were included in the final model to account for any potential confounding. These variables were age, gender, educational attainment, level of physical functional limitation, IRSED, BMI, duration of type 2 diabetes diagnosis (New type 2 diabetes group only), follow-up time and the baseline value of each outcome in specific models. To examine whether the association between greenspace and change in outcome variables modified by the presence of type 2 diabetes, a one-way interaction between the status of type 2 diabetes (New type 2 diabetes and No type 2 diabetes) and percentage of greenspace was explored. We then developed regression models, stratified by the presence of type 2 diabetes. Actual change values (i.e. marginal means) and associated 95% confidence intervals (CIs) were reported. Statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

Considering that neighbourhood safety is a premise to walking despite access to greenspace, for the walking outcome, we performed a sensitivity analysis by neighbourhood safety. Perception of neighbourhood safety was only asked at the follow-up survey using the following questions: “Does your area have a reputation for being a safe place?” and “The crime rate in my neighbourhood makes it unsafe to go on walks during the day”. For the second question, the responses were classified as strongly agree/agree and disagree/strongly disagree. Due to the small number of responses for the sensitivity analysis, percentage of greenspace of >10-15%, >15-20% and >20% were combined into >10%.

Results

Of the 24,220 participants living in Sydney Statistical Division, 628 were excluded due to inconsistent reporting between baseline and follow-up surveys, 1,498 were excluded due to reporting type 2 diabetes at both baseline and follow-up and an additional 4,000 were excluded because of severe level of physical function, making physical activity challenging or infeasible, leaving 18,094 participants in the analytical sample (Figure 1).

Figure 1: Flow chart of sample selection

Of the 18,094 participants, 260 (1.4%) reported type 2 diabetes in the follow-up survey but not in the baseline survey (New type 2 diabetes) whereas 17,834 (98.6%) participants did not report type 2 diabetes at both baseline and follow-up (No type 2 diabetes). The average duration of time since diagnosis was 1.8 $\pm$ 1.1 years (median=1.7 years). More than half of all the participants were female (52.0%) and the average age of participants was 59.5 $\pm$ 9.6 years. The majority of participants were born in an English speaking country (85.2%) and about one-quarter had not completed high school education (Table 1).

Table 1 shows changes in outcome variables at follow-up by baseline sociodemographic characteristics and access to greenspace. There were significant associations of age group, IRSED, physical functional limitation, BMI, with change in the amount of walking and MVPA. Significant associations were also found between gender and change in the amount of walking and sitting. Educational attainment was significantly associated with a change in sitting time. There were no significant associations between greenspace and changes in MVPA, walking and sitting.

Table 1: Changes in outcome variables at follow-up by baseline characteristics

		Change in MVPA[1] (hours/week)			Change in walking[2] (hours/week)			Change in sitting[3] (hours/week)		
	n	Mean	95% CI	p-value	Mean	95% CI	p-value	Mean	95% CI	p-value
Gender				0.072			0.018			0.013
Male	8,677	0.20	0.04 to 0.37		0.14	0.07 to 0.21		-0.47	-0.53 to -0.40	
Female	9,417	0.42	0.25 to 0.59		0.27	0.19 to 0.34		-0.59	-0.65 to -0.52	
Age (years)				<0.0001			<0.0001			<0.0001
45-55	6,581	0.19	0.01 to 0.38		0.07	-0.01 to 0.15		-0.17	-0.24 to -0.10	
>55-65	5,960	0.76	0.56 to 0.96		0.38	0.30 to 0.47		-0.72	-0.80 to -0.64	
>65	5,553	-0.12	-0.36 to 0.12		0.17	0.06 to 0.27		-0.86	-0.95 to -0.77	
Country of birth (missing=146)				0.082			0.164			0.27
English speaking countries	15,282	0.37	0.24 to 0.49		0.22	0.16 to 0.28		-0.51	-0.56 to -0.47	
Europe	1,213	0.12	-0.37 to 0.61		0.21	-0.01 to 0.42		-0.66	-0.85 to -0.48	
Middle East	192	-0.18	-1.43 to 1.07		-0.30	-0.85 to 0.24		-0.87	-1.34 to -0.39	
Asia	825	-0.42	-0.97 to 0.14		0.01	-0.24 to 0.25		-0.57	-0.78 to -0.36	
Other	438	0.22	-0.54 to 0.97		0.18	-0.15 to 0.51		-0.41	-0.70 to -0.11	
Highest level of education completed (missing=206)				0.496			0.158			<0.0001
University/TAFE[5]	10,491	0.27	0.12 to 0.42		0.16	0.09 to 0.22		-0.41	-0.46 to -0.35	
High school	3,306	0.46	0.18 to 0.74		0.26	0.14 to 0.39		-0.69	-0.80 to -0.59	
Did not complete high school	4,091	0.32	0.05 to 0.59		0.26	0.14 to 0.38		-0.76	-0.86 to -0.65	
IRSED				0.002			0.007			0.123
Least disadvantaged group	3,086	0.39	0.22 to 0.55		0.23	0.16 to 0.30		-0.50	-0.57 to -0.44	
2nd disadvantaged group	3,735	-0.06	-0.45 to 0.33		0.01	-0.17 to 0.18		-0.69	-0.84 to -0.54	
3rd disadvantaged group	3,850	-0.31	-0.69 to 0.07		0.03	-0.14 to 0.20		-0.55	-0.69 to -0.40	
4th disadvantaged group	3,691	0.51	0.28 to 0.74		0.30	0.20 to 0.41		-0.49	-0.57 to -0.40	
Most disadvantaged group	3,732	0.37	-0.16 to 0.89		0.10	-0.13 to 0.33		-0.64	-0.84 to -0.44	
Physical functional limitation (missing=3,123)				<0.0001			<0.001			0.301
Moderate	3,546	-0.48	-0.73 to -0.24		0.01	-0.09 to 0.12		-0.58	-0.68 to -0.49	
Minor	3,768	0.10	-0.13 to 0.33		0.21	0.11 to 0.32		-0.53	-0.62 to -0.44	
None	7,405	0.80	0.63 to 0.96		0.29	0.21 to 0.36		-0.50	-0.56 to -0.43	
Psychological distress (missing=355)				0.595			0.716			0.415
No	16,900	0.32	0.20 to 0.44		0.20	0.15 to 0.25		-0.52	-0.57 to -0.47	
Yes	812	0.16	-0.43 to 0.74		0.25	-0.01 to 0.51		-0.62	-0.85 to -0.39	
Body Mass Index (missing=857)				<0.0001			<0.0001			<0.0001

Under weight	244	0.30	-0.74 to 1.34		0.20	-0.26 to 0.66		-0.54	-0.94 to -0.14	
Acceptable weight	7,541	0.69	0.51 to 0.86		0.33	0.26 to 0.41		-0.63	-0.69 to -0.56	
Overweight	6,852	0.25	0.07 to 0.44		0.21	0.13 to 0.29		-0.51	-0.58 to -0.44	
Obese	2,547	-0.83	-1.15 to -0.50		0.28	0.13 to 0.42		-0.22	-0.34 to -0.09	
Greenspace within 500m				0.476			0.354			0.715
0-5%	13,762	0.34	0.21 to 0.48		0.19	0.13 to 0.25		-0.51	-0.56 to -0.46	
>5-10%	2,657	0.16	-0.14 to 0.47		0.25	0.12 to 0.39		-0.55	-0.67 to -0.43	
>10-15%	1,341	0.19	-0.24 to 0.63		0.23	0.03 to 0.42		-0.61	-0.78 to -0.44	
>15%	334	0.61	-0.26 to 1.49		0.28	-0.11 to 0.66		-0.50	-0.83 to -0.17	
Greenspace within 1km				0.224			0.128			0.951
0-5%	10,948	0.37	0.22 to 0.52		0.20	0.14 to 0.27		-0.52	-0.58 to -0.46	
>5-10%	4,843	0.12	-0.11 to 0.35		0.15	0.05 to 0.25		-0.52	-0.61 to -0.43	
>10-15%	1,497	0.29	-0.13 to 0.70		0.31	0.13 to 0.49		-0.59	-0.75 to -0.43	
>15-20%	451	0.52	-0.22 to 1.26		0.08	-0.25 to 0.40		-0.52	-0.81 to -0.23	
>20%	355	0.94	0.10 to 1.79		0.59	0.22 to 0.96		-0.47	-0.79 to -0.15	
Greenspace within 2km				0.477			0.682			0.221
0-5%	7,789	0.33	0.15 to 0.51		0.16	0.08 to 0.24		-0.55	-0.62 to -0.48	
>5-10%	6,980	0.21	0.02 to 0.40		0.23	0.15 to 0.32		-0.50	-0.57 to -0.43	
>10-15%	2,157	0.44	0.10 to 0.78		0.25	0.10 to 0.40		-0.53	-0.65 to -0.40	
>15-20%	688	0.46	-0.14 to 1.06		0.14	-0.13 to 0.40		-0.36	-0.59 to -0.13	
>20%	480	0.75	0.03 to 1.48		0.36	0.04 to 0.68		-0.77	--1.04 to -0.49	

Baseline correlates of the outcomes

Table 2 presents the outcome variables at baseline by type 2 diabetes group. The amount of time spent on MVPA at baseline was significantly higher among the "No type 2 diabetes" group. There were no significant differences in the amount of time spent on walking and sitting between New type 2 diabetes and No type 2 diabetes.

Table 2: Outcome variables at baseline by type 2 diabetes status

	New type 2 diabetes			No type 2 diabetes			Kruskal-Wallis, p-value
	Median	Mean	Interquartile range	Median	Mean	Interquartile range	
MVPA (hours/week)	6.00	8.13	2.52-11.67	7.25	9.13	3.67-13.00	0.006
Walking (hours/week)	2.00	2.99	0.50-4.00	2.00	2.95	0.83-4.00	0.538
Sitting (hours/week)	5.00	5.90	4.00-8.00	5.00	5.83	4.00-8.00	0.534

Although the interactions between access to greenspace and status of type 2 diabetes was not statistically significant for each outcome variable except for the changes in MVPA with percentage of greenspace within 2km, the differences in trends between status of type 2 diabetes were noted as shown in Figure 2.

Greenspace and outcomes by diagnosis of type 2 diabetes

Figure 2 presents marginal mean changes in the amount of walking, MVPA and sitting, and associated 95% CI by proportion of greenspace. A change in the outcome variable of greater than zero indicates an increase in that outcome at the follow-up study relative to the baseline study. Regardless of diabetes status and buffer size, there were no associations between percentage of greenspace and changes in amount of walking and sitting. For example, the 95% CI of changes in the amount of walking overlapped between each category of greenspace regardless of buffer size. Although there were no significant changes in amount of walking with the percentage of greenspace, increasing trends were apparent among New type 2 diabetes which peaked at >15-20% of greenspace, whereas fairly stable trends were found among No type 2 diabetes. Similar trends were also found for changes in the amount of MVPA.

Among New type 2 diabetes, there was a significant association between the percentage of greenspace within 2km buffer and changes in amount of MVPA. The changes in MVPA at >15-20% of greenspace within 2km was significantly higher than those with <15% of greenspace within 2km. Among No type 2 diabetes, the changes in amount of MVPA remained fairly stable with increasing percentage of greenspace (Figure 2).

For changes in sitting time, there were no significant associations with percentage of greenspace regardless of buffer size. Among New type 2 diabetes, the changes in amount of sitting decreased at percentage of greenspace >10%. Among No type 2 diabetes, the changes in amount of sitting significantly decreased at follow-up and remained stable with increasing proportion of greenspace.

Sub-analysis

In the sensitivity analysis (Figure 3), in participants who perceived their neighbourhood as safe, the association between percentage of greenspace and changes in amount of walking remained non-significant regardless of the buffer size. Increasing trends were apparent for percentage of greenspace within 1km and 2km buffers. Among participants who perceived their neighbourhood as unsafe, the association between percentage of greenspace and changes in amount of walking also remain non-significant regardless of the buffer size. However, there were decreasing trends of walking within 500m and 1km buffer sizes for people who perceived their neighbourhood to be unsafe. The decreasing trend was less pronounced within a 2km buffer size.

