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# BMJ Open

## 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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SCHOLARONE™  
Manuscripts

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3 1 Full title: Neighbourhood greenspace and physical activity and sedentary behaviour  
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5 2 among older adults with a recent diagnosis of type 2 diabetes: A Prospective  
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7 3 analysis  
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For peer review only

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3 65 Abstract  
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6 66 Objectives:  
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9 67 Regular physical activity can reduce the risk of complications and mortality among  
10  
11 68 people with type 2 diabetes. Greenspace is one of the important factors that can  
12  
13 69 promote an active lifestyle. The aim of this study was to investigate the association  
14  
15 70 between access to greenspace and changes in physical activity and sedentary  
16  
17 71 behaviour among people with newly diagnosed T2D.  
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20  
21 72 Design: Prospective cohort.  
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24 73 Setting: New South Wales, Australia  
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26 74 Methods:  
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28  
29 75 We used self-reported information from the New South Wales 45 and Up Study  
30  
31 76 (baseline) and a follow-up study. Information on sitting, walking and moderate to  
32  
33 77 vigorous physical activity was used as outcomes. The proportion of greenspace  
34  
35 78 within 500m, 1km and 2km road network buffers around participant's residential  
36  
37 79 address was generated as a proxy measure for access to greenspace. The  
38  
39 80 association between the access to greenspace and the outcomes were explored  
40  
41 81 among the newly diagnosed T2D group and those without T2D.  
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43  
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45  
46 82 Results:  
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48  
49 83 Of the 18,094 participants, 1.4% reported type 2 diabetes in the follow-up survey but  
50  
51 84 not in the baseline survey (New type 2 diabetes) whereas 98.6% participants did not  
52  
53 85 report type 2 diabetes at both baseline and follow-up. Among New type 2 diabetes,  
54  
55 86 although no significant changes were found in the amount of walking with the  
56  
57 87 percentage of greenspace, increasing trends were apparent. There was a significant  
58  
59 88 association between the percentage of greenspace within 2km buffer and changes in  
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3 89 amount of MVPA. Among No type 2 diabetes, the changes in amount of MVPA and  
4  
5 90 walking remained fairly stable with increasing percentage of greenspace. For  
6  
7  
8 91 changes in sitting time, there were no significant associations with percentage of  
9  
10 92 greenspace regardless of buffer size.  
11  
12

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15 94 Conclusions:16  
17 95 This study indicates that neighbourhood greenspace is related to active lifestyles  
18  
19 96 only to a very limited extent among people with newly diagnosed type 2 diabetes.  
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22 97

23  
24  
25 98 Strengths and Limitations of this study

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- 28 99 • This is the first study to explore environmental influences on the behaviours of
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- 29
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- 30 100 people who transition into living with type 2 diabetes.
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- 32 101 • Other strength of this study include a prospective design and a large
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- 34 102 population-based cohort study.
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- 36 103 • Change in duration of physical activity and sitting were calculated from self-
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- 38 104 reported survey, at two time points.
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6 113 Introduction  
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9 114 Type 2 diabetes is a lifelong condition and is associated with increased risk for  
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11 115 cardiovascular, renal disease<sup>1</sup> and mortality.<sup>2,3</sup> A healthy lifestyle that includes, for  
12  
13 116 example regular physical activity, can help maintain healthy blood glucose levels and  
14  
15 117 reduce the risk of complications of type 2 diabetes.<sup>4-7</sup> However, only about half of  
16  
17 118 Australians with diabetes achieve adequate control of their blood glucose level.<sup>3</sup>  
18  
19  
20 119  
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22  
23 120 It is recommended that adults, including those diagnosed with type 2 diabetes  
24  
25 121 engage in at least 30 minutes of physical activity every day.<sup>8</sup> In a population-based  
26  
27 122 study in Australia, participants with incident type 2 diabetes reported lack of changes  
28  
29 123 in their walking and moderate to vigorous physical activity (MVPA) after their  
30  
31 124 diagnosis. Studies reported that 60% of people aged 35-64 years with diabetes  
32  
33 125 (types 1 and 2) were not achieving the recommended level of physical activity,<sup>9</sup> one  
34  
35 126 third of adults with type 2 diabetes were completely inactive<sup>10</sup> and only a third  
36  
37 127 exercised on regular basis.<sup>10</sup> Physical activity behaviour is determined by a range of  
38  
39 128 biological, psychosocial and environmental factors.<sup>11</sup> Built environment attributes  
40  
41 129 are frequently found to be associated with physical activity,<sup>12</sup> and activity-unfriendly  
42  
43 130 environments may be associated with higher type 2 diabetes incidence.<sup>13</sup> For  
44  
45 131 example, a study reported that one of the barriers among inactive patients with  
46  
47 132 diabetes (both type 1 and 2) was lack of local facilities.<sup>14</sup>  
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53 133  
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56 134 One environmental attribute that plays an important role in physical activity is  
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58 135 greenspace.<sup>15-17</sup> Greenspace is defined as any vegetated land adjoining an urban  
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3 136 area which includes bushland, nature reserves, national parks, outdoor sports fields,  
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5 137 school playgrounds and rural or semi-rural areas immediately adjoining an urban  
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8 138 area.<sup>18</sup> Several studies have found that people who have better access to parks and  
9  
10 139 green spaces are more likely to report that they engage in physical activity.<sup>19 20</sup> The  
11  
12 140 potential mechanism for these associations may be that greenspace prompts,  
13  
14 141 facilitates, and reinforces location-specific physical activity,<sup>21</sup> while simultaneously  
15  
16 142 discouraging sedentary lifestyles . Thus, greener surroundings may be a motivating  
17  
18 143 factor among people with newly diagnosed diabetes to engage in more physical  
19  
20 144 activity. Given that diagnosis of type 2 diabetes may serve as a window opportunity  
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22 145 for behavioural modification,<sup>22 23</sup> we hypothesise that the association between  
23  
24 146 neighbourhood greens pace and physical activity among people with newly  
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26 147 diagnosed type 2 diabetes may be greater than those never diagnosed with type 2  
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28 148 diabetes.

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36 150 Using data from a large cohort study in New South Wales (NSW), Australia, we  
37  
38 151 aimed to 1) investigate the associations between the access to neighbourhood  
39  
40 152 greenspace and changes in physical activity and sitting time in this large population-  
41  
42 153 based sample; and 2) examine whether the associations differed by type 2 diabetes  
43  
44 154 diagnosis status.

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## 49 156 Materials and Method

### 50 157 Study population

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54 158 The study area was the Sydney Statistical Division which has a population of  
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56 159 approximately 4.12 million people and covers an area of 12,428 square kilometres. It  
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3 160 is the largest urban agglomeration in Australia, with a wide range of environmental  
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5 161 features and diverse sociodemographic characteristics.  
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8 162 Information about physical activity and relevant covariates at the individual level was  
9  
10 163 obtained from the baseline 45 and Up Study and the Social, Economic and  
11  
12 164 Environmental Factors (SEEF) follow-up Study. The 45 and Up Study is a  
13  
14 165 population-based cohort survey of NSW residents aged 45 years and older.  
15  
16 166 Recruitment was undertaken between 2006 and 2009. Potential participants were  
17  
18 167 randomly selected from the Medicare Australia database (Australia's universal public  
19  
20 168 health insurance system). Participants joined the study by completing a mailed self-  
21  
22 169 administered questionnaire and providing consent for long-term follow-up, including  
23  
24 170 linkage to various personal health records. The full study cohort consists of 267,153  
25  
26 171 people aged 45 years or older at the time of recruitment. The response rate was  
27  
28 172 18% and participants comprised 11% of the NSW population aged 45 years and  
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30 173 over.<sup>24</sup>  
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39 175 In 2010, the SEEF Study questionnaire was distributed to the first 100,000  
40  
41 176 participants of the 45 and Up Study, of whom 60,404 returned the completed  
42  
43 177 questionnaire. The average follow-up period was  $3.3 \pm 0.9$  years (median=2.8 years,  
44  
45 178 range=1.7-5.1 years, inter-quartile range=2.6 to 4.6 years). Questionnaires for both  
46  
47 179 the 45 and Up and the SEEF Study are available from the Sax Institute website<sup>25</sup>. Of  
48  
49 180 the 60,404 participants, 24,220 resided in the study area at the time of the baseline  
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51 181 45 and Up Study.  
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3 183 The baseline 45 and Up and the SEEF Study were approved by the University of  
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5 184 New South Wales Human Research Ethics Committee and the University of Sydney  
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8 185 Human Research Ethics Committee respectively.  
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## 10 186 Measures

### 11 187 *Exposure: access to greenspace*

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16 188 We used the percentage of greenspace within 500m, 1km and 2km polygon-based  
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18 189 road network (PBRN) buffers around participants' residences (available for the  
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20  
21 190 baseline survey only) as proxies for geographic access to greenspace. These buffer  
22  
23 191 sizes were chosen as they are considered as walkable distance.<sup>26</sup>  
24  
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28 193 Greenspace data was obtained from StreetPro (PitneyBowers Inc., USA). In this  
29  
30 194 dataset, greenspace includes national parks, nature reserves, historic sites, state  
31  
32 195 forests, State recreation areas, wildlife refuges, conservation parks, protected areas,  
33  
34 196 wildlife reserves, urban recreation parks and other urban greenspaces. The PBRN  
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37 197 buffers were created using the StreetPro Navigation (PitneyBowers Inc., USA) road  
38  
39 198 network file and ArcGIS network analyst to calculate the endpoints of all possible  
40  
41 199 routes up to the specified distance (500m, 1km and 2km) along the road network for  
42  
43  
44 200 each participant's residence. The endpoints were then connected to form irregular  
45  
46 201 polygons. Percentage of greenspace within PBRN buffers were categorised into 0-  
47  
48 202 5%, >5-10%, >10-15%, >15-20% and >20%. We combined >15-20% and >20% for  
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50  
51 203 greenspace within 500m buffers due to the small sample sizes.  
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### 54 205 *Outcomes: sitting and physical activity*

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3 206 Information on sitting (hours per week), walking (minutes per week) and MVPA  
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5 207 (minutes per week) was collected in both surveys. Duration of sitting was adapted  
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7 208 from the International Physical Activity Questionnaire which has acceptable  
8  
9 209 reliability<sup>27</sup> and validity.<sup>27</sup> Physical activity was assessed using the Active Australia  
10  
11 210 Survey<sup>28</sup> which also has acceptable reliability<sup>29</sup> and validity.<sup>30</sup> In this instrument,  
12  
13 211 walking is defined as walking for recreation or exercise or to get to or from places.  
14  
15 212 Vigorous physical activity refers to any activity that causes a participant to breathe  
16  
17 213 harder or puff and pant. Moderate physical activity refers to less intense activities  
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19 214 such as gentle swimming, social tennis, vigorous gardening or work around the  
20  
21 215 house. Total weighted minutes of MVPA per week is calculated by the sum of  
22  
23 216 minutes of walking, moderate physical activity and twice the minutes of vigorous  
24  
25 217 physical activity.<sup>29</sup> Reported time spent on walking and MVPA greater than 14 hours  
26  
27 218 per day was considered as an impossible value and recoded to 14 hours.<sup>31</sup> We  
28  
29 219 conceptualised walking and total MVPA as two separate outcomes because walking  
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31 220 is expected to be more specifically related to neighbourhood greenspace while total  
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33 221 MVPA is commonly used as a measure of overall levels of health-enhancing physical  
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35 222 activity.  
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#### 224 *Moderator: type 2 diabetes diagnosis*