Figure 2: Change (with 95% CI) in outcomes by proportion of greenspace

Figure 3: Change in walking by percentage of greenspace[1] among New type 2 diabetes by perception of neighbourhood safety

Discussion

This is the first study to explore environmental influences on the behaviours of people who transition into living with type 2 diabetes. Overall, we found that there was a lack of association between access to greenspace at baseline and change in walking, MVPA, and sitting time. We found no statistically significant interactions between access to greenspace and status of type 2 diabetes for each outcome variable, except for the changes in MVPA with percentage of greenspace within 2km. Although no significant interactions were found, possibly due to the small sample size of those with newly diagnosed type 2 diabetes, the magnitude of changes in walking and MVPA increased as percentage of greenspace increased among New T2D while remain fairly stable among No type 2 diabetes. There was no significant association between greenspace and sitting time with fairly stable trends among both New type 2 diabetes and No type 2 diabetes.

Among participants with newly diagnosed type 2 diabetes, there were gradual increases in walking and MVPA with increasing proportion of greenspace within 1km and 2km buffers. However, these increases in walking and MVPA were no longer evident with >20% greenspace. This may be because around half of the participants with more than 20% of greenspace within a 2km buffer (around 3% of the total sample) live near larger greenspace (area> 1km^2). These large greenspaces are mainly national parks and nature reserve that may have limited public access points. These areas are often located in suburbs on the outskirts of the city with minimal pedestrian or other infrastructure to facilitate the regular use of greenspace for physical activity. In this regard, the type and functionality of the greenspace may be a salient factor in addition to quantity[36].

Furthermore, the lack of association found between greenspace and walking and MVPA may be due to the increased participation in fitness activities taken place outside of neighbourhood greenspace. Such fitness activities include aerobics, fitness, gym activities, Pilates, weight training and yoga.[37] In Australia, fitness centre /gym activities is the second most popular physical recreational activity after walking.[38] Similarly, a Dutch study [15] found no significant association between the amount of greenspace within 1km radius of respondents' home and meeting the Dutch public health recommendation for physical activity possibly due to a high density of fitness centres and so that access to greenspace is not a necessary condition for being physically active.[39]

The weak associations between sitting and proportion of greenspace may be due to the lack of detailed information on the setting and domains of sitting (home, car, work or recreation environment). In the 45 and up study, only total sitting time was measured at both baseline and follow-up. Self-reported total sitting time is subject to substantial measurement errors and does not distinguish occupational and transportation sitting from recreational sitting. Previous studies have found that correlates of sitting differed considerably by domain of sitting.[40] Sperlich et al found a weak association between sitting duration and access to parks and recreation facilities[41] and suggest that research investigating association between sitting time and environment should consider the diverse domains of sitting.[41]

Overall, the association between proportion of greenspace and change in physical activity appeared more prominent in New type 2 diabetes than No type 2 diabetes. These findings suggest that greenspace may have more motivating effect on physical activity among those newly diagnosed with type 2 diabetes. Diabetes Australia recommends people with type 2 diabetes start with at least thirty minutes of moderate physical activity every day or between sixty and ninety minutes every day if they are trying to lose weight.[42] However, it appears that proximity to greenspace alone may not be sufficient to meet Diabetes Australia recommendations for those with newly diagnosed type 2 diabetes.

A sub-analysis among participants who perceived their neighbourhood as safe showed similar results to the overall findings. Among participants who perceived their neighbourhood as unsafe, decreasing trends for walking were found with increasing greenspace proportion but this was less pronounced as the buffer size increased. Chong et al have previously reported that perceptions of neighbourhood safety modified the relationship between greenspace and psychological distress.[43] In neighbourhoods perceived as unsafe more greenspace may exacerbate such perceptions leading to less physical activity. This is because greenspace is associated with lower population density, which in turn, means less passive surveillance (e.g., “eyes on the street”) leading to worse perceived safety.

The strengths of this study include a prospective design and a large population-based cohort study. Although diagnostic or clinical information was not available to confirm the diagnosis of type 2 diabetes among participants, in this sample self-reported diagnosis of type 2 diabetes has high sensitivity and specificity compared to hospital administrative data collections.[32] Having outcome measures at two time points only over two to five years has limited our ability to track changes in lifestyle behaviours over longer periods of time.

A few additional limitations apply. We were not able to differentiate between different domains of MVPA and sitting, such as recreational, transport or occupational physical activity and sitting. We also don't know whether each activity took place within the local greenspace. Further, greenspace included state forests and national parks which may or may not be conducive to walking and MVPA as urban parks and trails. We also could not categorise greenspace into more usable categories, for example, sports fields, bushland, presence of picnic facilities, etc., nor do we have access to the quality of the greenspace.

Conclusion

This study indicates that neighbourhood greenspace is related to active lifestyles only to a very limited extent among people with newly diagnosed type 2 diabetes. This is particularly so when there is moderate amount of greenspace (15-20% of the neighbourhood). Future studies should consider including more comprehensive environmental measures about greenspace and other environmental attributes (e.g., recreational facilities), more specific measures of physical activity and sedentary behaviour, such as the domain and location of each activity, and the more follow-up measures over longer period of time.

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Contributors

SC and SM participated in the design of the study. SC carried out the statistical analyses. All authors helped draft the manuscript, helped with the interpretation of the data and revised the manuscript.

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Competing interests

None declared.

Ethics approval

The 45 and Up Study was granted ethical approval by the NSW Population & Health Services Research Ethic Committee (reference HREC/15/CIOHS/4) and the Cancer Institute NSW (reference 2015/02/575).

Data sharing statement

No additional data are available.

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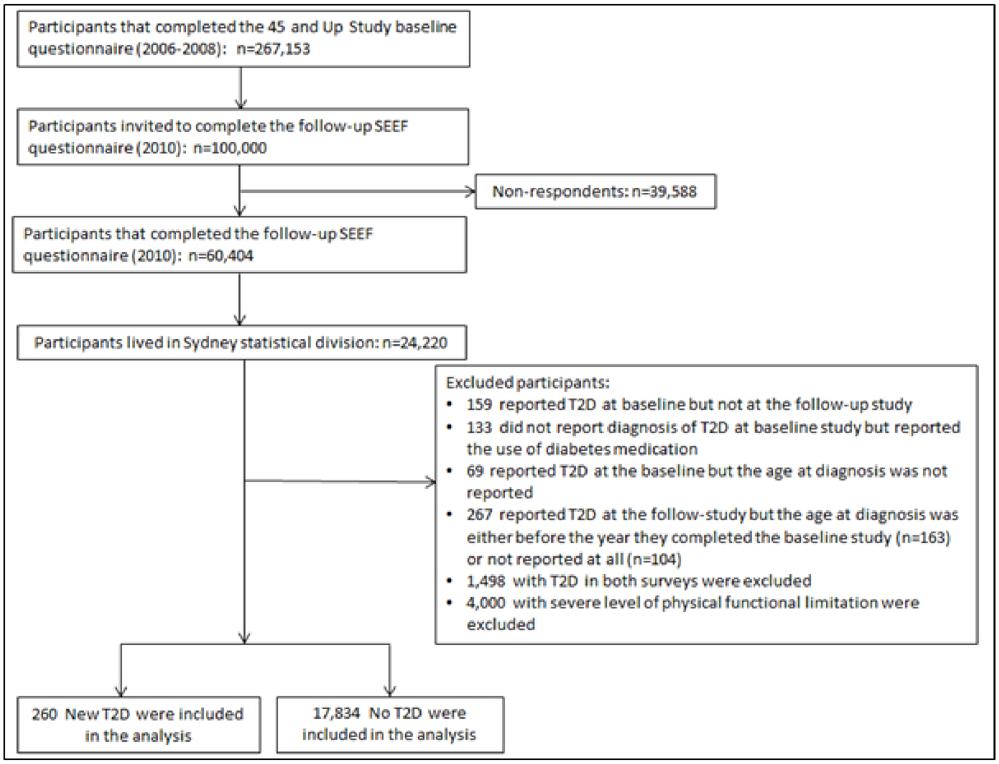

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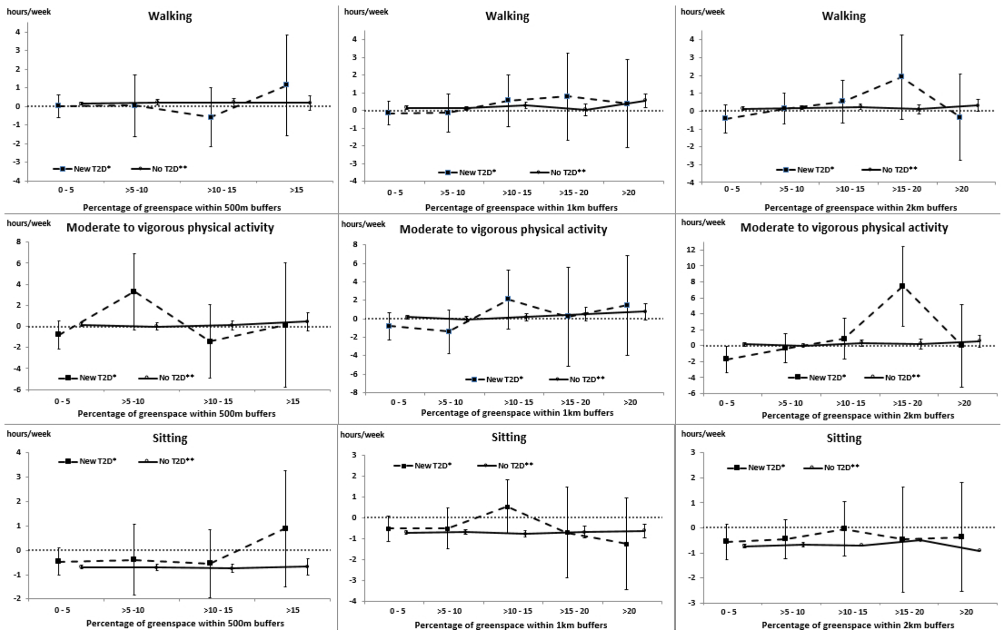

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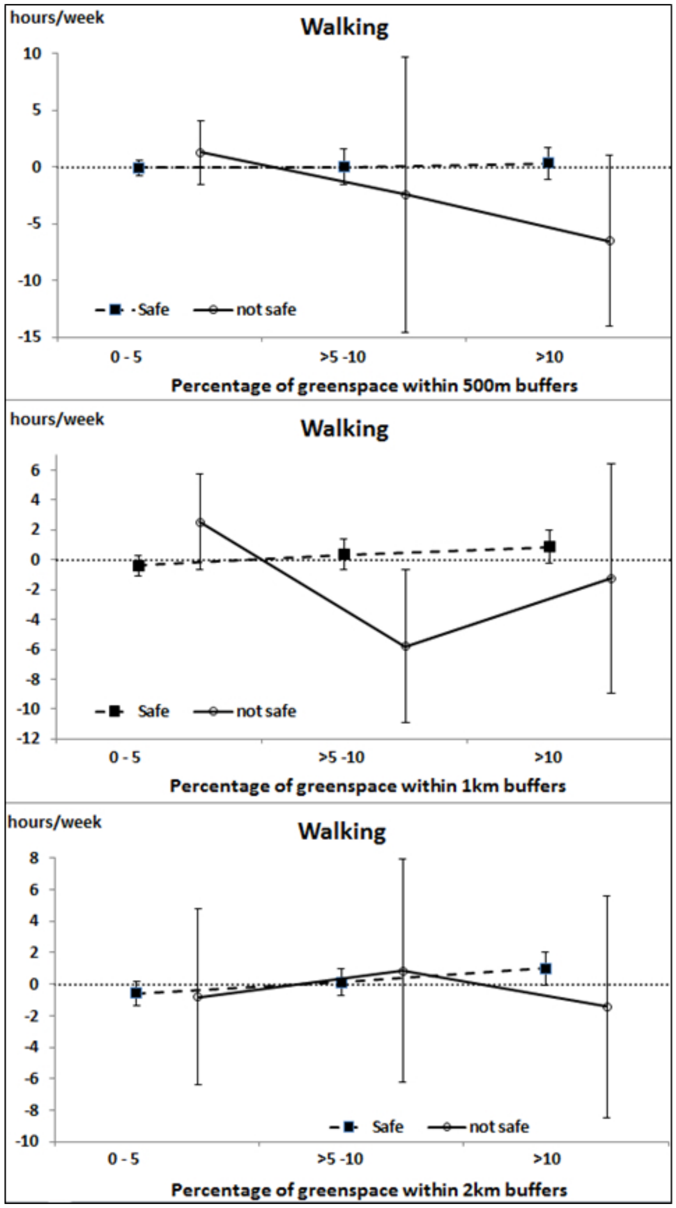

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Neighbourhood greenspace and physical activity and sedentary behaviour among older adults with a recent diagnosis of type 2 diabetes: A Prospective analysis

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Abstract

Objectives:

Greenspace is one of the important factors that can promote an active lifestyle. Thus, greener surroundings may be a motivating factor for people with newly diagnosed diabetes to engage in more physical activity. Given that diagnosis of type 2 diabetes (T2D) may serve as a window opportunity for behavioural modification, we hypothesise that the association between neighbourhood greenspace and physical activity among people with newly diagnosed T2D may be greater than those not diagnosed with T2D. The aim of this study was to investigate the association between access to greenspace and changes in physical activity and sedentary behaviour, and whether these associations differed by T2D.