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48 225 New cases of type 2 diabetes were defined as those participants who did not report  
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50 226 T2D at the baseline survey but reported type 2 diabetes at the follow-up survey (New  
51  
52 227 type 2 diabetes). The comparator group was participants who did not report type 2  
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54 228 diabetes at both baseline and follow-up surveys (No type 2 diabetes). The questions  
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56 229 asked to determine a diagnosis of type 2 diabetes at the baseline survey were “Has  
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3 230 a doctor ever told you that you have diabetes” and “Have you taken Diabex,  
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5 231 Diaformin, Metformin for most of the last 4 weeks”.  
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11 233 Participants who reported that they had been told by a doctor that they had diabetes  
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13 234 were then also asked about their age at diagnosis. For participants with newly  
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15 235 diagnosed type 2 diabetes, the time lapse since diagnosis to completion of the SEEF  
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17 236 Study questionnaire was also calculated (age at time of completion of SEEF Study  
18  
19 237 questionnaire minus age at type 2 diabetes diagnosis). Self-reported diagnosis of  
20  
21 238 type 2 diabetes in the 45 and Up Study has high sensitivity (83.7%) and specificity  
22  
23 239 (97.7%) compared to administrative hospitalisation data <sup>32</sup>.  
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#### 241 *Covariates*

242 Participant reported socio-demographic characteristics, including age, gender,  
243 country of birth (English speaking countries, Europe, Middle-East, Asia, Other) and  
244 body mass index (BMI) were included as covariates in the regression models. We  
245 also included physical functioning (measured using the Medical Outcomes Study  
246 (MOS) Physical Functioning Scale; it ranges from 0 to 100 and was categorised into  
247 no limitation (100), minor limitation (95-99), moderate limitation (85-94), or severe  
248 limitation (0-84)) <sup>33</sup>, psychological distress (Kessler-10 (K10); a K10 score of  $\geq 22$   
249 reflects high or very high psychological distress<sup>34</sup>) and an area-level deprivation  
250 score as covariates in the model. Area-level deprivation was measured by 2006  
251 Index of Relative Socio-Economic Disadvantage (IRSED) quintiles at the postcode  
252 level. The IRSED was created by the Australian Bureau of Statistics to compare  
253 social and economic disadvantage across geographical areas in Australia. The index

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3 254 is derived from the 2006 Census variables such as income, educational attainment,  
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5 255 unemployment, and people working in unskilled occupations<sup>35</sup>.  
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17 259 *Statistical analysis*  
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19 260 The Kruskal-Wallis test was used to compare continuous baseline lifestyle variables  
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21 261 between type 2 diabetes groups. Separate multivariate linear regression models  
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23 262 were used to examine the association between greenspace access and change in  
24  
25 263 outcome variables (in MVPA, walking, and sitting). Only statistically significant  
26  
27 264 variables from univariate regression analyses were included in the final model to  
28  
29 265 account for any potential confounding. These variables were age, gender,  
30  
31 266 educational attainment, level of physical functional limitation, IRSED, BMI, duration  
32  
33 267 of type 2 diabetes diagnosis (New type 2 diabetes group only), follow-up time and  
34  
35 268 the baseline value of each outcome in specific models. To examine whether the  
36  
37 269 association between greenspace and change in outcome variables modified by the  
38  
39 270 presence of type 2 diabetes, a one-way interaction between the status of type 2  
40  
41 271 diabetes (New type 2 diabetes and No type 2 diabetes) and percentage of  
42  
43 272 greenspace was explored. We then developed regression models, stratified by the  
44  
45 273 presence of type 2 diabetes. Actual change values (i.e. marginal means) and  
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47 274 associated 95% confidence intervals (CIs) were reported. Statistical analyses were  
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49 275 conducted using SAS version 9.4 (SAS Institute, Cary, NC).  
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3 277 Considering that neighbourhood safety is a premise to walking despite access to  
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5 278 greenspace, for the walking outcome, we performed a sensitivity analysis by  
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8 279 neighbourhood safety. Perception of neighbourhood safety was only asked at the  
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10 280 follow-up survey using the following questions: “Does your area have a reputation for  
11  
12 281 being a safe place?” and “The crime rate in my neighbourhood makes it unsafe to go  
13  
14 282 on walks during the day”. For the second question, the responses were classified as  
15  
16 283 strongly agree/agree and disagree/strongly disagree. Due to the small number of  
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18 284 responses for the sensitivity analysis, percentage of greenspace of >10-15%, >15-  
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20 285 20% and >20% were combined into >10%.  
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## 26 287 Results

28 288 Of the 24,220 participants living in Sydney Statistical Division, 628 were excluded  
29  
30 289 due to inconsistent reporting between baseline and follow-up surveys, 1,498 were  
31  
32 290 excluded due to reporting type 2 diabetes at both baseline and follow-up and an  
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34 291 additional 4,000 were excluded because of severe level of physical function, making  
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36 292 physical activity challenging or infeasible, leaving 18,094 participants in the analytical  
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38 293 sample (Figure 1).  
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### 44 294 Figure 1: Flow chart of sample selection

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48 296 Of the 18,094 participants, 260 (1.4%) reported type 2 diabetes in the follow-up  
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50 297 survey but not in the baseline survey (New type 2 diabetes) whereas 17,834 (98.6%)  
51  
52 298 participants did not report type 2 diabetes at both baseline and follow-up (No type 2  
53  
54 299 diabetes). The average duration of time since diagnosis was  $1.8 \pm 1.1$  years  
55  
56 300 (median=1.7 years). More than half of all the participants were female (52.0%) and  
57  
58 301 the average age of participants was  $59.5 \pm 9.6$  years. The majority of participants  
59  
60



302 were born in an English speaking country (85.2%) and about one-quarter had not  
303 completed high school education (Table 1).

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

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

	n	Change in MVPA <sup>1</sup> (hours/week)			Change in walking <sup>2</sup> (hours/week)			Change in sitting <sup>3</sup> (hours/week)		
		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 <sup>5</sup>	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	
2 <sup>nd</sup> 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	
3 <sup>rd</sup> 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	
4 <sup>th</sup> 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

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### 313 Baseline correlates of the outcomes

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

319 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

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

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56 326 Greenspace and outcomes by diagnosis of type 2 diabetes  
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9 327 Figure 2 presents marginal mean changes in the amount of walking, MVPA and  
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11 328 sitting, and associated 95% CI by proportion of greenspace. A change in the  
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13 329 outcome variable of greater than zero indicates an increase in that outcome at the  
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15 330 follow-up study relative to the baseline study. Regardless of diabetes status and  
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17 331 buffer size, there were no associations between percentage of greenspace and  
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19 332 changes in amount of walking and sitting. For example, the 95% CI of changes in the  
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21 333 amount of walking overlapped between each category of greenspace regardless of  
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23 334 buffer size. Although there were no significant changes in amount of walking with the  
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25 335 percentage of greenspace, increasing trends were apparent among New type 2  
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27 336 diabetes which peaked at >15-20% of greenspace, whereas fairly stable trends were  
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29 337 found among No type 2 diabetes. Similar trends were also found for changes in the  
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31 338 amount of MVPA.  
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40 340 Among New type 2 diabetes, there was a significant association between the  
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42 341 percentage of greenspace within 2km buffer and changes in amount of MVPA. The  
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44 342 changes in MVPA at >15-20% of greenspace within 2km was significantly higher  
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46 343 than those with <15% of greenspace within 2km. Among No type 2 diabetes, the  
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48 344 changes in amount of MVPA remained fairly stable with increasing percentage of  
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50 345 greenspace (Figure 2).  
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3 347 For changes in sitting time, there were no significant associations with percentage of  
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5 348 greenspace regardless of buffer size. Among New type 2 diabetes, the changes in  
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7 349 amount of sitting decreased at percentage of greenspace >10%. Among No type 2  
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10 350 diabetes, the changes in amount of sitting significantly decreased at follow-up and  
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12 351 remained stable with increasing proportion of greenspace.  
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### 21 354 Sub-analysis

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24 355 In the sensitivity analysis (Figure 3), in participants who perceived their  
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26 356 neighbourhood as safe, the association between percentage of greenspace and  
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28 357 changes in amount of walking remained non-significant regardless of the buffer size.  
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30 358 Increasing trends were apparent for percentage of greenspace within 1km and 2km  
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32 359 buffers. Among participants who perceived their neighbourhood as unsafe, the  
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34 360 association between percentage of greenspace and changes in amount of walking  
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36 361 also remain non-significant regardless of the buffer size. However, there were  
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38 362 decreasing trends of walking within 500m and 1km buffer sizes for people who  
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40 363 perceived their neighbourhood to be unsafe. The decreasing trend was less  
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42 364 pronounced within a 2km buffer size.  
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48 365 Figure 2: Change (with 95% CI) in outcomes by proportion of greenspace  
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50 367 Figure 3: Change in walking by percentage of greenspace<sup>1</sup> among New type 2  
51 368 diabetes by perception of neighbourhood safety  
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### 53 54 55 370 Discussion 56 57 58 59 60

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3 371 This is the first study to explore environmental influences on the behaviours of  
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5 372 people who transition into living with type 2 diabetes. Overall, we found that there  
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7 373 was a lack of association between access to greenspace at baseline and change in  
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9 374 walking, MVPA, and sitting time. We found no statistically significant interactions  
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11 375 between access to greenspace and status of type 2 diabetes for each outcome  
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13 376 variable, except for the changes in MVPA with percentage of greenspace within 2km.  
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15 377 Although no significant interactions were found, possibly due to the small sample  
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17 378 size of those with newly diagnosed type 2 diabetes, the magnitude of changes in  
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19 379 walking and MVPA increased as percentage of greenspace increased among New  
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21 380 T2D while remain fairly stable among No type 2 diabetes. There was no significant  
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23 381 association between greenspace and sitting time with fairly stable trends among both  
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25 382 New type 2 diabetes and No type 2 diabetes.  
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34 384 Among participants with newly diagnosed type 2 diabetes, there were gradual  
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36 385 increases in walking and MVPA with increasing proportion of greenspace within 1km  
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38 386 and 2km buffers. However, these increases in walking and MVPA were no longer  
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40 387 evident with >20% greenspace. This may be because around half of the participants  
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42 388 with more than 20% of greenspace within a 2km buffer (around 3% of the total  
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44 389 sample) live near larger greenspace (area > 1km<sup>2</sup>). These large greenspaces are  
45  
46 390 mainly national parks and nature reserve that may have limited public access points.  
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48 391 These areas are often located in suburbs on the outskirts of the city with minimal  
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50 392 pedestrian or other infrastructure to facilitate the regular use of greenspace for  
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52 393 physical activity. In this regard, the type and functionality of the greenspace may be  
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54 394 a salient factor in addition to quantity<sup>36</sup>.  
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3 395 Furthermore, the lack of association found between greenspace and walking and  
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5 396 MVPA may be due to the increased participation in fitness activities taken place  
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7 397 outside of neighbourhood greenspace. Such fitness activities include aerobics,  
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10 398 fitness, gym activities, Pilates, weight training and yoga.<sup>37</sup> In Australia, fitness centre  
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12 399 /gym activities is the second most popular physical recreational activity after  
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14 400 walking.<sup>38</sup> Similarly, a Dutch study<sup>15</sup> found no significant association between the  
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16 401 amount of greenspace within 1km radius of respondents' home and meeting the  
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18 402 Dutch public health recommendation for physical activity possibly due to a high  
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20 403 density of fitness centres and so that access to greenspace is not a necessary  
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22 404 condition for being physically active.<sup>39</sup>  
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29 406 The weak associations between sitting and proportion of greenspace may be due to  
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31 407 the lack of detailed information on the setting and domains of sitting (home, car, work  
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33 408 or recreation environment). In the 45 and up study, only total sitting time was  
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35 409 measured at both baseline and follow-up. Self-reported total sitting time is subject to  
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37 410 substantial measurement errors and does not distinguish occupational and  
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39 411 transportation sitting from recreational sitting. Previous studies have found that  
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41 412 correlates of sitting differed considerably by domain of sitting.<sup>40</sup> Sperlich et al found  
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43 413 a weak association between sitting duration and access to parks and recreation  
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45 414 facilities<sup>41</sup> and suggest that research investigating association between sitting time  
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47 415 and environment should consider the diverse domains of sitting.<sup>41</sup>  
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55 417 Overall, the association between proportion of greenspace and change in physical  
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57 418 activity appeared more prominent in New type 2 diabetes than No type 2 diabetes.  
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59 419 These findings suggest that greenspace may have more motivating effect on

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3 420 physical activity among those newly diagnosed with type 2 diabetes. Diabetes  
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5 421 Australia recommends people with type 2 diabetes start with at least thirty minutes of  
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7 422 moderate physical activity every day or between sixty and ninety minutes every day  
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9 423 if they are trying to lose weight.<sup>42</sup> However, it appears that proximity to greenspace  
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11 424 alone may not be sufficient to meet Diabetes Australia recommendations for those  
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13 425 with newly diagnosed type 2 diabetes.  
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20 427 A sub-analysis among participants who perceived their neighbourhood as safe  
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22 428 showed similar results to the overall findings. Among participants who perceived  
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24 429 their neighbourhood as unsafe, decreasing trends for walking were found with  
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26 430 increasing greenspace proportion but this was less pronounced as the buffer size  
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28 431 increased. Chong et al have previously reported that perceptions of neighbourhood  
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30 432 safety modified the relationship between greenspace and psychological distress.<sup>43</sup> In  
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32 433 neighbourhoods perceived as unsafe more greenspace may exacerbate such  
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34 434 perceptions leading to less physical activity. This is because greenspace is  
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36 435 associated with lower population density, which in turn, means less passive  
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38 436 surveillance (e.g., “eyes on the street”) leading to worse perceived safety.  
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46 438 The strengths of this study include a prospective design and a large population-  
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48 439 based cohort study. Although diagnostic or clinical information was not available to  
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50 440 confirm the diagnosis of type 2 diabetes among participants, in this sample self-  
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52 441 reported diagnosis of type 2 diabetes has high sensitivity and specificity compared to  
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54 442 hospital administrative data collections.<sup>32</sup> Having outcome measures at two time  
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3 443 points only over two to five years has limited our ability to track changes in lifestyle  
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5 444 behaviours over longer periods of time.  
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11 446 A few additional limitations apply. We were not able to differentiate between different  
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13 447 domains of MVPA and sitting, such as recreational, transport or occupational  
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15 448 physical activity and sitting. We also don't know whether each activity took place  
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17 449 within the local greenspace. Further, greenspace included state forests and national  
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19 450 parks which may or may not be conducive to walking and MVPA as urban parks and  
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21 451 trails. We also could not categorise greenspace into more usable categories, for  
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23 452 example, sports fields, bushland, presence of picnic facilities, etc., nor do we have  
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25 453 access to the quality of the greenspace.  
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## 30 31 32 455 Conclusion

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35 456 This study indicates that neighbourhood greenspace is related to active lifestyles  
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37 457 only to a very limited extent among people with newly diagnosed type 2 diabetes.

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39 458 This is particularly so when there is moderate amount of greenspace (15-20% of the  
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41 459 neighbourhood). Future studies should consider including more comprehensive  
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43 460 environmental measures about greenspace and other environmental attributes (e.g.,  
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45 461 recreational facilities), more specific measures of physical activity and sedentary  
46  
47 462 behaviour, such as the domain and location of each activity, and the more follow-up  
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49 463 measures over longer period of time.  
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#### 21 22 474 Contributors

23  
24  
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26  
27 476 analyses. All authors helped draft the manuscript, helped with the interpretation of  
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29 477 the data and revised the manuscript.  
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#### 44 45 46 483 Competing interests

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49 484 None declared.  
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#### 53 54 486 Ethics approval

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3 487 The 45 and Up Study was granted ethical approval by the NSW Population & Health  
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5 488 Services Research Ethic Committee (reference HREC/15/CIOHS/4) and the Cancer  
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7 489 Institute NSW (reference 2015/02/575).  
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13 491 Data sharing statement

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16 492 No additional data are available.  
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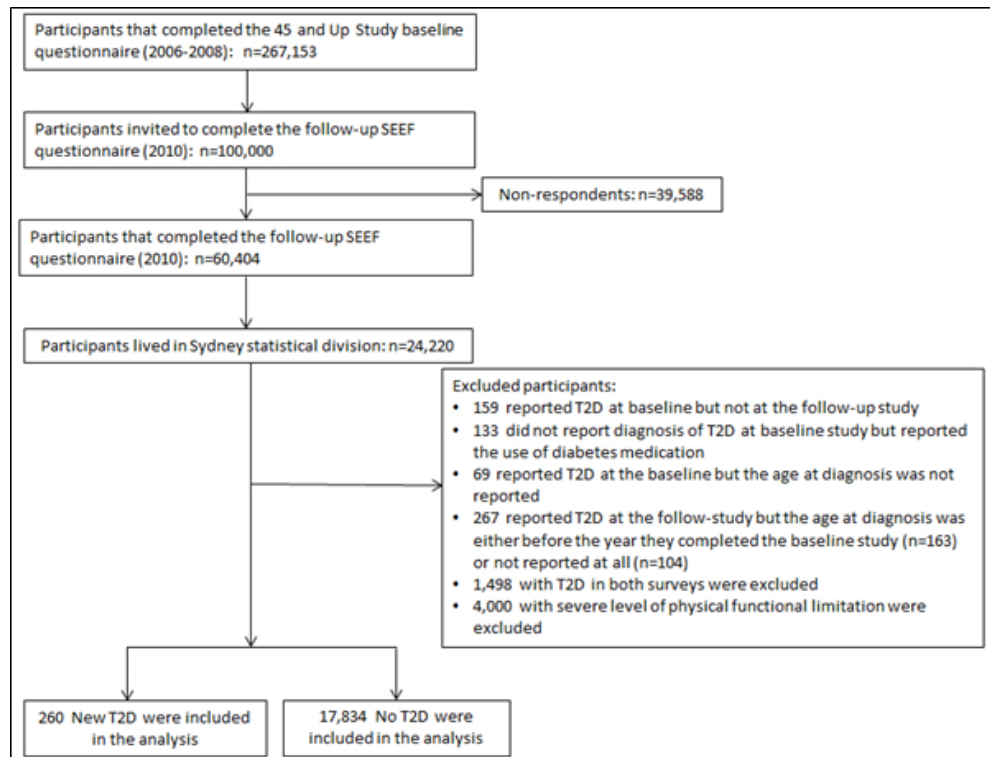
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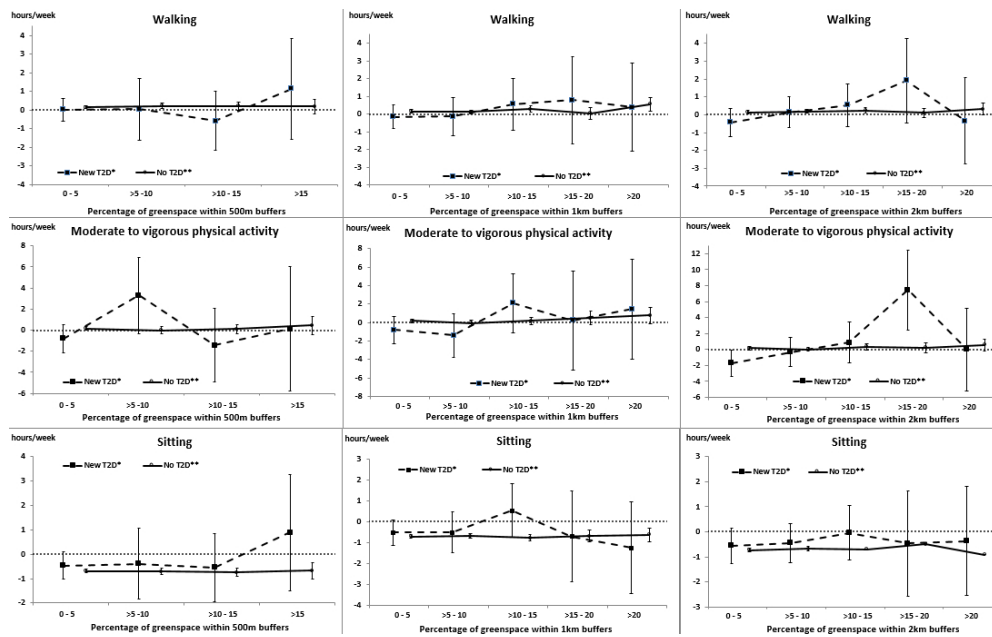
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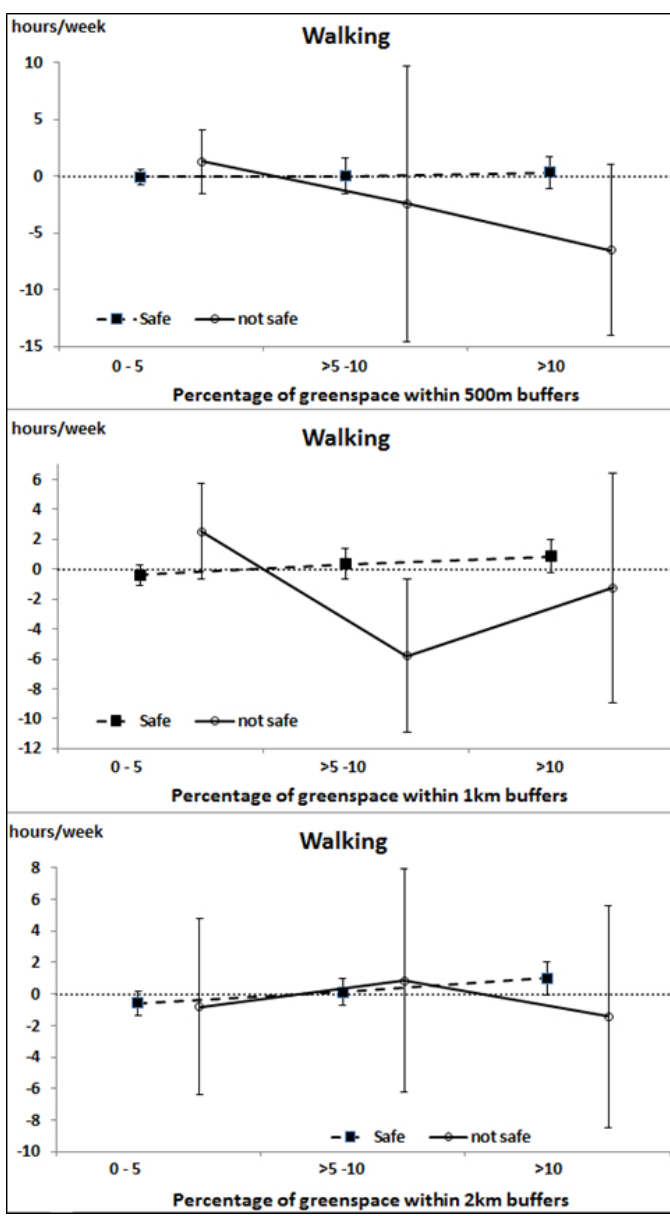


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# BMJ Open

## 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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<b>Primary Subject Heading</b>:	Diabetes and endocrinology
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3 1 Full title: Neighbourhood greenspace and physical activity and sedentary behaviour  
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5 2 among older adults with a recent diagnosis of type 2 diabetes: A Prospective  
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7 3 analysis  
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3 65 Abstract  
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6 66 Objectives:  
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9 67 Greenspace is one of the important factors that can promote an active lifestyle.