Design: Prospective cohort.

Setting: New South Wales, Australia

Methods:

We used self-reported information from the New South Wales 45 and Up Study (baseline) and a follow-up study. Information on sitting, walking and moderate to vigorous physical activity was used as outcomes. The proportion of greenspace within 500m, 1km and 2km road network buffers around participant's residential address was generated as a proxy measure for access to greenspace. The association between the access to greenspace and the outcomes were explored among the newly diagnosed T2D group and those without T2D.

Results:

Among New T2D, although no significant changes were found in the amount of walking with the percentage of greenspace, increasing trends were apparent. There

was a significant association between the percentage of greenspace within 2km buffer and changes in amount of MVPA. Among No T2D, there were no significant associations between the amount of MVPA and walking, and percentage of greenspace. For changes in sitting time, there were no significant associations with percentage of greenspace regardless of buffer size.

Conclusions:

This study indicates that neighbourhood greenspace is related to increases in MVPA, but only within the 2km buffer, among people with newly diagnosed T2D.

Strengths and Limitations of this study

- This is the first study to explore environmental influences on the behaviours of people who transition into living with type 2 diabetes, and compare its association with those without T2DM.
- This is a large population-based cohort with data available at two time points.
- A limitation is that the change in duration of physical activity and sitting were calculated from self-reported surveys.

Introduction

Type 2 diabetes is a lifelong condition and is associated with increased risk for cardiovascular, renal disease[1] and mortality.[2,3] A healthy lifestyle that includes, for example regular physical activity, can help maintain healthy blood glucose levels and reduce the risk of complications of type 2 diabetes.[4-7] However, only about half of Australians with diabetes achieve adequate control of their blood glucose level.[3]

It is recommended that adults, including those diagnosed with type 2 diabetes engage in at least 30 minutes of physical activity every day.[8] In a population-based study in Australia, participants with incident type 2 diabetes reported lack of changes in their walking and moderate to vigorous physical activity (MVPA) after their diagnosis. Studies reported that 60% of people aged 35-64 years with diabetes (types 1 and 2) were not achieving the recommended level of physical activity,[9] one third of adults with type 2 diabetes were completely inactive[10] and only a third exercised on regular basis.[10] Physical activity behaviour is determined by a range of biological, psychosocial and environmental factors.[11] Built environment attributes are frequently found to be associated with physical activity,[12] and activity-unfriendly environments may be associated with higher type 2 diabetes incidence.[13] For example, a study reported that one of the barriers among inactive patients with diabetes (both type 1 and 2) was lack of local facilities.[14]

One environmental attribute that plays an important role in physical activity is greenspace.[15-17] Greenspace is defined as any vegetated land adjoining an urban area which includes bushland, nature reserves, national parks, outdoor sports fields, school playgrounds and rural or semi-rural areas immediately adjoining an urban area.[18] Several studies have found that people who have better access to parks and green spaces are more likely to report that they engage in physical activity.[19 20] The potential mechanism for these associations may be that greenspace prompts, facilitates, and reinforces location-specific physical activity,[21] while simultaneously discouraging sedentary lifestyles . Thus, greener surroundings may be a motivating factor among people with newly diagnosed diabetes to engage in more physical activity. Given that diagnosis of type 2 diabetes may serve as a window opportunity for behavioural modification,[22 23] we hypothesise that the association between neighbourhood greens pace and physical activity among people with newly diagnosed type 2 diabetes may be greater than those never diagnosed with type 2 diabetes.

Using data from a large cohort study in New South Wales (NSW), Australia, we aimed to investigate the associations between the access to neighbourhood greenspace and changes in physical activity and sitting time by type 2 diabetes diagnosis status.

Materials and Method

Study population

The study area was the Sydney Statistical Division (Figure 1a) which has a population of approximately 4.12 million people and covers an area of 12,428 square kilometres. It is the largest urban agglomeration in Australia, with a wide range of environmental features and diverse sociodemographic characteristics.

Information about physical activity and relevant covariates at the individual level was obtained from the baseline 45 and Up Study and the Social, Economic and Environmental Factors (SEEF) follow-up Study. The 45 and Up Study is a population-based cohort survey of NSW residents aged 45 years and older. Recruitment was undertaken between 2006 and 2009. Potential participants were randomly selected from the Medicare Australia database (Australia's universal public health insurance system). Participants joined the study by completing a mailed self-administered questionnaire and providing consent for long-term follow-up, including linkage to various personal health records. The response rate was 18% and participants comprised 11% of the NSW population aged 45 years and over.[24] The full study cohort consists of 267,153 people aged 45 years or older at the time of recruitment.

Figure 1: Sydney statistical division (1a) and 500m polygon-based network buffer (1b).

In 2010, the SEEF Study questionnaire was distributed to the first 100,000 participants of the 45 and Up Study, of whom 60,404 returned the completed questionnaire. The average follow-up period was 3.3 $\pm$ 0.9 years (median=2.8 years, range=1.7-5.1 years, inter-quartile range=2.6 to 4.6 years). Questionnaires for both the 45 and Up and the SEEF Study are available from the Sax Institute website[25]. Of the 60,404 participants, 24,220 resided in the study area at the time of the baseline 45 and Up Study.

The baseline 45 and Up and the SEEF Study were approved by the University of New South Wales Human Research Ethics Committee and the University of Sydney Human Research Ethics Committee respectively.

Measures

Exposure: access to greenspace

We used the percentage of greenspace within 500m, 1km and 2km polygon-based road network (PBRN) buffers (Figure 1b) around participants' residences (available for the baseline survey only) as proxies for geographic access to greenspace. These buffer sizes were chosen as they are considered as walkable distance.[26]

Greenspace data was obtained from StreetPro (PitneyBowers Inc., USA). In this dataset, greenspace includes national parks, nature reserves, historic sites, state forests, State recreation areas, wildlife refuges, conservation parks, protected areas, wildlife reserves, urban recreation parks and other urban greenspaces. The PBRN buffers were created using the StreetPro Navigation (PitneyBowers Inc., USA) road network file and ArcGIS network analyst to calculate the endpoints of all possible routes up to the specified distance (500m, 1km and 2km) along the road network for each participant's residence. The endpoints were then connected to form irregular polygons. Percentage of greenspace within PBRN buffers were categorised into 0-5%, >5-10%, >10-15%, >15-20% and >20%. We combined >15-20% and >20% for greenspace within 500m buffers due to the small sample sizes.

Outcomes: duration of sitting and physical activity

Information on sitting (hours per week), walking (minutes per week) and MVPA (minutes per week) was collected in both surveys. Duration of sitting was adapted from the International Physical Activity Questionnaire which has acceptable reliability[27] and validity.[27] Physical activity was assessed using the Active Australia Survey[28] which also has acceptable reliability[29] and validity.[30] In this instrument, walking is defined as walking for recreation or exercise or to get to or from places. Vigorous physical activity refers to any activity that causes a participant to breathe harder or puff and pant. Moderate physical activity refers to less intense activities such as gentle swimming, social tennis, vigorous gardening or work around the house. Total weighted minutes of MVPA per week is calculated by the sum of minutes of walking, moderate physical activity and twice the minutes of vigorous physical activity.[29] Reported time spent on walking and MVPA greater than 14 hours per day was considered as an impossible value and recoded to 14 hours. [31] We conceptualised walking and total MVPA as two separate outcomes because walking is expected to be more specifically related to neighbourhood greenspace while total MVPA is commonly used as a measure of overall levels of health-enhancing physical activity.

Type 2 diabetes diagnosis

New cases of type 2 diabetes were defined as those participants who did not report T2D at the baseline survey but reported type 2 diabetes at the follow-up survey (New type 2 diabetes). The comparator group was participants who did not report type 2 diabetes at both baseline and follow-up surveys (No type 2 diabetes). The questions asked to determine a diagnosis of type 2 diabetes at the baseline survey were "Has a doctor ever told you that you have diabetes" and "Have you taken Diabex, Diaformin, Metformin for most of the last 4 weeks".

Participants who reported that they had been told by a doctor that they had diabetes were then also asked about their age at diagnosis. For participants with newly diagnosed type 2 diabetes, the time lapse since diagnosis to completion of the SEEF Study questionnaire was also calculated (age at time of completion of SEEF Study questionnaire minus age at type 2 diabetes diagnosis). Self-reported diagnosis of type 2 diabetes in the 45 and Up Study has high sensitivity (83.7%) and specificity (97.7%) compared to administrative hospitalisation data [32].

Covariates

A directed acyclic graph (DAG) was used to select potential covariates (Figure 2) to predict physical activity and duration of sitting, and likely influence where people lived (and thus their neighbourhood exposure to greenspace). A list of covariates include socio-demographic characteristics (age, gender, country of birth (English speaking countries, Europe, Middle-East, Asia, Other)) and an area-level deprivation score . Area-level deprivation was measured by 2006 Index of Relative Socio-Economic Disadvantage (IRSED) quintiles at the postcode level. The IRSED was created by the Australian Bureau of Statistics to compare social and economic disadvantage across geographical areas in Australia. The index is derived from the 2006 Census variables such as income, educational attainment, unemployment, and people working in unskilled occupations[33].

We also included physical functioning (measured using the Medical Outcomes Study (MOS) Physical Functioning Scale; it ranges from 0 to 100 and was categorised into no limitation (100), minor limitation (95-99), moderate limitation (85-94), or severe limitation (0-84)) [34], psychological distress (Kessler-10 (K10); a K10 score of ≥22 reflects high or very high psychological distress[35]) and body mass index (BMI) as potential covariates.

Figure 2: Directed acyclic graph of the relationship between neighbourhood greenspace and physical activity and sitting.

Statistical analysis

The Kruskal-Wallis test was used to compare continuous baseline lifestyle variables between type 2 diabetes groups. Separate multivariate linear regression models were used to examine the association between greenspace access and change in outcome variables (in MVPA, walking, and sitting). All the potential confounders presented in DAG (Figure 2) were tested in univariate regression model. Only statistically significant variables from univariate regression analyses were included in the final model to account for any potential confounding. These variables were age, gender, educational attainment, level of physical functional limitation, IRSED, BMI, duration of type 2 diabetes diagnosis (New type 2 diabetes group only), follow-up time and the baseline value of each outcome in specific models. To examine whether the association between greenspace and change in outcome variables modified by the presence of type 2 diabetes, a two-way interaction between the status of type 2 diabetes (New type 2 diabetes and No type 2 diabetes) and percentage of greenspace was explored. We then developed regression models, stratified by the presence of type 2 diabetes. Predicted values of change and associated 95% confidence intervals (CIs) were reported. To adjust for multiple comparison, Bonferroni method were used in the final models. Statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

Results

Of the 24,220 participants living in Sydney Statistical Division, 628 were excluded due to inconsistent reporting between baseline and follow-up surveys, 1,498 were excluded due to reporting type 2 diabetes at both baseline and follow-up and an additional 4,000 were excluded because of severe level of physical function, making physical activity challenging or infeasible, leaving 18,094 participants in the analytical sample (Figure 3).