10  
11 68 Thus, greener surroundings may be a motivating factor for people with newly  
12  
13 69 diagnosed diabetes to engage in more physical activity. Given that diagnosis of type  
14  
15 70 2 diabetes (T2D) may serve as a window opportunity for behavioural modification,  
16  
17 71 we hypothesise that the association between neighbourhood greenspace and  
18  
19 72 physical activity among people with newly diagnosed T2D may be greater than those  
20  
21 73 not diagnosed with T2D. The aim of this study was to investigate the association  
22  
23 74 between access to greenspace and changes in physical activity and sedentary  
24  
25 75 behaviour, and whether these associations differed by T2D.  
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30 76 Design: Prospective cohort.  
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33 77 Setting: New South Wales, Australia  
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36 78 Methods:  
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39 79 We used self-reported information from the New South Wales 45 and Up Study  
40  
41 80 (baseline) and a follow-up study. Information on sitting, walking and moderate to  
42  
43 81 vigorous physical activity was used as outcomes. The proportion of greenspace  
44  
45 82 within 500m, 1km and 2km road network buffers around participant's residential  
46  
47 83 address was generated as a proxy measure for access to greenspace. The  
48  
49 84 association between the access to greenspace and the outcomes were explored  
50  
51 85 among the newly diagnosed T2D group and those without T2D.  
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55 86 Results:  
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58 87 Among New T2D, although no significant changes were found in the amount of  
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60 88 walking with the percentage of greenspace, increasing trends were apparent. There

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3 89 was a significant association between the percentage of greenspace within 2km  
4  
5 90 buffer and changes in amount of MVPA. Among No T2D, there were no significant  
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7 91 associations between the amount of MVPA and walking, and percentage of  
8  
9 92 greenspace. For changes in sitting time, there were no significant associations with  
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11 93 percentage of greenspace regardless of buffer size.  
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95 Conclusions:

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

98 Strengths and Limitations of this study

- 99
- 100 • This is the first study to explore environmental influences on the behaviours of  
101 people who transition into living with type 2 diabetes, and compare its  
102 association with those without T2DM.
  - 103 • This is a large population-based cohort with data available at two time points.
  - 104 • A limitation is that the change in duration of physical activity and sitting were  
105 calculated from self-reported surveys.
- 106  
107

108 Introduction

109 Type 2 diabetes is a lifelong condition and is associated with increased risk for  
110 cardiovascular, renal disease<sup>1</sup> and mortality.<sup>2,3</sup> A healthy lifestyle that includes, for  
111 example regular physical activity, can help maintain healthy blood glucose levels and

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3 112 reduce the risk of complications of type 2 diabetes.<sup>4-7</sup> However, only about half of  
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5 113 Australians with diabetes achieve adequate control of their blood glucose level.<sup>3</sup>  
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10 115 It is recommended that adults, including those diagnosed with type 2 diabetes  
11  
12 116 engage in at least 30 minutes of physical activity every day.<sup>8</sup> In a population-based  
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14 117 study in Australia, participants with incident type 2 diabetes reported lack of changes  
15  
16 118 in their walking and moderate to vigorous physical activity (MVPA) after their  
17  
18 119 diagnosis. Studies reported that 60% of people aged 35-64 years with diabetes  
19  
20 120 (types 1 and 2) were not achieving the recommended level of physical activity,<sup>9</sup> one  
21  
22 121 third of adults with type 2 diabetes were completely inactive<sup>10</sup> and only a third  
23  
24 122 exercised on regular basis.<sup>10</sup> Physical activity behaviour is determined by a range of  
25  
26 123 biological, psychosocial and environmental factors.<sup>11</sup> Built environment attributes  
27  
28 124 are frequently found to be associated with physical activity,<sup>12</sup> and activity-unfriendly  
29  
30 125 environments may be associated with higher type 2 diabetes incidence.<sup>13</sup> For  
31  
32 126 example, a study reported that one of the barriers among inactive patients with  
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34 127 diabetes (both type 1 and 2) was lack of local facilities.<sup>14</sup>  
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42  
43 129 One environmental attribute that plays an important role in physical activity is  
44  
45 130 greenspace.<sup>15-17</sup> Greenspace is defined as any vegetated land adjoining an urban  
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47 131 area which includes bushland, nature reserves, national parks, outdoor sports fields,  
48  
49 132 school playgrounds and rural or semi-rural areas immediately adjoining an urban  
50  
51 133 area.<sup>18</sup> Several studies have found that people who have better access to parks and  
52  
53 134 green spaces are more likely to report that they engage in physical activity.<sup>19 20</sup> The  
54  
55 135 potential mechanism for these associations may be that greenspace prompts,  
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57 136 facilitates, and reinforces location-specific physical activity,<sup>21</sup> while simultaneously

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3 137 discouraging sedentary lifestyles . Thus, greener surroundings may be a motivating  
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5 138 factor among people with newly diagnosed diabetes to engage in more physical  
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7 139 activity. Given that diagnosis of type 2 diabetes may serve as a window opportunity  
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10 140 for behavioural modification,<sup>22 23</sup> we hypothesise that the association between  
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12 141 neighbourhood greens pace and physical activity among people with newly  
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14 142 diagnosed type 2 diabetes may be greater than those never diagnosed with type 2  
15  
16 143 diabetes.

144

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

149

## 150 Materials and Method

### 151 Study population

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

156 Information about physical activity and relevant covariates at the individual level was  
157 obtained from the baseline 45 and Up Study and the Social, Economic and  
158 Environmental Factors (SEEF) follow-up Study. The 45 and Up Study is a  
159 population-based cohort survey of NSW residents aged 45 years and older.

160 Recruitment was undertaken between 2006 and 2009. Potential participants were

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3 161 randomly selected from the Medicare Australia database (Australia's universal public  
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5 162 health insurance system). Participants joined the study by completing a mailed self-  
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7 163 administered questionnaire and providing consent for long-term follow-up, including  
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10 164 linkage to various personal health records. The response rate was 18% and  
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12 165 participants comprised 11% of the NSW population aged 45 years and over.<sup>24</sup> The  
13  
14 166 full study cohort consists of 267,153 people aged 45 years or older at the time of  
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16  
17 167 recruitment.

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20 168  
21  
22 169 Figure 1: Sydney statistical division (1a) and 500m polygon-based network buffer  
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25 170 (1b).

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27 171 In 2010, the SEEF Study questionnaire was distributed to the first 100,000  
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29 172 participants of the 45 and Up Study, of whom 60,404 returned the completed  
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31 173 questionnaire. The average follow-up period was  $3.3 \pm 0.9$  years (median=2.8 years,  
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33 174 range=1.7-5.1 years, inter-quartile range=2.6 to 4.6 years). Questionnaires for both  
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35 175 the 45 and Up and the SEEF Study are available from the Sax Institute website<sup>25</sup>. Of  
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37 176 the 60,404 participants, 24,220 resided in the study area at the time of the baseline  
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39 177 45 and Up Study.

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46 179 The baseline 45 and Up and the SEEF Study were approved by the University of  
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48 180 New South Wales Human Research Ethics Committee and the University of Sydney  
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50 181 Human Research Ethics Committee respectively.

## 51 52 182 Measures

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55 183 *Exposure: access to greenspace*



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3 184 We used the percentage of greenspace within 500m, 1km and 2km polygon-based  
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5 185 road network (PBRN) buffers (Figure 1b) around participants' residences (available  
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7 186 for the baseline survey only) as proxies for geographic access to greenspace. These  
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10 187 buffer sizes were chosen as they are considered as walkable distance.<sup>26</sup>  
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12 188  
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14 189 Greenspace data was obtained from StreetPro (PitneyBowers Inc., USA). In this  
15  
16 190 dataset, greenspace includes national parks, nature reserves, historic sites, state  
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18 191 forests, State recreation areas, wildlife refuges, conservation parks, protected areas,  
19  
20 192 wildlife reserves, urban recreation parks and other urban greenspaces. The PBRN  
21  
22 193 buffers were created using the StreetPro Navigation (PitneyBowers Inc., USA) road  
23  
24 194 network file and ArcGIS network analyst to calculate the endpoints of all possible  
25  
26 195 routes up to the specified distance (500m, 1km and 2km) along the road network for  
27  
28 196 each participant's residence. The endpoints were then connected to form irregular  
29  
30 197 polygons. Percentage of greenspace within PBRN buffers were categorised into 0-  
31  
32 198 5%, >5-10%, >10-15%, >15-20% and >20%. We combined >15-20% and >20% for  
33  
34 199 greenspace within 500m buffers due to the small sample sizes.  
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#### 42 201 *Outcomes: duration of sitting and physical activity*

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45 202 Information on sitting (hours per week), walking (minutes per week) and MVPA  
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47 203 (minutes per week) was collected in both surveys. Duration of sitting was adapted  
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49 204 from the International Physical Activity Questionnaire which has acceptable  
50  
51 205 reliability<sup>27</sup> and validity.<sup>27</sup> Physical activity was assessed using the Active Australia  
52  
53 206 Survey<sup>28</sup> which also has acceptable reliability<sup>29</sup> and validity.<sup>30</sup> In this instrument,  
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55 207 walking is defined as walking for recreation or exercise or to get to or from places.  
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57 208 Vigorous physical activity refers to any activity that causes a participant to breathe  
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3 209 harder or puff and pant. Moderate physical activity refers to less intense activities  
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5 210 such as gentle swimming, social tennis, vigorous gardening or work around the  
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7 211 house. Total weighted minutes of MVPA per week is calculated by the sum of  
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9 212 minutes of walking, moderate physical activity and twice the minutes of vigorous  
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11 213 physical activity.<sup>29</sup> Reported time spent on walking and MVPA greater than 14 hours  
12  
13 214 per day was considered as an impossible value and recoded to 14 hours. <sup>31</sup> We  
14  
15 215 conceptualised walking and total MVPA as two separate outcomes because walking  
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17 216 is expected to be more specifically related to neighbourhood greenspace while total  
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19 217 MVPA is commonly used as a measure of overall levels of health-enhancing physical  
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21 218 activity.  
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### 29 220 *Type 2 diabetes diagnosis*

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32 221 New cases of type 2 diabetes were defined as those participants who did not report  
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34 222 T2D at the baseline survey but reported type 2 diabetes at the follow-up survey (New  
35  
36 223 type 2 diabetes). The comparator group was participants who did not report type 2  
37  
38 224 diabetes at both baseline and follow-up surveys (No type 2 diabetes). The questions  
39  
40 225 asked to determine a diagnosis of type 2 diabetes at the baseline survey were “Has  
41  
42 226 a doctor ever told you that you have diabetes” and “Have you taken Diabex,  
43  
44 227 Diaformin, Metformin for most of the last 4 weeks”.  
45  
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49 228  
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51 229 Participants who reported that they had been told by a doctor that they had diabetes  
52  
53 230 were then also asked about their age at diagnosis. For participants with newly  
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55 231 diagnosed type 2 diabetes, the time lapse since diagnosis to completion of the SEEF  
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57 232 Study questionnaire was also calculated (age at time of completion of SEEF Study  
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3 233 questionnaire minus age at type 2 diabetes diagnosis). Self-reported diagnosis of  
4  
5 234 type 2 diabetes in the 45 and Up Study has high sensitivity (83.7%) and specificity  
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8 235 (97.7%) compared to administrative hospitalisation data <sup>32</sup>.  
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### 13 237 *Covariates*

16 238 A directed acyclic graph (DAG) was used to select potential covariates (Figure 2) to  
17  
18 239 predict physical activity and duration of sitting, and likely influence where people  
19  
20 240 lived (and thus their neighbourhood exposure to greenspace). A list of covariates  
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22  
23 241 include socio-demographic characteristics (age, gender, country of birth (English  
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25 242 speaking countries, Europe, Middle-East, Asia, Other)) and an area-level deprivation  
26  
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28 243 score . Area-level deprivation was measured by 2006 Index of Relative Socio-  
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30 244 Economic Disadvantage (IRSED) quintiles at the postcode level. The IRSED was  
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32 245 created by the Australian Bureau of Statistics to compare social and economic  
33  
34 246 disadvantage across geographical areas in Australia. The index is derived from the  
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37 247 2006 Census variables such as income, educational attainment, unemployment, and  
38  
39 248 people working in unskilled occupations<sup>33</sup>.  
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42 249 We also included physical functioning (measured using the Medical Outcomes Study  
43  
44 250 (MOS) Physical Functioning Scale; it ranges from 0 to 100 and was categorised into  
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46 251 no limitation (100), minor limitation (95-99), moderate limitation (85-94), or severe  
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48  
49 252 limitation (0-84)) <sup>34</sup>, psychological distress (Kessler-10 (K10); a K10 score of  $\geq 22$   
50  
51 253 reflects high or very high psychological distress<sup>35</sup>) and body mass index (BMI) as  
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53 254 potential covariates.  
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55

56 255 Figure 2: Directed acyclic graph of the relationship between neighbourhood  
57 256 greenspace and physical activity and sitting.  
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56 259 *Statistical analysis*  
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9 260 The Kruskal-Wallis test was used to compare continuous baseline lifestyle variables  
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11 261 between type 2 diabetes groups. Separate multivariate linear regression models  
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13 262 were used to examine the association between greenspace access and change in  
14  
15 263 outcome variables (in MVPA, walking, and sitting). All the potential confounders  
16  
17 264 presented in DAG (Figure 2) were tested in univariate regression model. Only  
18  
19 265 statistically significant variables from univariate regression analyses were included in  
20  
21 266 the final model to account for any potential confounding. These variables were age,  
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23 267 gender, educational attainment, level of physical functional limitation, IRSED, BMI,  
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25 268 duration of type 2 diabetes diagnosis (New type 2 diabetes group only), follow-up  
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27 269 time and the baseline value of each outcome in specific models. To examine  
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29 270 whether the association between greenspace and change in outcome variables  
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31 271 modified by the presence of type 2 diabetes, a two-way interaction between the  
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33 272 status of type 2 diabetes (New type 2 diabetes and No type 2 diabetes) and  
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35 273 percentage of greenspace was explored. We then developed regression models,  
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37 274 stratified by the presence of type 2 diabetes. Predicted values of change and  
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39 275 associated 95% confidence intervals (CIs) were reported. To adjust for multiple  
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41 276 comparison, Bonferroni method were used in the final models. Statistical analyses  
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43 277 were conducted using SAS version 9.4 (SAS Institute, Cary, NC).  
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5253 279  
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5556 280 **Results**  
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3 281 Of the 24,220 participants living in Sydney Statistical Division, 628 were excluded  
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5 282 due to inconsistent reporting between baseline and follow-up surveys, 1,498 were  
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7 283 excluded due to reporting type 2 diabetes at both baseline and follow-up and an  
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10 284 additional 4,000 were excluded because of severe level of physical function, making  
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12 285 physical activity challenging or infeasible, leaving 18,094 participants in the analytical  
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14 286 sample (Figure 3).

17 287 Figure 3: Flow chart of sample selection  
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19 288

21 289 Of the 18,094 participants, 260 (1.4%) reported type 2 diabetes in the follow-up  
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23 290 survey but not in the baseline survey (New type 2 diabetes) whereas 17,834 (98.6%)  
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25 291 participants did not report type 2 diabetes at both baseline and follow-up (No type 2  
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27 292 diabetes). The average duration of time since diagnosis was  $1.8 \pm 1.1$  years  
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29 293 (median=1.7 years). More than half of all the participants were female (52.0%) and  
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31 294 the average age of participants was  $59.5 \pm 9.6$  years. The majority of participants  
32  
33 295 were born in an English speaking country (85.2%) and about one-quarter had not  
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35 296 completed high school education (Table 1).

41 297 Table 1 shows changes in outcome variables at follow-up by baseline  
42  
43 298 sociodemographic characteristics and access to greenspace. There were significant  
44  
45 299 associations of age group, IRSED, physical functional limitation, BMI, with change in  
46  
47 300 the amount of walking and MVPA. Significant associations were also found between  
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49 301 gender and change in the amount of walking and sitting. Educational attainment was  
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51 302 significantly associated with a change in sitting time. There were no significant  
52  
53 303 associations between greenspace and changes in MVPA, walking and sitting.

58 304 Table 1: Changes in outcome variables at follow-up by baseline characteristics

		Change in MVPA <sup>1</sup> (hours/week)	Change in walking <sup>2</sup> (hours/week)	Change in sitting <sup>3</sup>
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								(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 <sup>5</sup>	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	
2 <sup>nd</sup> 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	
3 <sup>rd</sup> 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	
4 <sup>th</sup> 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	

305 <sup>1</sup>Mean adjusted for baseline amount of time spent on MVPA per week.

306 <sup>2</sup>Mean adjusted for baseline amount of time spent on walking per week.

307 <sup>3</sup>Mean adjusted for baseline amount of time spent on sitting per week.

308 Baseline correlates of the outcomes

309  
310 Table 2 presents the outcome variables at baseline by type 2 diabetes group. The  
311 amount of time spent on MVPA at baseline was significantly higher among the “No  
312 type 2 diabetes” group. There were no significant differences in the amount of time  
313 spent on walking and sitting between New type 2 diabetes and No type 2 diabetes.

314 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

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

322 Greenspace and outcomes by diagnosis of type 2 diabetes

323 Figure 4 presents marginal mean changes in the amount of walking, MVPA and  
324 sitting, and associated 95% CI by proportion of greenspace. A change in the  
325 outcome variable of greater than zero indicates an increase in that outcome at the  
326 follow-up study relative to the baseline study. Regardless of diabetes status and  
327 buffer size, there were no associations between percentage of greenspace and  
328 changes in amount of walking and sitting. For example, the 95% CI of changes in the  
329 amount of walking overlapped between each category of greenspace regardless of



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3 330 buffer size. Although there were no significant changes in amount of walking with the  
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5 331 percentage of greenspace, increasing trends were apparent among New type 2  
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7 332 diabetes which peaked at >15-20% of greenspace, whereas fairly stable trends were  
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9 333 found among No type 2 diabetes. Similar trends were also found for changes in the  
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11 334 amount of MVPA.  
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18 336 Among New type 2 diabetes, there was a significant association between the  
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20 337 percentage of greenspace within 2km buffer and changes in amount of MVPA. The  
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22 338 changes in MVPA at >15-20% of greenspace within 2km was significantly higher  
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24 339 than those with <15% of greenspace within 2km. Among No type 2 diabetes, the  
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26 340 changes in amount of MVPA remained fairly stable with increasing percentage of  
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28 341 greenspace (Figure 4).  
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36 343 For changes in sitting time, there were no significant associations with percentage of  
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38 344 greenspace regardless of buffer size. Among New type 2 diabetes, the changes in  
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40 345 amount of sitting decreased at percentage of greenspace >10%. Among No type 2  
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42 346 diabetes, the changes in amount of sitting significantly decreased at follow-up and  
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44 347 remained stable with increasing proportion of greenspace.  
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51 349 Figure 4: Change (with 95% CI) in outcomes by proportion of greenspace (Bonferroni  
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53 350 method was applied for multiple comparison)  
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58 353 Discussion  
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3 354 This is the first study to explore environmental influences on the behaviours of  
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5 355 people who transition into living with type 2 diabetes. Overall, we found that there  
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7 356 was a lack of association between access to greenspace at baseline and change in  
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10 357 walking, MVPA, and sitting time. We found no statistically significant interactions  
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12 358 between access to greenspace and status of type 2 diabetes for each outcome  
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14 359 variable, except for the changes in MVPA with percentage of greenspace within 2km.  
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17 360 Although no significant interactions were found, possibly due to the small sample  
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19 361 size of those with newly diagnosed type 2 diabetes, the magnitude of changes in  
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21 362 walking and MVPA increased as percentage of greenspace increased among New  
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23 363 T2D while remain fairly stable among No type 2 diabetes. There was no significant  
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25 364 association between greenspace and sitting time with fairly stable trends among both  
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28 365 New type 2 diabetes and No type 2 diabetes.  
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34 367 Among participants with newly diagnosed type 2 diabetes, there were gradual  
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36 368 increases in walking and MVPA with increasing proportion of greenspace within 1km  
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38 369 and 2km buffers. However, these increases in walking and MVPA were no longer  
39  
40 370 evident with >20% greenspace. This may be because around half of the participants  
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42 371 with more than 20% of greenspace within a 2km buffer (around 3% of the total  
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44 372 sample) live near larger greenspace (area > 1km<sup>2</sup>). These large greenspaces are  
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46 373 mainly national parks and nature reserve that may have limited public access points.  
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48 374 These areas are often located in suburbs on the outskirts of the city with minimal  
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50 375 pedestrian or other infrastructure to facilitate the regular use of greenspace for  
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52 376 physical activity<sup>36</sup>. Francis et al suggested that the type and functionality of the  
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54 377 greenspace may be a salient factor in addition to quantity<sup>37</sup>.  
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3 379 Furthermore, the lack of association found between greenspace and walking and  
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5 380 MVPA may be due to the increased participation in fitness activities taken place  
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7 381 outside of neighbourhood greenspace. Such fitness activities include aerobics,  
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9 382 fitness, gym activities, Pilates, weight training and yoga.<sup>38</sup> In Australia, fitness centre  
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11 383 /gym activities is the second most popular physical recreational activity after  
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13 384 walking.<sup>39</sup> Similarly, a Dutch study<sup>15</sup> found no significant association between the  
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15 385 amount of greenspace within 1km radius of respondents' home and meeting the  
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17 386 Dutch public health recommendation for physical activity possibly due to a high  
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19 387 density of fitness centres and so that access to greenspace is not a necessary  
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21 388 condition for being physically active.<sup>40</sup>  
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29 390 The weak associations between sitting and proportion of greenspace may be due to  
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31 391 the lack of detailed information on the setting and domains of sitting (home, car, work  
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33 392 or recreation environment). In the 45 and up study, only total sitting time was  
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35 393 measured at both baseline and follow-up. Self-reported total sitting time is subject to  
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37 394 substantial measurement errors and does not distinguish occupational and  
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39 395 transportation sitting from recreational sitting. Previous studies have found that  
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41 396 correlates of sitting differed considerably by domain of sitting.<sup>41</sup> Sperlich et al found  
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43 397 a weak association between sitting duration and access to parks and recreation  
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45 398 facilities<sup>42</sup> and suggest that research investigating association between sitting time  
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47 399 and environment should consider the diverse domains of sitting.<sup>42</sup>  
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55 401 Overall, the association between proportion of greenspace and change in physical  
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57 402 activity appeared more prominent in New type 2 diabetes than No type 2 diabetes.  
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59 403 These findings suggest that greenspace may have more motivating effect on

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3 404 physical activity among those newly diagnosed with type 2 diabetes. Diabetes  
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5 405 Australia recommends people with type 2 diabetes start with at least thirty minutes of  
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7 406 moderate physical activity every day or between sixty and ninety minutes every day  
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9 407 if they are trying to lose weight.<sup>43</sup> However, it appears that proximity to greenspace  
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11 408 alone may not be sufficient to meet Diabetes Australia recommendations for those  
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13 409 with newly diagnosed type 2 diabetes.  
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23 412 The strengths of this study include a prospective design and a large population-  
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25 413 based cohort study. Although diagnostic or clinical information was not available to  
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27 414 confirm the diagnosis of type 2 diabetes among participants, in this sample self-  
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29 415 reported diagnosis of type 2 diabetes has high sensitivity and specificity compared to  
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31 416 hospital administrative data collections.<sup>32</sup> Having outcome measures at two time  
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33 417 points only over two to five years has limited our ability to track changes in lifestyle  
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35 418 behaviours over longer periods of time.  
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42 420 A few additional limitations apply. We were not able to differentiate between different  
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44 421 domains of MVPA and sitting, such as recreational, transport or occupational  
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46 422 physical activity and sitting. We also don't know whether each activity took place  
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48 423 within the local greenspace. Further, greenspace included state forests and national  
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50 424 parks which may or may not be conducive to walking and MVPA as urban parks and  
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52 425 trails. We also could not categorise greenspace into more usable categories, for  
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54 426 example, sports fields, bushland, presence of picnic facilities, etc., nor do we have  
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56 427 access to the quality of the greenspace. Moreover, although we adjusted for a  
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3 428 number of important potential confounders, there may yet be some residual  
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5 429 confounding. However, we share this limitation with most other published studies on  
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7 430 neighbourhoods and health.  
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## 11 432 Conclusion