Figure 3: Flow chart of sample selection

Of the 18,094 participants, 260 (1.4%) reported type 2 diabetes in the follow-up survey but not in the baseline survey (New type 2 diabetes) whereas 17,834 (98.6%) participants did not report type 2 diabetes at both baseline and follow-up (No type 2 diabetes). The average duration of time since diagnosis was 1.8 $\pm$ 1.1 years (median=1.7 years). More than half of all the participants were female (52.0%) and the average age of participants was 59.5 $\pm$ 9.6 years. The majority of participants were born in an English speaking country (85.2%) and about one-quarter had not completed high school education (Table 1).

Table 1 shows changes in outcome variables at follow-up by baseline sociodemographic characteristics and access to greenspace. There were significant associations of age group, IRSED, physical functional limitation, BMI, with change in the amount of walking and MVPA. Significant associations were also found between gender and change in the amount of walking and sitting. Educational attainment was significantly associated with a change in sitting time. There were no significant associations between greenspace and changes in MVPA, walking and sitting.

Table 1: Changes in outcome variables at follow-up by baseline characteristics

		Change in MVPA[1] (hours/week)	Change in walking[2] (hours/week)	Change in sitting[3]

									(hours/week)	
	n	Mean	95% CI	p-value	Mean	95% CI	p-value	Mean	95% CI	p-value
Gender				0.072			0.018			0.013
Male	8,677	0.20	0.04 to 0.37		0.14	0.07 to 0.21		-0.47	-0.53 to -0.40	
Female	9,417	0.42	0.25 to 0.59		0.27	0.19 to 0.34		-0.59	-0.65 to -0.52	
Age (years)				<0.0001			<0.0001			<0.0001
45-55	6,581	0.19	0.01 to 0.38		0.07	-0.01 to 0.15		-0.17	-0.24 to -0.10	
>55-65	5,960	0.76	0.56 to 0.96		0.38	0.30 to 0.47		-0.72	-0.80 to -0.64	
>65	5,553	-0.12	-0.36 to 0.12		0.17	0.06 to 0.27		-0.86	-0.95 to -0.77	
Country of birth (missing=146)				0.082			0.164			0.27
English speaking countries	15,282	0.37	0.24 to 0.49		0.22	0.16 to 0.28		-0.51	-0.56 to -0.47	
Europe	1,213	0.12	-0.37 to 0.61		0.21	-0.01 to 0.42		-0.66	-0.85 to -0.48	
Middle East	192	-0.18	-1.43 to 1.07		-0.30	-0.85 to 0.24		-0.87	-1.34 to -0.39	
Asia	825	-0.42	-0.97 to 0.14		0.01	-0.24 to 0.25		-0.57	-0.78 to -0.36	
Other	438	0.22	-0.54 to 0.97		0.18	-0.15 to 0.51		-0.41	-0.70 to -0.11	
Highest level of education completed (missing=206)				0.496			0.158			<0.0001
University/TAFE[5]	10,491	0.27	0.12 to 0.42		0.16	0.09 to 0.22		-0.41	-0.46 to -0.35	
High school	3,306	0.46	0.18 to 0.74		0.26	0.14 to 0.39		-0.69	-0.80 to -0.59	
Did not complete high school	4,091	0.32	0.05 to 0.59		0.26	0.14 to 0.38		-0.76	-0.86 to -0.65	
IRSED				0.002			0.007			0.123
Least disadvantaged group	3,086	0.39	0.22 to 0.55		0.23	0.16 to 0.30		-0.50	-0.57 to -0.44	
2nd disadvantaged group	3,735	-0.06	-0.45 to 0.33		0.01	-0.17 to 0.18		-0.69	-0.84 to -0.54	
3rd disadvantaged group	3,850	-0.31	-0.69 to 0.07		0.03	-0.14 to 0.20		-0.55	-0.69 to -0.40	
4th disadvantaged group	3,691	0.51	0.28 to 0.74		0.30	0.20 to 0.41		-0.49	-0.57 to -0.40	
Most disadvantaged group	3,732	0.37	-0.16 to 0.89		0.10	-0.13 to 0.33		-0.64	-0.84 to -0.44	
Physical functional limitation (missing=3,123)				<0.0001			<0.001			0.301
Moderate	3,546	-0.48	-0.73 to -0.24		0.01	-0.09 to 0.12		-0.58	-0.68 to -0.49	
Minor	3,768	0.10	-0.13 to 0.33		0.21	0.11 to 0.32		-0.53	-0.62 to -0.44	
None	7,405	0.80	0.63 to 0.96		0.29	0.21 to 0.36		-0.50	-0.56 to -0.43	
Psychological distress (missing=355)				0.595			0.716			0.415
No	16,900	0.32	0.20 to 0.44		0.20	0.15 to 0.25		-0.52	-0.57 to -0.47	
Yes	812	0.16	-0.43 to 0.74		0.25	-0.01 to 0.51		-0.62	-0.85 to -0.39	
Body Mass Index (missing=857)				<0.0001			<0.0001			<0.0001
Under weight	244	0.30	-0.74 to 1.34		0.20	-0.26 to 0.66		-0.54	-0.94 to -0.14	
Healthy weight	7,541	0.69	0.51 to 0.86		0.33	0.26 to 0.41		-0.63	-0.69 to -0.56	
Overweight	6,852	0.25	0.07 to 0.44		0.21	0.13 to 0.29		-0.51	-0.58 to -0.44	
Obese	2,547	-0.83	-1.15 to -0.50		0.28	0.13 to 0.42		-0.22	-0.34 to -0.09	
Greenspace within 500m				0.476			0.354			0.715
0-5%	13,762	0.34	0.21 to 0.48		0.19	0.13 to 0.25		-0.51	-0.56 to -0.46	
>5-10%	2,657	0.16	-0.14 to 0.47		0.25	0.12 to 0.39		-0.55	-0.67 to -0.43	
>10-15%	1,341	0.19	-0.24 to 0.63		0.23	0.03 to 0.42		-0.61	-0.78 to -0.44	
>15%	334	0.61	-0.26 to 1.49		0.28	-0.11 to 0.66		-0.50	-0.83 to -0.17	
Greenspace within 1km				0.224			0.128			0.951
0-5%	10,948	0.37	0.22 to 0.52		0.20	0.14 to 0.27		-0.52	-0.58 to -0.46	
>5-10%	4,843	0.12	-0.11 to 0.35		0.15	0.05 to 0.25		-0.52	-0.61 to -0.43	
>10-15%	1,497	0.29	-0.13 to 0.70		0.31	0.13 to 0.49		-0.59	-0.75 to -0.43	
>15-20%	451	0.52	-0.22 to 1.26		0.08	-0.25 to 0.40		-0.52	-0.81 to -0.23	
>20%	355	0.94	0.10 to 1.79		0.59	0.22 to 0.96		-0.47	-0.79 to -0.15	
Greenspace within 2km				0.477			0.682			0.221
0-5%	7,789	0.33	0.15 to 0.51		0.16	0.08 to 0.24		-0.55	-0.62 to -0.48	
>5-10%	6,980	0.21	0.02 to 0.40		0.23	0.15 to 0.32		-0.50	-0.57 to -0.43	
>10-15%	2,157	0.44	0.10 to 0.78		0.25	0.10 to 0.40		-0.53	-0.65 to -0.40	
>15-20%	688	0.46	-0.14 to 1.06		0.14	-0.13 to 0.40		-0.36	-0.59 to -0.13	
>20%	480	0.75	0.03 to 1.48		0.36	0.04 to 0.68		-0.77	--1.04 to -0.49	

[1]Mean adjusted for baseline amount of time spent on MVPA per week.
[2]Mean adjusted for baseline amount of time spent on walking per week.
[3]Mean adjusted for baseline amount of time spent on sitting per week.

Baseline correlates of the outcomes

Table 2 presents the outcome variables at baseline by type 2 diabetes group. The amount of time spent on MVPA at baseline was significantly higher among the "No type 2 diabetes" group. There were no significant differences in the amount of time spent on walking and sitting between New type 2 diabetes and No type 2 diabetes.

Table 2: Outcome variables at baseline by type 2 diabetes status

	New type 2 diabetes			No type 2 diabetes			Kruskal-Wallis, p-value
	Median	Mean	Interquartile range	Median	Mean	Interquartile range	
MVPA (hours/week)	6.00	8.13	2.52-11.67	7.25	9.13	3.67-13.00	0.006
Walking (hours/week)	2.00	2.99	0.50-4.00	2.00	2.95	0.83-4.00	0.538
Sitting (hours/week)	5.00	5.90	4.00-8.00	5.00	5.83	4.00-8.00	0.534

Although the interactions between access to greenspace and status of type 2 diabetes was not statistically significant for each outcome variable except for the changes in MVPA with percentage of greenspace within 2km (p=0.039), the differences in trends between status of type 2 diabetes were noted as shown in Figure 4.

Greenspace and outcomes by diagnosis of type 2 diabetes

Figure 4 presents marginal mean changes in the amount of walking, MVPA and sitting, and associated 95% CI by proportion of greenspace. A change in the outcome variable of greater than zero indicates an increase in that outcome at the follow-up study relative to the baseline study. Regardless of diabetes status and buffer size, there were no associations between percentage of greenspace and changes in amount of walking and sitting. For example, the 95% CI of changes in the amount of walking overlapped between each category of greenspace regardless of buffer size. Although there were no significant changes in amount of walking with the percentage of greenspace, increasing trends were apparent among New type 2 diabetes which peaked at >15-20% of greenspace, whereas fairly stable trends were found among No type 2 diabetes. Similar trends were also found for changes in the amount of MVPA.

Among New type 2 diabetes, there was a significant association between the percentage of greenspace within 2km buffer and changes in amount of MVPA. The changes in MVPA at >15-20% of greenspace within 2km was significantly higher than those with <15% of greenspace within 2km. Among No type 2 diabetes, the changes in amount of MVPA remained fairly stable with increasing percentage of greenspace (Figure 4).

For changes in sitting time, there were no significant associations with percentage of greenspace regardless of buffer size. Among New type 2 diabetes, the changes in amount of sitting decreased at percentage of greenspace >10%. Among No type 2 diabetes, the changes in amount of sitting significantly decreased at follow-up and remained stable with increasing proportion of greenspace.

Figure 4: Change (with 95% CI) in outcomes by proportion of greenspace (Bonferroni method was applied for multiple comparison)

Discussion

This is the first study to explore environmental influences on the behaviours of people who transition into living with type 2 diabetes. Overall, we found that there was a lack of association between access to greenspace at baseline and change in walking, MVPA, and sitting time. We found no statistically significant interactions between access to greenspace and status of type 2 diabetes for each outcome variable, except for the changes in MVPA with percentage of greenspace within 2km. Although no significant interactions were found, possibly due to the small sample size of those with newly diagnosed type 2 diabetes, the magnitude of changes in walking and MVPA increased as percentage of greenspace increased among New T2D while remain fairly stable among No type 2 diabetes. There was no significant association between greenspace and sitting time with fairly stable trends among both New type 2 diabetes and No type 2 diabetes.

Among participants with newly diagnosed type 2 diabetes, there were gradual increases in walking and MVPA with increasing proportion of greenspace within 1km and 2km buffers. However, these increases in walking and MVPA were no longer evident with >20% greenspace. This may be because around half of the participants with more than 20% of greenspace within a 2km buffer (around 3% of the total sample) live near larger greenspace (area> 1km2). These large greenspaces are mainly national parks and nature reserve that may have limited public access points. These areas are often located in suburbs on the outskirts of the city with minimal pedestrian or other infrastructure to facilitate the regular use of greenspace for physical activity [36]. Francis et al suggested that the type and functionality of the greenspace may be a salient factor in addition to quantity[37].