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15 433 This study indicates that neighbourhood greenspace is related to active lifestyles  
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17 434 only to a very limited extent among people with newly diagnosed type 2 diabetes.  
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19 435 This is particularly so when there is moderate amount of greenspace (15-20% of the  
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21 436 neighbourhood). Future studies should consider including more comprehensive  
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23 437 environmental measures about greenspace and other environmental attributes (e.g.,  
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25 438 recreational facilities), more specific measures of physical activity and sedentary  
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27 439 behaviour, such as the domain and location of each activity, and the more follow-up  
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29 440 measures over longer period of time.  
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37 441

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39  
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41  
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43  
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45  
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## 61 451 Contributors

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3 452 Shanley Chong participated in the design of the study, carried out the statistical  
4  
5 453 analyses and drafted the manuscript. Soumya Mazumdar participated in the design  
6  
7 454 of the study, helped draft the manuscript, helped with the interpretation and revised  
8  
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10  
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13 457 Bauman helped with the interpretation of the data and revised the manuscript. Bin  
14  
15 458 Jalaludin supervised the study, helped draft the manuscript, helped with the  
16  
17 459 interpretation of the data and revised the manuscript.  
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464

464

#### 465 Competing interests

466 None declared.  
467

467

#### 468 Ethics approval

469 The 45 and Up Study was granted ethical approval by the NSW Population & Health  
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#### 473 Data sharing statement

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3 474 This research was completed using data collected through the 45 and Up Study  
4  
5 475 (www.saxinstitute.org.au).  
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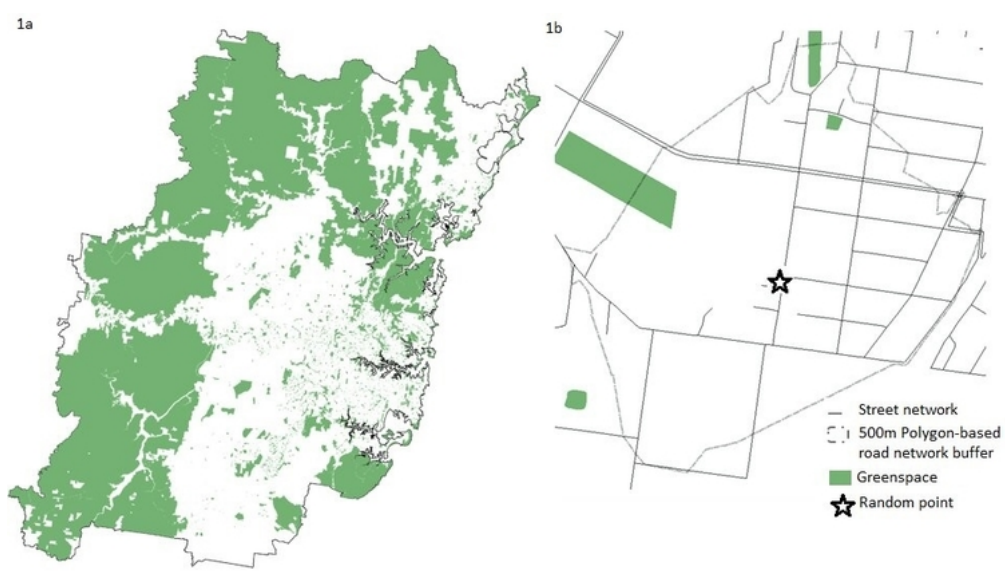
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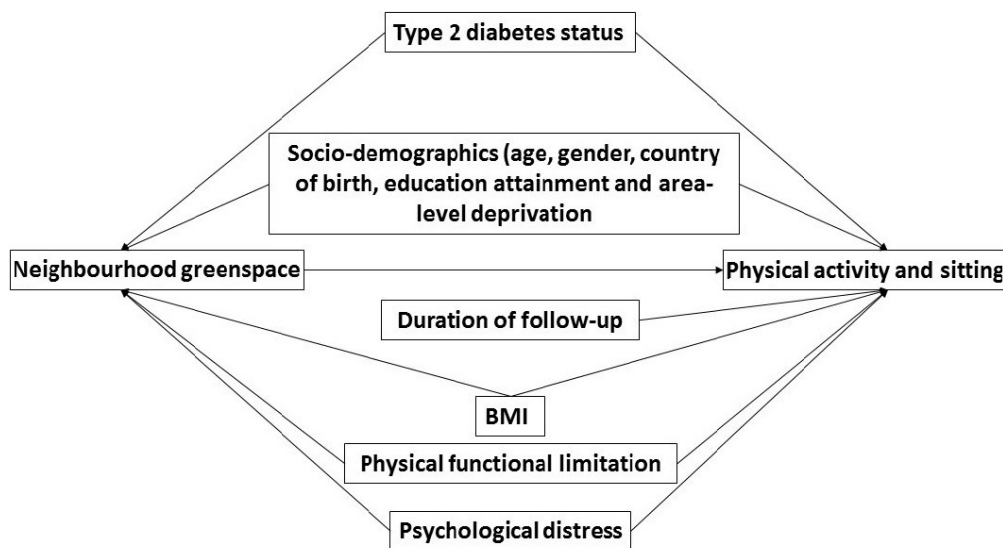
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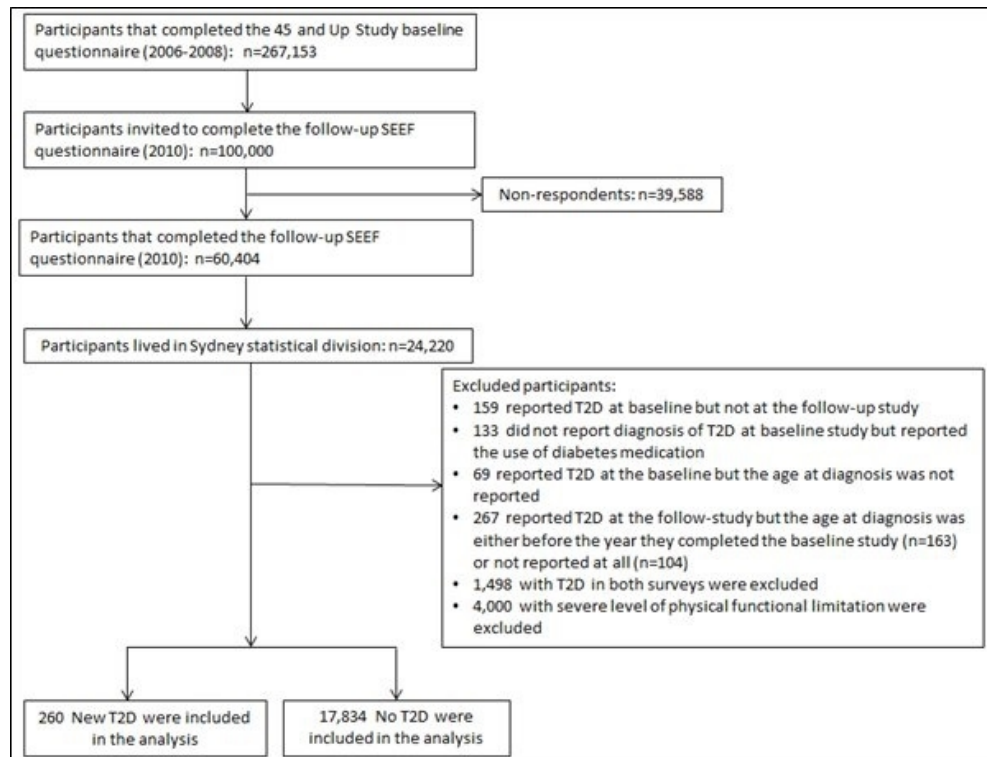
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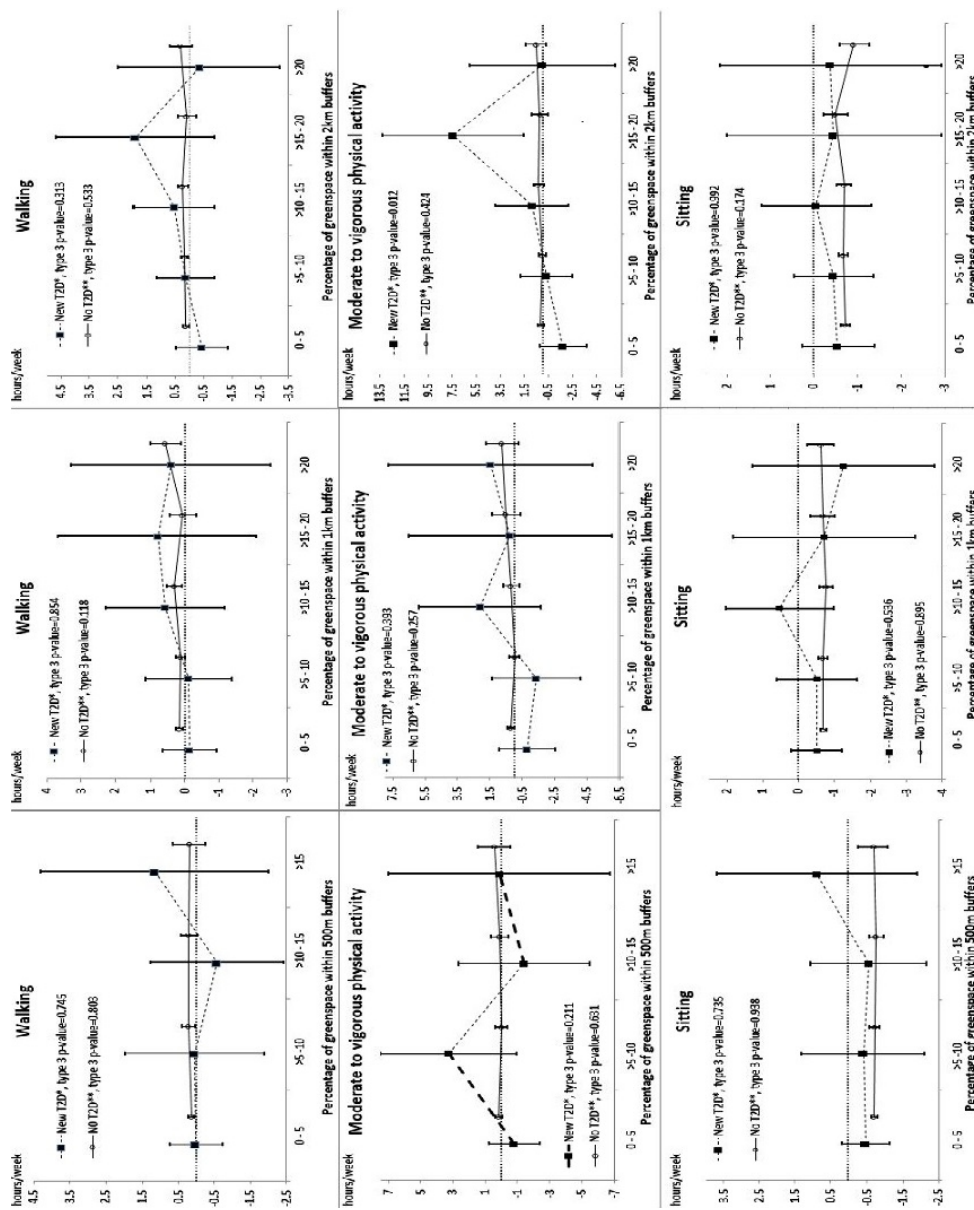
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# BMJ Open

## 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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<b>Primary Subject Heading</b>:	Diabetes and endocrinology
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Keywords:	physical activity, diabetes, green space

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Manuscripts

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5 2 among older adults with a recent diagnosis of type 2 diabetes: A Prospective  
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For peer review only



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3 65 Abstract  
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6 66 Objectives:  
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9 67 Greenspace is one of the important factors that can promote an active lifestyle.