Furthermore, the lack of association found between greenspace and walking and MVPA may be due to the increased participation in fitness activities taken place outside of neighbourhood greenspace. Such fitness activities include aerobics, fitness, gym activities, Pilates, weight training and yoga.[38] In Australia, fitness centre /gym activities is the second most popular physical recreational activity after walking.[39] Similarly, a Dutch study [15] found no significant association between the amount of greenspace within 1km radius of respondents' home and meeting the Dutch public health recommendation for physical activity possibly due to a high density of fitness centres and so that access to greenspace is not a necessary condition for being physically active.[40]

The weak associations between sitting and proportion of greenspace may be due to the lack of detailed information on the setting and domains of sitting (home, car, work or recreation environment). In the 45 and up study, only total sitting time was measured at both baseline and follow-up. Self-reported total sitting time is subject to substantial measurement errors and does not distinguish occupational and transportation sitting from recreational sitting. Previous studies have found that correlates of sitting differed considerably by domain of sitting.[41] Sperlich et al found a weak association between sitting duration and access to parks and recreation facilities[42] and suggest that research investigating association between sitting time and environment should consider the diverse domains of sitting.[42]

Overall, the association between proportion of greenspace and change in physical activity appeared more prominent in New type 2 diabetes than No type 2 diabetes. These findings suggest that greenspace may have more motivating effect on physical activity among those newly diagnosed with type 2 diabetes. Diabetes Australia recommends people with type 2 diabetes start with at least thirty minutes of moderate physical activity every day or between sixty and ninety minutes every day if they are trying to lose weight.[43] However, it appears that proximity to greenspace alone may not be sufficient to meet Diabetes Australia recommendations for those with newly diagnosed type 2 diabetes.

The strengths of this study include a prospective design and a large population-based cohort study. Although diagnostic or clinical information was not available to confirm the diagnosis of type 2 diabetes among participants, in this sample self-reported diagnosis of type 2 diabetes has high sensitivity and specificity compared to hospital administrative data collections.[32] Having outcome measures at two time points only over two to five years has limited our ability to track changes in lifestyle behaviours over longer periods of time.

A few additional limitations apply. We were not able to differentiate between different domains of MVPA and sitting, such as recreational, transport or occupational physical activity and sitting. We also don't know whether each activity took place within the local greenspace. Further, greenspace included state forests and national parks which may or may not be conducive to walking and MVPA as urban parks and trails. We also could not categorise greenspace into more usable categories, for example, sports fields, bushland, presence of picnic facilities, etc., nor do we have access to the quality of the greenspace. Moreover, although we adjusted for a number of important potential confounders, there may yet be some residual confounding. However, we share this limitation with most other published studies on neighbourhoods and health.

Conclusion

This study indicates that neighbourhood greenspace is related to active lifestyles only to a very limited extent among people with newly diagnosed type 2 diabetes. This is particularly so when there is moderate amount of greenspace (15-20% of the neighbourhood). Future studies should consider including more comprehensive environmental measures about greenspace and other environmental attributes (e.g., recreational facilities), more specific measures of physical activity and sedentary behaviour, such as the domain and location of each activity, and the more follow-up measures over longer period of time.

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Contributors

Shanley Chong participated in the design of the study, carried out the statistical analyses and drafted the manuscript. Soumya Mazumdar participated in the design of the study, helped draft the manuscript, helped with the interpretation and revised the manuscript. Ding Ding helped draft the manuscript, helped with the interpretation of the data and revised the manuscript. Geoff Morgan, Elizabeth Comino and Adrian Bauman helped with the interpretation of the data and revised the manuscript. Bin Jalaludin supervised the study, helped draft the manuscript, helped with the interpretation of the data and revised the manuscript.

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Competing interests

None declared.

Ethics approval

The 45 and Up Study was granted ethical approval by the NSW Population & Health Services Research Ethic Committee (reference HREC/15/CIOHS/4) and the Cancer Institute NSW (reference 2015/02/575).

Data sharing statement

This research was completed using data collected through the 45 and Up Study (www.saxinstitute.org.au).

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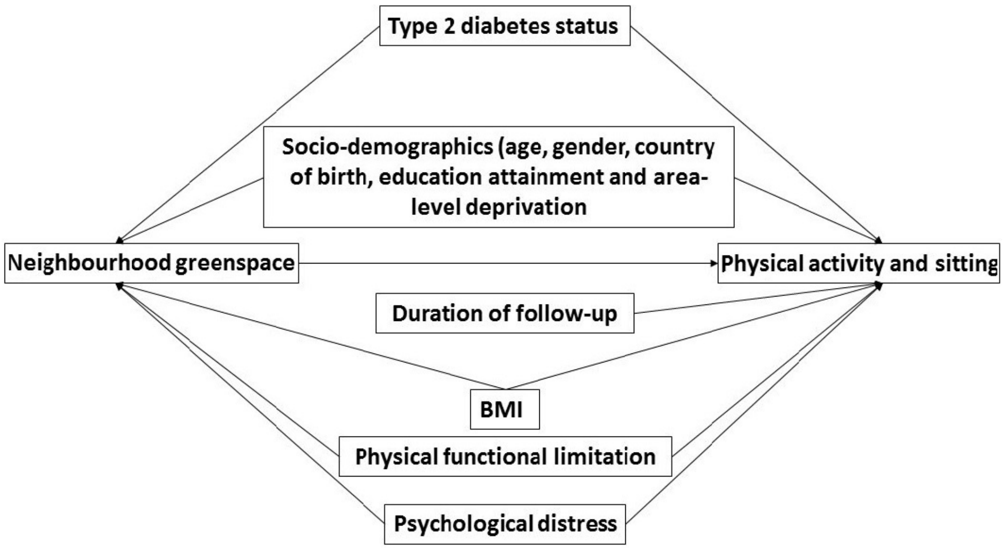

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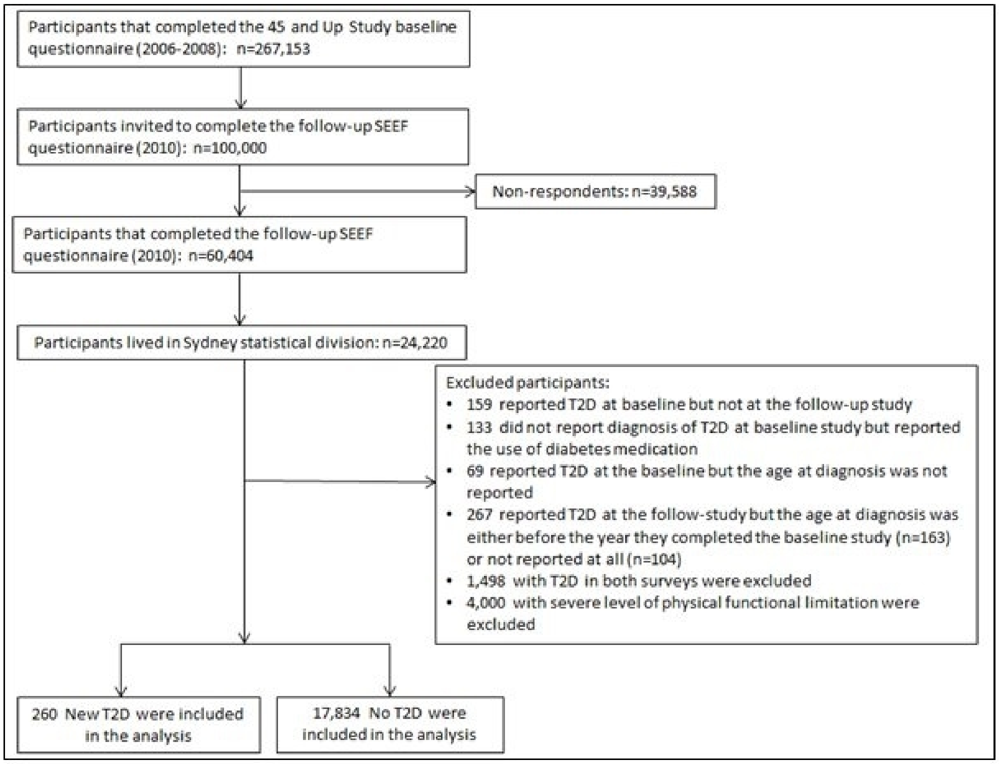

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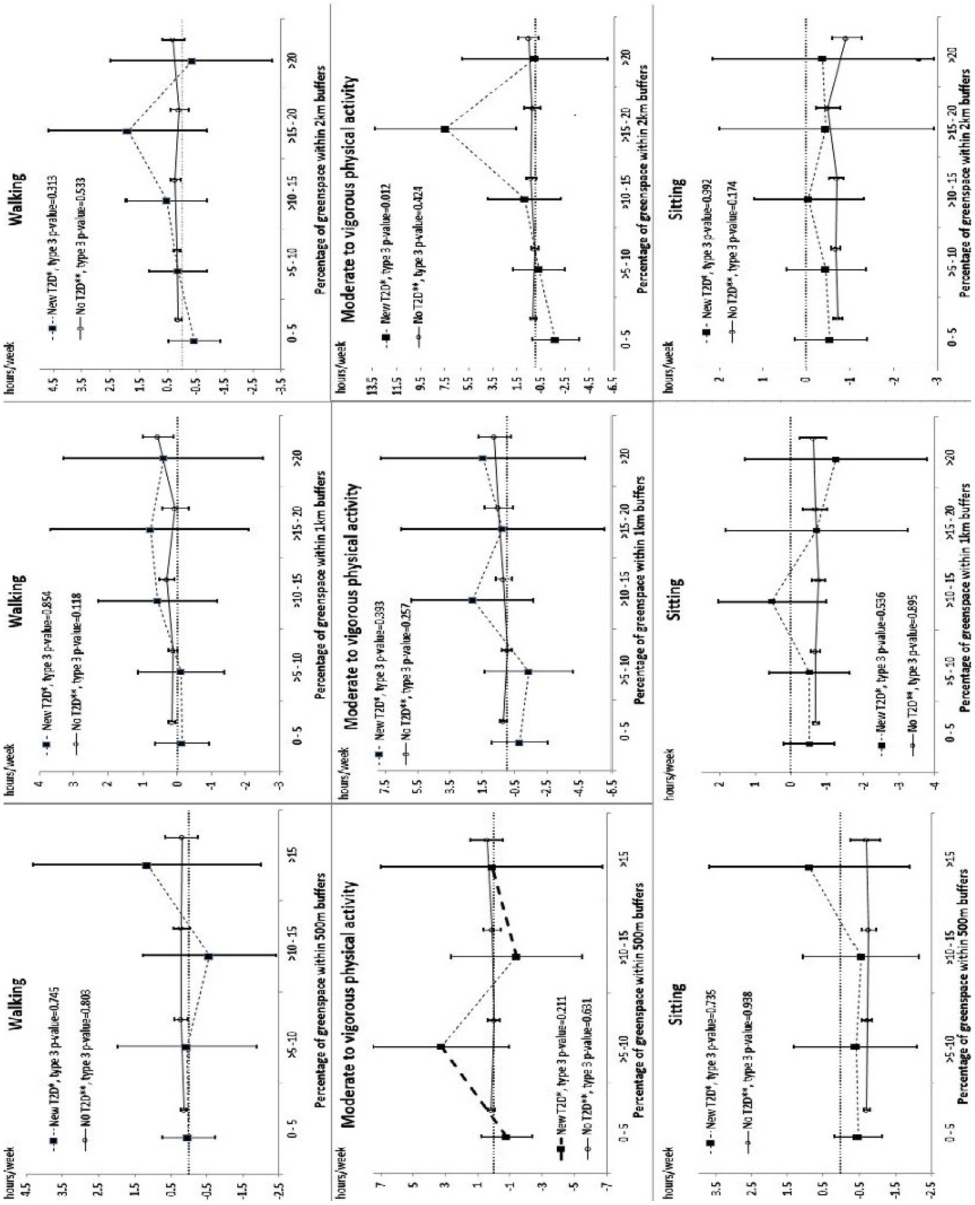

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Neighbourhood greenspace and physical activity and sedentary behaviour among older adults with a recent diagnosis of type 2 diabetes: A Prospective analysis

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Abstract

Objectives:

Greenspace is one of the important factors that can promote an active lifestyle. Thus, greener surroundings may be a motivating factor for people with newly diagnosed diabetes to engage in more physical activity. Given that diagnosis of type 2 diabetes (T2D) may serve as a window opportunity for behavioural modification, we hypothesise that the association between neighbourhood greenspace and physical activity among people with newly diagnosed T2D may be greater than those not diagnosed with T2D. The aim of this study was to investigate the association between access to greenspace and changes in physical activity and sedentary behaviour, and whether these associations differed by T2D.