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11 68 Thus, greener surroundings may be a motivating factor for people with newly

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13 69 diagnosed diabetes to engage in more physical activity. Given that diagnosis of type

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15 70 2 diabetes (T2D) may serve as a window opportunity for behavioural modification,

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17 71 we hypothesise that the association between neighbourhood greenspace and

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19 72 physical activity among people with newly diagnosed T2D may be greater than those

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21 73 not diagnosed with T2D. The aim of this study was to investigate the association

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23 74 between access to greenspace and changes in physical activity and sedentary

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25 75 behaviour, and whether these associations differed by T2D.  
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29 76 Design: Prospective cohort.  
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32 77 Setting: New South Wales, Australia  
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36 78 Methods:  
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39 79 We used self-reported information from the New South Wales 45 and Up Study

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41 80 (baseline) and a follow-up study. Information on sitting, walking and moderate to

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43 81 vigorous physical activity was used as outcomes. The proportion of greenspace

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45 82 within 500m, 1km and 2km road network buffers around participant's residential

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47 83 address was generated as a proxy measure for access to greenspace. The

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49 84 association between the access to greenspace and the outcomes were explored

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51 85 among the newly diagnosed T2D group and those without T2D.  
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55 86 Results:  
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58 87 Among New T2D, although no significant changes were found in the amount of

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60 88 walking with the percentage of greenspace, increasing trends were apparent. There

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3 89 was no significant association between the percentage of greenspace and changes  
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5 90 in amount of MVPA. Among No T2D, there were no significant associations between  
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7 91 the amount of MVPA and walking, and percentage of greenspace. For changes in  
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9 92 sitting time, there were no significant associations with percentage of greenspace  
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11 93 regardless of buffer size.  
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#### 17 95 Conclusions:

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19 96 In this study, there was no association between access to greenspace at baseline  
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21 97 and change in walking, MVPA, and sitting time, regardless of T2D status.  
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#### 25 98 Strengths and Limitations of this study

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- 28 100 • This is the first study to explore environmental influences on the behaviours of  
29 101 people who transition into living with T2D, and compare its association with  
30 102 those without T2DM.  
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32 103 • This is a large population-based cohort with data available at two time points.  
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34 104 • A limitation is that the change in duration of physical activity and sitting were  
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36 105 calculated from self-reported surveys.  
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#### 109 Introduction

110 Type 2 diabetes (T2D) is a lifelong condition and is associated with increased risk for  
111 cardiovascular, renal disease<sup>1</sup> and mortality.<sup>2,3</sup> A healthy lifestyle that includes, for  
example, regular physical activity, can help maintain healthy blood glucose levels

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3 112 and reduce the risk of complications of T2D.<sup>4-7</sup> However, only about half of  
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5 113 Australians with diabetes achieve adequate control of their blood glucose level.<sup>3</sup>  
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10 115 It is recommended that adults, including those diagnosed with T2D engage in at  
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12 116 least 30 minutes of physical activity every day.<sup>8</sup> In a population-based study in  
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14 117 Australia, participants with incident T2D reported lack of changes in their walking and  
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16 118 moderate to vigorous physical activity (MVPA) after their diagnosis. Studies reported  
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18 119 that 60% of people aged 35-64 years with diabetes (types 1 and 2) were not  
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20 120 achieving the recommended level of physical activity,<sup>9</sup> one third of adults with T2D  
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22 121 were completely inactive<sup>10</sup> and only a third exercised on regular basis.<sup>10</sup> Physical  
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24 122 activity behaviour is determined by a range of biological, psychosocial and  
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26 123 environmental factors.<sup>11</sup> Built environment attributes are frequently found to be  
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28 124 associated with physical activity,<sup>12</sup> and activity-unfriendly environments may be  
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30 125 associated with higher T2D incidence.<sup>13</sup> For example, a study reported that one of  
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32 126 the barriers among inactive patients with diabetes (both type 1 and 2) was lack of  
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34 127 local facilities.<sup>14</sup>  
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43 129 One environmental attribute that plays an important role in physical activity is  
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45 130 greenspace.<sup>15-17</sup> Greenspace is defined as any vegetated land adjoining an urban  
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47 131 area which includes bushland, nature reserves, national parks, outdoor sports fields,  
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49 132 school playgrounds and rural or semi-rural areas immediately adjoining an urban  
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51 133 area.<sup>18</sup> Several studies have found that people who have better access to parks and  
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53 134 green spaces are more likely to report that they engage in physical activity.<sup>19 20</sup> The  
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55 135 potential mechanism for these associations may be that greenspace prompts,  
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57 136 facilitates, and reinforces location-specific physical activity,<sup>21</sup> while simultaneously  
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3 137 discouraging sedentary lifestyles . Thus, greener surroundings may be a motivating  
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5 138 factor among people with newly diagnosed diabetes to engage in more physical  
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7 139 activity. Given that diagnosis of T2D may serve as a window opportunity for  
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10 140 behavioural modification,<sup>22 23</sup> we hypothesise that the association between  
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12 141 neighbourhood greens pace and physical activity among people with newly  
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14 142 diagnosed T2D may be greater than those never diagnosed with type 2 diabetes.  
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20 144 Using data from a large cohort study in New South Wales (NSW), Australia, we  
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22 145 aimed to investigate the associations between the access to neighbourhood  
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24 146 greenspace and changes in physical activity and sitting time by T2D diagnosis  
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26 147 status.  
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## 30 31 32 149 Materials and Method

### 33 34 35 150 Study population

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38 151 The study area was the Sydney Statistical Division (Figure 1a) which has a  
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40 152 population of approximately 4.12 million people and covers an area of 12,428 square  
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42 153 kilometres. It is the largest urban agglomeration in Australia, with a wide range of  
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44 154 environmental features and diverse sociodemographic characteristics.  
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47 155 Information about physical activity and relevant covariates at the individual level was  
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49 156 obtained from the baseline 45 and Up Study and the Social, Economic and  
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51 157 Environmental Factors (SEEF) follow-up Study. The 45 and Up Study is a  
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53 158 population-based cohort survey of NSW residents aged 45 years and older.  
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57 159 Recruitment was undertaken between 2006 and 2009. Potential participants were  
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59 160 randomly selected from the Medicare Australia database (Australia's universal public  
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3 161 health insurance system). Participants joined the study by completing a mailed self-  
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5 162 administered questionnaire and providing consent for long-term follow-up, including  
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7 163 linkage to various personal health records. The response rate was 18% and  
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9 164 participants comprised 11% of the NSW population aged 45 years and over.<sup>24</sup> The  
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11 165 full study cohort consists of 267,153 people aged 45 years or older at the time of  
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13 166 recruitment.  
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20 168 Figure 1: Sydney statistical division (1a) and 500m polygon-based network buffer  
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25 170 In 2010, the SEEF Study questionnaire was distributed to the first 100,000  
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27 171 participants of the 45 and Up Study, of whom 60,404 returned the completed  
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29 172 questionnaire. The average follow-up period was  $3.3 \pm 0.9$  years (median=2.8 years,  
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31 173 inter-quartile range=2.6 to 4.6 years). Questionnaires for both the 45 and Up and the  
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33 174 SEEF Study are available from the Sax Institute website. Of the 60,404 participants,  
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35 175 24,220 resided in the study area at the time of the baseline 45 and Up Study.  
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42 177 The baseline 45 and Up Study and the SEEF Study were approved by the University  
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44 178 of New South Wales Human Research Ethics Committee and the University of  
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46 179 Sydney Human Research Ethics Committee respectively.  
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50 180 Measures

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52 181 *Exposure: access to greenspace*

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55 182 We used the percentage of greenspace within 500m, 1km and 2km polygon-based  
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57 183 road network (PBRN) buffers (Figure 1b) around participants' residences (available  
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3 184 for the baseline survey only) as proxies for geographic access to greenspace. These  
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5 185 buffer sizes were chosen as they are considered as walkable distance.<sup>25</sup>  
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10 187 Greenspace data was obtained from StreetPro (PitneyBowers Inc., USA). In this  
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12 188 dataset, greenspace includes national parks, nature reserves, historic sites, state  
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14 189 forests, State recreation areas, wildlife refuges, conservation parks, protected areas,  
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17 190 wildlife reserves, urban recreation parks and other urban greenspaces. The PBRN  
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19 191 buffers were created using the StreetPro Navigation (PitneyBowers Inc., USA) road  
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21 192 network file and ArcGIS network analyst to calculate the endpoints of all possible  
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23 193 routes up to the specified distance (500m, 1km and 2km) along the road network for  
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25 194 each participant's residence. The endpoints were then connected to form irregular  
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27 195 polygons. Percentage of greenspace within PBRN buffers were categorised into 0-  
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29 196 5%, >5-10%, >10-15%, >15-20% and >20%. We combined >15-20% and >20% for  
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31 197 greenspace within 500m buffers due to the small sample sizes.  
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### 37 199 *Outcomes: duration of sitting and physical activity*

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40 200 Information on sitting (hours per week), walking (minutes per week) and MVPA  
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42 201 (minutes per week) was collected in both surveys. Duration of sitting was adapted  
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44 202 from the International Physical Activity Questionnaire which has acceptable  
45  
46 203 reliability<sup>26</sup> and validity.<sup>26</sup> Physical activity was assessed using the Active Australia  
47  
48 204 Survey<sup>27</sup> which also has acceptable reliability<sup>28</sup> and validity.<sup>29</sup> In this instrument,  
49  
50 205 walking is defined as walking for recreation or exercise or to get to or from places.  
51  
52 206 Vigorous physical activity refers to any activity that causes a participant to breathe  
53  
54 207 harder or puff and pant. Moderate physical activity refers to less intense activities  
55  
56 208 such as gentle swimming, social tennis, vigorous gardening or work around the  
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3 209 house. Total weighted minutes of MVPA per week is calculated by the sum of  
4  
5 210 minutes of walking, moderate physical activity and twice the minutes of vigorous  
6  
7 211 physical activity.<sup>28</sup> Reported time spent on walking and MVPA greater than 14 hours  
8  
9 212 per day was considered as an impossible value and recoded to 14 hours.<sup>30</sup> We  
10  
11 213 conceptualised walking and total MVPA as two separate outcomes because walking  
12  
13 214 is expected to be more specifically related to neighbourhood greenspace while total  
14  
15 215 MVPA is commonly used as a measure of overall levels of health-enhancing physical  
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17 216 activity.  
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### 25 218 *T2D diagnosis*

26  
27 219 New cases of T2D were defined as those participants who did not report T2D at the  
28  
29 220 baseline survey but reported T2D at the follow-up survey (New type 2 diabetes). The  
30  
31 221 comparator group was participants who did not report T2D at both baseline and  
32  
33 222 follow-up surveys (No type 2 diabetes). The questions asked to determine a  
34  
35 223 diagnosis of T2D at the baseline survey were “Has a doctor ever told you that you  
36  
37 224 have diabetes” and “Have you taken Diabex, Diaformin, Metformin for most of the  
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39 225 last 4 weeks”.  
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47 227 Participants who reported that they had been told by a doctor that they had diabetes  
48  
49 228 were then also asked about their age at diagnosis. For participants with newly  
50  
51 229 diagnosed type 2 diabetes, the time lapse since diagnosis to completion of the SEEF  
52  
53 230 Study questionnaire was also calculated (age at time of completion of SEEF Study  
54  
55 231 questionnaire minus age at T2D diagnosis). Self-reported diagnosis of T2D in the 45  
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3 232 and Up Study has high sensitivity (83.7%) and specificity (97.7%) compared to  
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5 233 administrative hospitalisation data<sup>31</sup>.

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11 235 *Covariates*

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14 236 A directed acyclic graph (DAG) was used to identify potential covariates (Figure 2),  
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16 237 measured at baseline, to predict physical activity and duration of sitting. The list of  
17  
18 238 covariates, reported at baseline, include socio-demographic characteristics (age,  
19  
20 239 gender, country of birth (English speaking countries, Europe, Middle-East, Asia,  
21  
22 240 Other)) and an area-level deprivation score. Area-level deprivation was measured by  
23  
24 241 the 2006 Index of Relative Socio-Economic Disadvantage (IRSED) quintiles at the  
25  
26 242 postcode level. The IRSED was created by the Australian Bureau of Statistics to  
27  
28 243 compare social and economic disadvantage across geographical areas in Australia.  
29  
30 244 The index is derived from the 2006 Census variables such as income, educational  
31  
32 245 attainment, unemployment, and people working in unskilled occupations<sup>32</sup>.