Design: Prospective cohort.

Setting: New South Wales, Australia

Methods:

We used self-reported information from the New South Wales 45 and Up Study (baseline) and a follow-up study. Information on sitting, walking and moderate to vigorous physical activity was used as outcomes. The proportion of greenspace within 500m, 1km and 2km road network buffers around participant's residential address was generated as a proxy measure for access to greenspace. The association between the access to greenspace and the outcomes were explored among the newly diagnosed T2D group and those without T2D.

Results:

Among New T2D, although no significant changes were found in the amount of walking with the percentage of greenspace, increasing trends were apparent. There

was no significant association between the percentage of greenspace and changes in amount of MVPA. Among No T2D, there were no significant associations between the amount of MVPA and walking, and percentage of greenspace. For changes in sitting time, there were no significant associations with percentage of greenspace regardless of buffer size.

Conclusions:

In this study, there was no association between access to greenspace at baseline and change in walking, MVPA, and sitting time, regardless of T2D status.

Strengths and Limitations of this study

- This is the first study to explore environmental influences on the behaviours of people who transition into living with T2D, and compare its association with those without T2DM.
- This is a large population-based cohort with data available at two time points.
- A limitation is that the change in duration of physical activity and sitting were calculated from self-reported surveys.

Introduction

Type 2 diabetes (T2D) is a lifelong condition and is associated with increased risk for cardiovascular, renal disease[1] and mortality.[2,3] A healthy lifestyle that includes, for example, regular physical activity, can help maintain healthy blood glucose levels and reduce the risk of complications of T2D.[4-7] However, only about half of Australians with diabetes achieve adequate control of their blood glucose level.[3]

It is recommended that adults, including those diagnosed with T2D engage in at least 30 minutes of physical activity every day.[8] In a population-based study in Australia, participants with incident T2D reported lack of changes in their walking and moderate to vigorous physical activity (MVPA) after their diagnosis. Studies reported that 60% of people aged 35-64 years with diabetes (types 1 and 2) were not achieving the recommended level of physical activity,[9] one third of adults with T2D were completely inactive[10] and only a third exercised on regular basis.[10] Physical activity behaviour is determined by a range of biological, psychosocial and environmental factors. [11] Built environment attributes are frequently found to be associated with physical activity,[12] and activity-unfriendly environments may be associated with higher T2D incidence.[13] For example, a study reported that one of the barriers among inactive patients with diabetes (both type 1 and 2) was lack of local facilities.[14]

One environmental attribute that plays an important role in physical activity is greenspace.[15-17] Greenspace is defined as any vegetated land adjoining an urban area which includes bushland, nature reserves, national parks, outdoor sports fields, school playgrounds and rural or semi-rural areas immediately adjoining an urban area.[18] Several studies have found that people who have better access to parks and green spaces are more likely to report that they engage in physical activity.[19 20] The potential mechanism for these associations may be that greenspace prompts, facilitates, and reinforces location-specific physical activity, [21] while simultaneously discouraging sedentary lifestyles . Thus, greener surroundings may be a motivating factor among people with newly diagnosed diabetes to engage in more physical activity. Given that diagnosis of T2D may serve as a window opportunity for behavioural modification,[22 23] we hypothesise that the association between neighbourhood greens pace and physical activity among people with newly diagnosed T2D may be greater than those never diagnosed with type 2 diabetes.

Using data from a large cohort study in New South Wales (NSW), Australia, we aimed to investigate the associations between the access to neighbourhood greenspace and changes in physical activity and sitting time by T2D diagnosis status.

Materials and Method

Study population

The study area was the Sydney Statistical Division (Figure 1a) which has a population of approximately 4.12 million people and covers an area of 12,428 square kilometres. It is the largest urban agglomeration in Australia, with a wide range of environmental features and diverse sociodemographic characteristics.

Information about physical activity and relevant covariates at the individual level was obtained from the baseline 45 and Up Study and the Social, Economic and Environmental Factors (SEEF) follow-up Study. The 45 and Up Study is a population-based cohort survey of NSW residents aged 45 years and older. Recruitment was undertaken between 2006 and 2009. Potential participants were randomly selected from the Medicare Australia database (Australia's universal public health insurance system). Participants joined the study by completing a mailed self-administered questionnaire and providing consent for long-term follow-up, including linkage to various personal health records. The response rate was 18% and participants comprised 11% of the NSW population aged 45 years and over.[24] The full study cohort consists of 267,153 people aged 45 years or older at the time of recruitment.

Figure 1: Sydney statistical division (1a) and 500m polygon-based network buffer (1b).

In 2010, the SEEF Study questionnaire was distributed to the first 100,000 participants of the 45 and Up Study, of whom 60,404 returned the completed questionnaire. The average follow-up period was 3.3 $\pm$ 0.9 years (median=2.8 years, inter-quartile range=2.6 to 4.6 years). Questionnaires for both the 45 and Up and the SEEF Study are available from the Sax Institute website. Of the 60,404 participants, 24,220 resided in the study area at the time of the baseline 45 and Up Study.

The baseline 45 and Up Study and the SEEF Study were approved by the University of New South Wales Human Research Ethics Committee and the University of Sydney Human Research Ethics Committee respectively.

Measures

Exposure: access to greenspace

We used the percentage of greenspace within 500m, 1km and 2km polygon-based road network (PBRN) buffers (Figure 1b) around participants' residences (available for the baseline survey only) as proxies for geographic access to greenspace. These buffer sizes were chosen as they are considered as walkable distance.[25]

Greenspace data was obtained from StreetPro (PitneyBowers Inc., USA). In this dataset, greenspace includes national parks, nature reserves, historic sites, state forests, State recreation areas, wildlife refuges, conservation parks, protected areas, wildlife reserves, urban recreation parks and other urban greenspaces. The PBRN buffers were created using the StreetPro Navigation (PitneyBowers Inc., USA) road network file and ArcGIS network analyst to calculate the endpoints of all possible routes up to the specified distance (500m, 1km and 2km) along the road network for each participant's residence. The endpoints were then connected to form irregular polygons. Percentage of greenspace within PBRN buffers were categorised into 0-5%, >5-10%, >10-15%, >15-20% and >20%. We combined >15-20% and >20% for greenspace within 500m buffers due to the small sample sizes.

Outcomes: duration of sitting and physical activity

Information on sitting (hours per week), walking (minutes per week) and MVPA (minutes per week) was collected in both surveys. Duration of sitting was adapted from the International Physical Activity Questionnaire which has acceptable reliability[26] and validity.[26] Physical activity was assessed using the Active Australia Survey[27] which also has acceptable reliability[28] and validity.[29] In this instrument, walking is defined as walking for recreation or exercise or to get to or from places. Vigorous physical activity refers to any activity that causes a participant to breathe harder or puff and pant. Moderate physical activity refers to less intense activities such as gentle swimming, social tennis, vigorous gardening or work around the house. Total weighted minutes of MVPA per week is calculated by the sum of minutes of walking, moderate physical activity and twice the minutes of vigorous physical activity.[28] Reported time spent on walking and MVPA greater than 14 hours per day was considered as an impossible value and recoded to 14 hours. [30] We conceptualised walking and total MVPA as two separate outcomes because walking is expected to be more specifically related to neighbourhood greenspace while total MVPA is commonly used as a measure of overall levels of health-enhancing physical activity.

T2D diagnosis

New cases of T2D were defined as those participants who did not report T2D at the baseline survey but reported T2D at the follow-up survey (New type 2 diabetes). The comparator group was participants who did not report T2D at both baseline and follow-up surveys (No type 2 diabetes). The questions asked to determine a diagnosis of T2D at the baseline survey were “Has a doctor ever told you that you have diabetes” and “Have you taken Diabex, Diaformin, Metformin for most of the last 4 weeks”.

Participants who reported that they had been told by a doctor that they had diabetes were then also asked about their age at diagnosis. For participants with newly diagnosed type 2 diabetes, the time lapse since diagnosis to completion of the SEEF Study questionnaire was also calculated (age at time of completion of SEEF Study questionnaire minus age at T2D diagnosis). Self-reported diagnosis of T2D in the 45 and Up Study has high sensitivity (83.7%) and specificity (97.7%) compared to administrative hospitalisation data[31].

Covariates

A directed acyclic graph (DAG) was used to identify potential covariates (Figure 2), measured at baseline, to predict physical activity and duration of sitting. The list of covariates, reported at baseline, include socio-demographic characteristics (age, gender, country of birth (English speaking countries, Europe, Middle-East, Asia, Other)) and an area-level deprivation score. Area-level deprivation was measured by the 2006 Index of Relative Socio-Economic Disadvantage (IRSED) quintiles at the postcode level. The IRSED was created by the Australian Bureau of Statistics to compare social and economic disadvantage across geographical areas in Australia. The index is derived from the 2006 Census variables such as income, educational attainment, unemployment, and people working in unskilled occupations[32].

We also included physical functioning at baseline (measured using the Medical Outcomes Study (MOS) Physical Functioning Scale; it ranges from 0 to 100 and was categorised into no limitation (100), minor limitation (95-99), moderate limitation (85-94), or severe limitation (0-84)) [33], psychological distress at baseline (Kessler-10 (K10); a K10 score of ≥22 reflects high or very high psychological distress[34]) and body mass index (BMI) at baseline as potential covariates.

As several studies have reported the beneficial effect of greenspace on mental health[35-37] And that poor mental health can impact on physical activity[38-40], we also tested whether psychological distress at baseline could be a potential mediator between neighbourhood greenspace at baseline and changes in physical activity at follow-up (see DAG Figure 2).

Similarly, we also tested for BMI reported at baseline as another potential mediator between neighbourhood greenspace at baseline and changes in physical activity at follow-up. Increased greenspace has been associated with reduced weight[41], less weight gain[42], and people are less likely to be obese in greener areas[43]. Moreover, people who are overweight or obese reported spending less f time in physical activity than those who are normal-weight[44-46].

Figure 2: Directed acyclic graph of the relationship between neighbourhood greenspace and physical activity and sitting.

Statistical analysis

The Kruskal-Wallis test was used to compare continuous baseline lifestyle variables between the two T2D groups. Separate regression models were used to examine the association between neighbourhood greenspace access and change in outcome variables (in MVPA, walking, and sitting). To adjust for correlation between participants within local government areas (LGA), generalised estimating equations (GEE) model was applied. Assuming no specific order between observations in the same LGA, the compound-symmetric correlation structure was used. BMI and psychological distress were tested for mediation between neighbourhood greenspace and physical activity. There were no associations between neighbourhood greenspace and BMI and psychological distress. However, BMI, but not psychological distress, was associated with changes in the outcome variables and therefore included in the final models. Psychological distress was not included in the final models. The final set of variables included in the final models was age, gender, educational attainment, level of physical functional limitation, IRSED, BMI at baseline, and duration of T2D diagnosis (New T2D group only), follow-up time and the baseline value of each outcome in specific models. To examine whether the association between greenspace and change in outcome variables modified by the presence of type 2 diabetes, a two-way interaction between the status of T2D (New T2D and No type 2 diabetes) and percentage of greenspace was explored. We then developed regression models, stratified by the presence of type 2 diabetes. Predicted values of change and associated 95% confidence intervals (CIs) were reported. To adjust for multiple comparison, Bonferroni method were used in the final models. Statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

Patient and Public Involvement

In the 45 and Up Study, participants completed a baseline questionnaire and have provided informed consent for long-term follow-up and for the use of their data for research purposes. However, patients and the public were not involved in the design of this study.

Results

Of the 24,220 participants living in Sydney Statistical Division, 628 were excluded due to inconsistent reporting between baseline and follow-up surveys, 1,498 were excluded due to reporting T2D at both baseline and follow-up and an additional 4,000 were excluded because of severe level of physical function, making physical activity challenging or infeasible, leaving 18,094 participants in the analytical sample (Figure 3).

Figure 3: Flow chart of sample selection

Of the 18,094 participants, 260 (1.4%) reported T2D in the follow-up survey but not in the baseline survey (New type 2 diabetes) whereas 17,834 (98.6%) participants did not report T2D at both baseline and follow-up (No type 2 diabetes). The average duration of time since diagnosis was 1.8 $\pm$ 1.1 years (median=1.7 years). More than half of all the participants were female (52.0%) and the average age of participants was 59.5 $\pm$ 9.6 years. The majority of participants were born in an English speaking country (85.2%) and about one-quarter had not completed high school education (Table 1).

Table 1 shows changes in outcome variables at follow-up by baseline sociodemographic characteristics and access to greenspace. There were significant associations of age group, IRSED, physical functional limitation, BMI, with change in the amount of walking and MVPA. Significant associations were also found between gender and change in the amount of walking and sitting. Educational attainment was significantly associated with a change in sitting time. There were no significant associations between greenspace and changes in MVPA, walking and sitting.

Table 1: Changes in outcome variables at follow-up by baseline characteristics

		Change in MVPA[1] (hours/week)			Change in walking[2] (hours/week)			Change in sitting[3] (hours/week)		
	n	Mean	95% CI	p-value	Mean	95% CI	p-value	Mean	95% CI	p-value
Gender				0.070			0.018			0.013
Male	8,677	0.20	0.04 to 0.37		0.14	0.07 to 0.21		-0.47	-0.53 to -0.40	
Female	9,417	0.42	0.25 to 0.59		0.27	0.19 to 0.34		-0.59	-0.65 to -0.52	
Age (years)				<0.0001			<0.0001			<0.0001
45-55	6,581	0.19	0.01 to 0.38		0.07	-0.01 to 0.15		-0.17	-0.24 to -0.10	
>55-65	5,960	0.76	0.56 to 0.96		0.38	0.30 to 0.47		-0.72	-0.80 to -0.64	
>65	5,553	-0.12	-0.36 to 0.12		0.17	0.06 to 0.27		-0.86	-0.95 to -0.77	
Country of birth (missing=146)				0.082			0.164			0.27
English speaking countries	15,282	0.37	0.24 to 0.49		0.22	0.16 to 0.28		-0.51	-0.56 to -0.47	
Europe	1,213	0.12	-0.37 to 0.61		0.21	-0.01 to 0.42		-0.66	-0.85 to -0.48	
Middle East	192	-0.18	-1.43 to 1.07		-0.30	-0.85 to 0.24		-0.87	-1.34 to -0.39	
Asia	825	-0.42	-0.97 to 0.14		0.01	-0.24 to 0.25		-0.57	-0.78 to -0.36	
Other	438	0.22	-0.54 to 0.97		0.18	-0.15 to 0.51		-0.41	-0.70 to -0.11	
Highest level of education completed (missing=206)				0.496			0.158			<0.0001
University/TAFE[5]	10,491	0.27	0.12 to 0.42		0.16	0.09 to 0.22		-0.41	-0.46 to -0.35	
High school	3,306	0.46	0.18 to 0.74		0.26	0.14 to 0.39		-0.69	-0.80 to -0.59	
Did not complete high school	4,091	0.32	0.05 to 0.59		0.26	0.14 to 0.38		-0.76	-0.86 to -0.65	
IRSED				0.002			0.007			0.123
Most disadvantaged group	3,449	0.39	0.22 to 0.55		0.23	0.16 to 0.30		-0.50	-0.57 to -0.44	
2nd disadvantaged group	3,345	-0.06	-0.45 to 0.33		0.01	-0.17 to 0.18		-0.69	-0.84 to -0.54	
3rd disadvantaged group	3,763	-0.31	-0.69 to 0.07		0.03	-0.14 to 0.20		-0.55	-0.69 to -0.40	
4th disadvantaged group	3,683	0.51	0.28 to 0.74		0.30	0.20 to 0.41		-0.49	-0.57 to -0.40	
Least disadvantaged group	3,843	0.37	-0.16 to 0.89		0.10	-0.13 to 0.33		-0.64	-0.84 to -0.44	
Physical functional limitation (missing=3,123)				<0.0001			<0.001			0.301
Moderate	3,546	-0.48	-0.73 to -0.24		0.01	-0.09 to 0.12		-0.58	-0.68 to -0.49	
Minor	3,768	0.10	-0.13 to 0.33		0.21	0.11 to 0.32		-0.53	-0.62 to -0.44	
None	7,405	0.80	0.63 to 0.96		0.29	0.21 to 0.36		-0.50	-0.56 to -0.43	
Psychological distress (missing=355)				0.595			0.716			0.415
No	16,900	0.32	0.20 to 0.44		0.20	0.15 to 0.25		-0.52	-0.57 to -0.47	
Yes	812	0.16	-0.43 to 0.74		0.25	-0.01 to 0.51		-0.62	-0.85 to -0.39	
Body Mass Index (missing=857)				<0.0001			<0.0001			<0.0001
Under weight	244	0.30	-0.74 to 1.34		0.20	-0.26 to 0.66		-0.54	-0.94 to -0.14	
Healthy weight	7,541	0.69	0.51 to 0.86		0.33	0.26 to 0.41		-0.63	-0.69 to -0.56	
Overweight	6,852	0.25	0.07 to 0.44		0.21	0.13 to 0.29		-0.51	-0.58 to -0.44	
Obese	2,547	-0.83	-1.15 to -0.50		0.28	0.13 to 0.42		-0.22	-0.34 to -0.09	
Greenspace within 500m				0.476			0.354			0.715
0-5%	13,762	0.34	0.21 to 0.48		0.19	0.13 to 0.25		-0.51	-0.56 to -0.46	
>5-10%	2,657	0.16	-0.14 to 0.47		0.25	0.12 to 0.39		-0.55	-0.67 to -0.43	
>10-15%	1,341	0.19	-0.24 to 0.63		0.23	0.03 to 0.42		-0.61	-0.78 to -0.44	
>15%	334	0.61	-0.26 to 1.49		0.28	-0.11 to 0.66		-0.50	-0.83 to -0.17	
Greenspace within 1km				0.224			0.128			0.951
0-5%	10,948	0.37	0.22 to 0.52		0.20	0.14 to 0.27		-0.52	-0.58 to -0.46	
>5-10%	4,843	0.12	-0.11 to 0.35		0.15	0.05 to 0.25		-0.52	-0.61 to -0.43	
>10-15%	1,497	0.29	-0.13 to 0.70		0.31	0.13 to 0.49		-0.59	-0.75 to -0.43	
>15-20%	451	0.52	-0.22 to 1.26		0.08	-0.25 to 0.40		-0.52	-0.81 to -0.23	
>20%	355	0.94	0.10 to 1.79		0.59	0.22 to 0.96		-0.47	-0.79 to -0.15	
Greenspace within 2km				0.477			0.682			0.221
0-5%	7,789	0.33	0.15 to 0.51		0.16	0.08 to 0.24		-0.55	-0.62 to -0.48	
>5-10%	6,980	0.21	0.02 to 0.40		0.23	0.15 to 0.32		-0.50	-0.57 to -0.43	
>10-15%	2,157	0.44	0.10 to 0.78		0.25	0.10 to 0.40		-0.53	-0.65 to -0.40	
>15-20%	688	0.46	-0.14 to 1.06		0.14	-0.13 to 0.40		-0.36	-0.59 to -0.13	
>20%	480	0.75	0.03 to 1.48		0.36	0.04 to 0.68		-0.77	--1.04 to -0.49	

[1]Mean adjusted for baseline amount of time spent on MVPA per week.

[2]Mean adjusted for baseline amount of time spent on walking per week.

[3]Mean adjusted for baseline amount of time spent on sitting per week.

Baseline correlates of the outcomes

Table 2 presents the outcome variables at baseline by T2D group. The amount of time spent on MVPA at baseline was significantly higher among the "No type 2 diabetes" group. There were no significant differences in the amount of time spent on walking and sitting between New T2D and No type 2 diabetes.

Table 2: Outcome variables at baseline by T2D status

	New type 2 diabetes			No type 2 diabetes			Kruskal-Wallis, p-value
	Median	Mean	Interquartile range	Median	Mean	Interquartile range	
MVPA (hours/week)	6.00	8.13	2.52-11.67	7.25	9.13	3.67-13.00	0.006
Walking (hours/week)	2.00	2.99	0.50-4.00	2.00	2.95	0.83-4.00	0.538
Sitting (hours/week)	5.00	5.90	4.00-8.00	5.00	5.83	4.00-8.00	0.534

Although the interactions between access to greenspace for each buffer size and status of T2D was not statistically significant for each outcome variable except for the changes in MVPA with percentage of greenspace within 2km (p=0.039), the differences in trends between status of T2D were apparent as shown in Figure 4.

Greenspace and outcomes by diagnosis of type 2 diabetes

Figure 4 presents marginal mean changes in the amount of walking, MVPA and sitting, and associated 95% CI by proportion of greenspace. A change in the outcome variable of greater than zero indicates an increase in that outcome at the follow-up study relative to the baseline study. Regardless of diabetes status and buffer size, there were no associations between percentage of greenspace and changes in amount of walking and sitting. For example, the 95% CI of changes in the amount of walking were overlapping between each category of greenspace regardless of buffer size. Although there were no significant changes in amount of walking with the percentage of greenspace, increasing trends were apparent among New T2D which peaked at >15-20% of greenspace, whereas fairly stable trends were found among No type 2 diabetes. Similar trends were also found for changes in the amount of MVPA.

Among New type 2 diabetes, there was no significant association between the percentage of greenspace within 2km buffer and changes in amount of MVPA. However, increasing trend was apparent with the peak at >15-20% of greenspace. Among No type 2 diabetes, the changes in amount of MVPA remained fairly stable with increasing percentage of greenspace (Figure 4).

For changes in sitting time, there were no significant associations with percentage of greenspace regardless of buffer size. Among New type 2 diabetes, the changes in amount of sitting decreased at percentage of greenspace >10%. Among No type 2 diabetes, the changes in amount of sitting significantly decreased at follow-up and remained stable with increasing proportion of greenspace.

Figure 4: Change (with 95% CI) in outcomes by proportion of greenspace (Bonferroni method was applied for multiple comparison)

Discussion

This is the first study to explore environmental influences on the behaviours of people who transition into living with type 2 diabetes. Overall, we found that there was a lack of association between access to greenspace at baseline and change in walking, MVPA, and sitting time. We found no statistically significant interactions between access to greenspace and status of T2D for each outcome variable, except for the changes in MVPA with percentage of greenspace within 2km. Although no significant interactions were found, possibly due to the small sample size of those with newly diagnosed type 2 diabetes, the magnitude of changes in walking and MVPA increased as percentage of greenspace increased among New T2D while remain fairly stable among No type 2 diabetes. There was no significant association between greenspace and sitting time with fairly stable trends among both New T2D and No type 2 diabetes.

Among participants with newly diagnosed type 2 diabetes, there were gradual increases in walking and MVPA with increasing proportion of greenspace within 1km and 2km buffers. However, these increases in walking and MVPA were no longer evident with >20% greenspace. This may be because around half of the participants with more than 20% of greenspace within a 2km buffer (around 3% of the total sample) live near larger greenspace (area> 1km^2). These large greenspaces are mainly national parks and nature reserve that may have limited public access points. These areas are often located in suburbs on the outskirts of the city with minimal pedestrian or other infrastructure to facilitate the regular use of greenspace for physical activity [47]. Francis et al suggested that the type and functionality of the greenspace may be a salient factor in addition to quantity[48].

Furthermore, the lack of association found between greenspace and walking and MVPA may be due to the increased participation in fitness activities taken place outside of neighbourhood greenspace. Such fitness activities include aerobics, fitness, gym activities, Pilates, weight training and yoga.[49] In Australia, fitness centre /gym activities is the second most popular physical recreational activity after walking.[50] Similarly, a Dutch study [15] found no significant association between the amount of greenspace within 1km radius of respondents' home and meeting the Dutch public health recommendation for physical activity possibly due to a high density of fitness centres and so that access to greenspace is not a necessary condition for being physically active.[51]

The weak associations between sitting and proportion of greenspace may be due to the lack of detailed information on the setting and domains of sitting (home, car, work or recreation environment). In the 45 and up study, only total sitting time was measured at both baseline and follow-up. Self-reported total sitting time is subject to substantial measurement errors and does not distinguish occupational and transportation sitting from recreational sitting. Previous studies have found that correlates of sitting differed considerably by domain of sitting.[52] Sperlich et al found a weak association between sitting duration and access to parks and recreation facilities[53] and suggest that research investigating association between sitting time and environment should consider the diverse domains of sitting.[53]

Overall, the association between proportion of greenspace and change in physical activity appeared more prominent in New T2D than No type 2 diabetes. These findings suggest that greenspace may have more motivating effect on physical activity among those newly diagnosed with type 2 diabetes. Diabetes Australia recommends people with T2D start with at least thirty minutes of moderate physical activity every day or between sixty and ninety minutes every day if they are trying to lose weight.[54] However, it appears that proximity to greenspace alone may not be sufficient to meet Diabetes Australia recommendations for those with newly diagnosed type 2 diabetes.

The strengths of this study include a prospective design and a large population-based cohort study. Although diagnostic or clinical information was not available to confirm the diagnosis of T2D among participants, in this sample self-reported diagnosis of T2D has high sensitivity and specificity compared to hospital administrative data collections.[31] Having outcome measures at two time points only over two to five years has limited our ability to track changes in lifestyle behaviours over longer periods of time.

A few additional limitations apply. We were not able to differentiate between different domains of MVPA and sitting, such as recreational, transport or occupational physical activity and sitting. We also don't know whether each activity took place within the local greenspace. Further, greenspace included state forests and national parks which may or may not be conducive to walking and MVPA as urban parks and trails. We also could not categorise greenspace into more usable categories, for example, sports fields, bushland, presence of picnic facilities, etc., nor do we have access to the quality of the greenspace. Moreover, although we adjusted for a number of important potential confounders, there may yet be some residual confounding. However, we share this limitation with most other published studies on neighbourhoods and health.

Conclusion

This study indicates that neighbourhood greenspace is related to active lifestyles only to a very limited extent among people with newly diagnosed type 2 diabetes. This is particularly so when there is moderate amount of greenspace (15-20% of the neighbourhood). Future studies should consider including more comprehensive environmental measures about greenspace and other environmental attributes (e.g., recreational facilities), more specific measures of physical activity and sedentary behaviour, such as the domain and location of each activity, and the more follow-up measures over longer period of time.

Ethics approval

The baseline 45 and Up Study and the SEEF Study were approved by the University of New South Wales Human Research Ethics Committee and the University of Sydney Human Research Ethics Committee respectively.

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This research was completed using data collected through the 45 and Up Study (www.saxinstitute.org.au). The 45 and Up Study is managed by the Sax Institute in collaboration with major partner Cancer Council NSW; and partners: the National Heart Foundation of Australia (NSW Division); NSW Ministry of Health; NSW

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Contributors

Shanley Chong participated in the design of the study, carried out the statistical analyses and drafted the manuscript. Soumya Mazumdar participated in the design of the study, helped draft the manuscript, helped with the interpretation and revised the manuscript. Ding Ding helped draft the manuscript, helped with the interpretation of the data and revised the manuscript. Geoff Morgan, Elizabeth Comino and Adrian Bauman helped with the interpretation of the data and revised the manuscript. Bin Jalaludin supervised the study, helped draft the manuscript, helped with the interpretation of the data and revised the manuscript.

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Competing interests

None declared.

Ethics approval

The 45 and Up Study was granted ethical approval by the NSW Population & Health Services Research Ethic Committee (reference HREC/15/CIOHS/4) and the Cancer Institute NSW (reference 2015/02/575).

Data sharing statement

This research was completed using data collected through the 45 and Up Study (www.saxinstitute.org.au).

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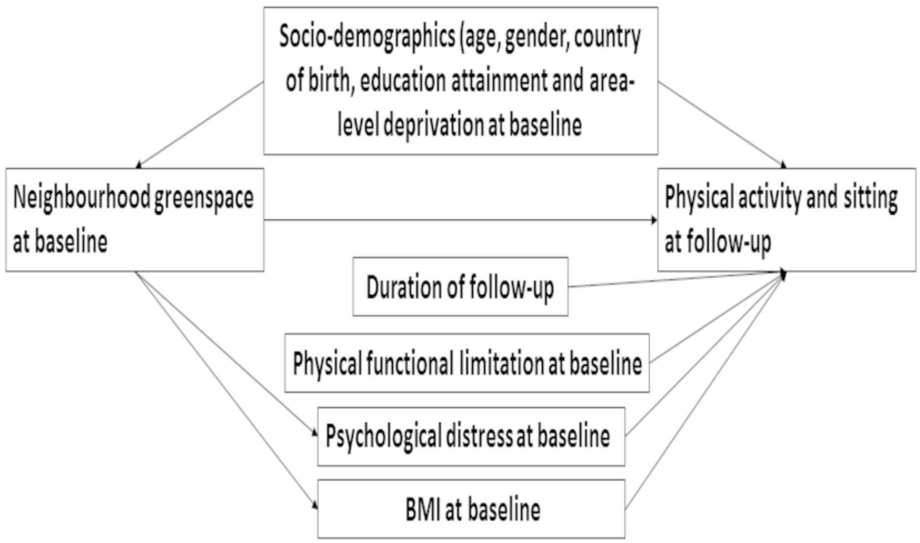

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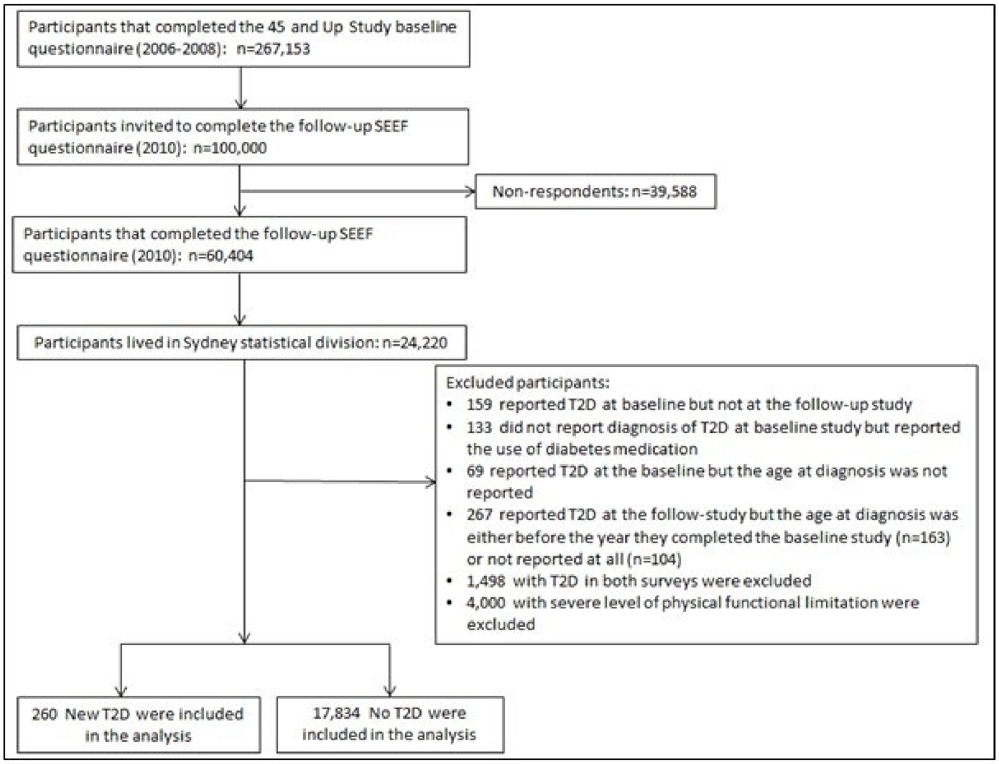

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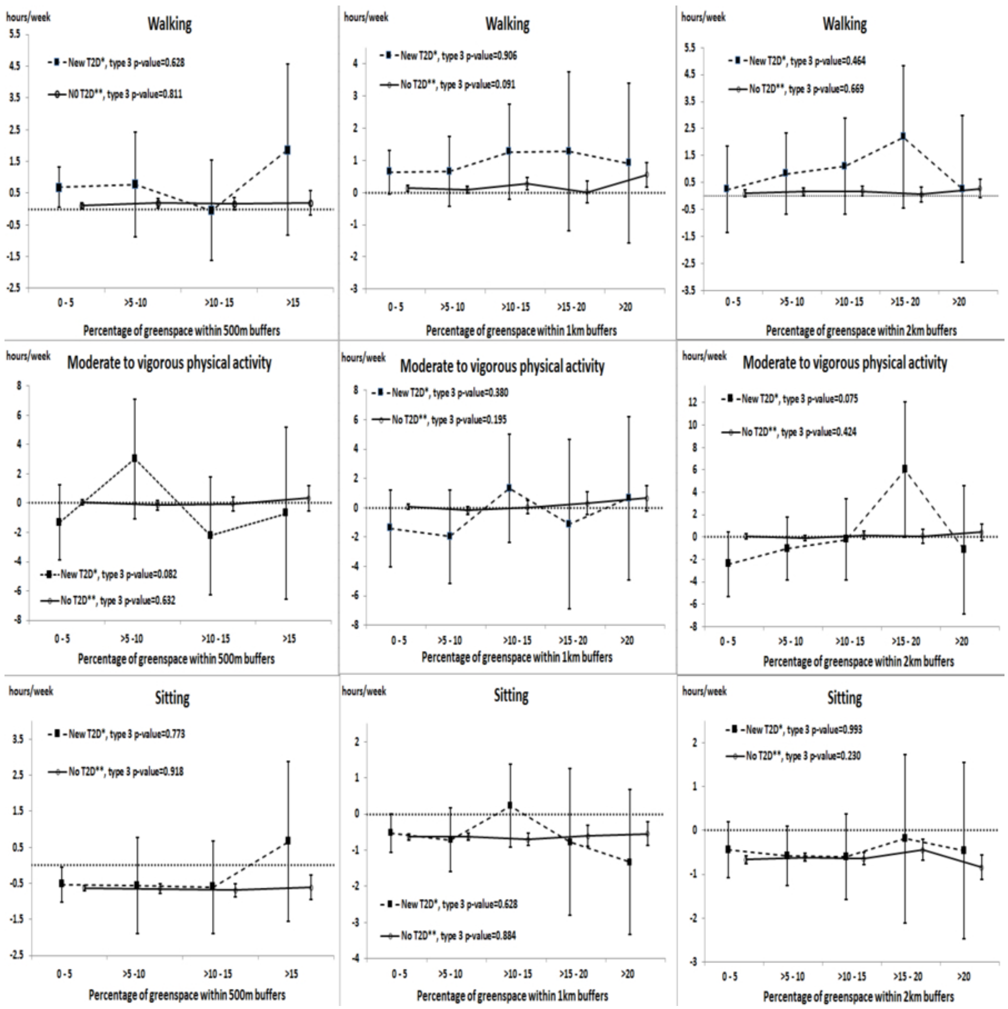

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