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34  
35 246 We also included physical functioning at baseline (measured using the Medical  
36  
37 247 Outcomes Study (MOS) Physical Functioning Scale; it ranges from 0 to 100 and was  
38  
39 248 categorised into no limitation (100), minor limitation (95-99), moderate limitation (85-  
40  
41 249 94), or severe limitation (0-84))<sup>33</sup>, psychological distress at baseline (Kessler-10  
42  
43 250 (K10); a K10 score of  $\geq 22$  reflects high or very high psychological distress<sup>34</sup>) and  
44  
45 251 body mass index (BMI) at baseline as potential covariates.

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51 252 As several studies have reported the beneficial effect of greenspace on mental  
52  
53 253 health<sup>35-37</sup> And that poor mental health can impact on physical activity<sup>38-40</sup>, we also  
54  
55 254 tested whether psychological distress at baseline could be a potential mediator  
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3 255 between neighbourhood greenspace at baseline and changes in physical activity at  
4  
5 256 follow-up (see DAG Figure 2).  
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8 257 Similarly, we also tested for BMI reported at baseline as another potential mediator  
9  
10 258 between neighbourhood greenspace at baseline and changes in physical activity at  
11  
12 259 follow-up. Increased greenspace has been associated with reduced weight<sup>41</sup>, less  
13  
14 260 weight gain<sup>42</sup>, and people are less likely to be obese in greener areas<sup>43</sup>. Moreover,  
15  
16 261 people who are overweight or obese reported spending less time in physical activity  
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18 262 than those who are normal-weight<sup>44-46</sup>.  
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22  
23 263 Figure 2: Directed acyclic graph of the relationship between neighbourhood  
24 264 greenspace and physical activity and sitting.  
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### 30 267 *Statistical analysis*

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33 268 The Kruskal-Wallis test was used to compare continuous baseline lifestyle variables  
34  
35 269 between the two T2D groups. Separate regression models were used to examine the  
36  
37 270 association between neighbourhood greenspace access and change in outcome  
38  
39 271 variables (in MVPA, walking, and sitting). To adjust for correlation between  
40  
41 272 participants within local government areas (LGA), generalised estimating equations  
42  
43 273 (GEE) model was applied. Assuming no specific order between observations in the  
44  
45 274 same LGA, the compound-symmetric correlation structure was used. BMI and  
46  
47 275 psychological distress were tested for mediation between neighbourhood  
48  
49 276 greenspace and physical activity. There were no associations between  
50  
51 277 neighbourhood greenspace and BMI and psychological distress. However, BMI, but  
52  
53 278 not psychological distress, was associated with changes in the outcome variables  
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55 279 and therefore included in the final models. Psychological distress was not included in  
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3 280 the final models. The final set of variables included in the final models was age,  
4  
5 281 gender, educational attainment, level of physical functional limitation, IRSED, BMI at  
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7 282 baseline, and duration of T2D diagnosis (New T2D group only), follow-up time and  
8  
9 283 the baseline value of each outcome in specific models. To examine whether the  
10  
11 284 association between greenspace and change in outcome variables modified by the  
12  
13 285 presence of type 2 diabetes, a two-way interaction between the status of T2D (New  
14  
15 286 T2D and No type 2 diabetes) and percentage of greenspace was explored. We then  
16  
17 287 developed regression models, stratified by the presence of type 2 diabetes.  
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19 288 Predicted values of change and associated 95% confidence intervals (CIs) were  
20  
21 289 reported. To adjust for multiple comparison, Bonferroni method were used in the final  
22  
23 290 models. Statistical analyses were conducted using SAS version 9.4 (SAS Institute,  
24  
25 291 Cary, NC).

292

## 293 Patient and Public Involvement

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

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## 299 Results

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3 300 Of the 24,220 participants living in Sydney Statistical Division, 628 were excluded  
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5 301 due to inconsistent reporting between baseline and follow-up surveys, 1,498 were  
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7 302 excluded due to reporting T2D at both baseline and follow-up and an additional  
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10 303 4,000 were excluded because of severe level of physical function, making physical  
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12 304 activity challenging or infeasible, leaving 18,094 participants in the analytical sample  
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15 305 (Figure 3).

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17 306 Figure 3: Flow chart of sample selection  
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22 308 Of the 18,094 participants, 260 (1.4%) reported T2D in the follow-up survey but not  
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24 309 in the baseline survey (New type 2 diabetes) whereas 17,834 (98.6%) participants  
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26 310 did not report T2D at both baseline and follow-up (No type 2 diabetes). The average  
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28 311 duration of time since diagnosis was  $1.8 \pm 1.1$  years (median=1.7 years). More than  
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30 312 half of all the participants were female (52.0%) and the average age of participants  
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33 313 was  $59.5 \pm 9.6$  years. The majority of participants were born in an English speaking  
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36 314 country (85.2%) and about one-quarter had not completed high school education  
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38 315 (Table 1).

39  
40  
41 316 Table 1 shows changes in outcome variables at follow-up by baseline  
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43 317 sociodemographic characteristics and access to greenspace. There were significant  
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45 318 associations of age group, IRSED, physical functional limitation, BMI, with change in  
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47  
48 319 the amount of walking and MVPA. Significant associations were also found between  
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50 320 gender and change in the amount of walking and sitting. Educational attainment was  
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52 321 significantly associated with a change in sitting time. There were no significant  
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55 322 associations between greenspace and changes in MVPA, walking and sitting.

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

	n	Change in MVPA <sup>1</sup> (hours/week)			Change in walking <sup>2</sup> (hours/week)			Change in sitting <sup>3</sup> (hours/week)		
		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 <sup>5</sup>	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	
2 <sup>nd</sup> 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	
3 <sup>rd</sup> 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	
4 <sup>th</sup> 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	

326 <sup>1</sup>Mean adjusted for baseline amount of time spent on MVPA per week.327 <sup>2</sup>Mean adjusted for baseline amount of time spent on walking per week.

328 <sup>3</sup>Mean adjusted for baseline amount of time spent on sitting per week.

### 329 Baseline correlates of the outcomes

330  
331 Table 2 presents the outcome variables at baseline by T2D group. The amount of  
332 time spent on MVPA at baseline was significantly higher among the “No type 2  
333 diabetes” group. There were no significant differences in the amount of time spent on  
334 walking and sitting between New T2D and No type 2 diabetes.

335 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

336  
337 Although the interactions between access to greenspace for each buffer size and  
338 status of T2D was not statistically significant for each outcome variable except for  
339 the changes in MVPA with percentage of greenspace within 2km (p=0.039), the  
340 differences in trends between status of T2D were apparent as shown in Figure 4.

### 342 Greenspace and outcomes by diagnosis of type 2 diabetes

343 Figure 4 presents marginal mean changes in the amount of walking, MVPA and  
344 sitting, and associated 95% CI by proportion of greenspace. A change in the  
345 outcome variable of greater than zero indicates an increase in that outcome at the  
346 follow-up study relative to the baseline study. Regardless of diabetes status and  
347 buffer size, there were no associations between percentage of greenspace and  
348 changes in amount of walking and sitting. For example, the 95% CI of changes in the

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3 349 amount of walking were overlapping between each category of greenspace  
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5 350 regardless of buffer size. Although there were no significant changes in amount of  
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8 351 walking with the percentage of greenspace, increasing trends were apparent among  
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10 352 New T2D which peaked at >15-20% of greenspace, whereas fairly stable trends  
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12 353 were found among No type 2 diabetes. Similar trends were also found for changes in  
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15 354 the amount of MVPA.

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21 356 Among New type 2 diabetes, there was no significant association between the  
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23 357 percentage of greenspace within 2km buffer and changes in amount of MVPA.  
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25 358 However, increasing trend was apparent with the peak at >15-20% of greenspace.  
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27 359 Among No type 2 diabetes, the changes in amount of MVPA remained fairly stable  
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30 360 with increasing percentage of greenspace (Figure 4).  
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36 362 For changes in sitting time, there were no significant associations with percentage of  
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38 363 greenspace regardless of buffer size. Among New type 2 diabetes, the changes in  
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40 364 amount of sitting decreased at percentage of greenspace >10%. Among No type 2  
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42 365 diabetes, the changes in amount of sitting significantly decreased at follow-up and  
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45 366 remained stable with increasing proportion of greenspace.  
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52 368 Figure 4: Change (with 95% CI) in outcomes by proportion of greenspace (Bonferroni  
53 369 method was applied for multiple comparison)

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58 372 Discussion  
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3 373 This is the first study to explore environmental influences on the behaviours of  
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5 374 people who transition into living with type 2 diabetes. Overall, we found that there  
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8 375 was a lack of association between access to greenspace at baseline and change in  
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10 376 walking, MVPA, and sitting time. We found no statistically significant interactions  
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12 377 between access to greenspace and status of T2D for each outcome variable, except  
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14 378 for the changes in MVPA with percentage of greenspace within 2km. Although no  
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16 379 significant interactions were found, possibly due to the small sample size of those  
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18 380 with newly diagnosed type 2 diabetes, the magnitude of changes in walking and  
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20 381 MVPA increased as percentage of greenspace increased among New T2D while  
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22 382 remain fairly stable among No type 2 diabetes. There was no significant association  
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24 383 between greenspace and sitting time with fairly stable trends among both New T2D  
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26 384 and No type 2 diabetes.  
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34 386 Among participants with newly diagnosed type 2 diabetes, there were gradual  
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36 387 increases in walking and MVPA with increasing proportion of greenspace within 1km  
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38 388 and 2km buffers. However, these increases in walking and MVPA were no longer  
39  
40 389 evident with >20% greenspace. This may be because around half of the participants  
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42 390 with more than 20% of greenspace within a 2km buffer (around 3% of the total  
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44 391 sample) live near larger greenspace (area > 1km<sup>2</sup>). These large greenspaces are  
45  
46 392 mainly national parks and nature reserve that may have limited public access points.  
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48 393 These areas are often located in suburbs on the outskirts of the city with minimal  
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50 394 pedestrian or other infrastructure to facilitate the regular use of greenspace for  
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52 395 physical activity<sup>47</sup>. Francis et al suggested that the type and functionality of the  
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54 396 greenspace may be a salient factor in addition to quantity<sup>48</sup>.  
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3 398 Furthermore, the lack of association found between greenspace and walking and  
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5 399 MVPA may be due to the increased participation in fitness activities taken place  
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7 400 outside of neighbourhood greenspace. Such fitness activities include aerobics,  
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9 401 fitness, gym activities, Pilates, weight training and yoga.<sup>49</sup> In Australia, fitness centre  
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11 402 /gym activities is the second most popular physical recreational activity after  
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13 403 walking.<sup>50</sup> Similarly, a Dutch study<sup>15</sup> found no significant association between the  
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15 404 amount of greenspace within 1km radius of respondents' home and meeting the  
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17 405 Dutch public health recommendation for physical activity possibly due to a high  
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19 406 density of fitness centres and so that access to greenspace is not a necessary  
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21 407 condition for being physically active.<sup>51</sup>  
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29 409 The weak associations between sitting and proportion of greenspace may be due to  
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31 410 the lack of detailed information on the setting and domains of sitting (home, car, work  
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33 411 or recreation environment). In the 45 and up study, only total sitting time was  
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35 412 measured at both baseline and follow-up. Self-reported total sitting time is subject to  
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37 413 substantial measurement errors and does not distinguish occupational and  
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39 414 transportation sitting from recreational sitting. Previous studies have found that  
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41 415 correlates of sitting differed considerably by domain of sitting.<sup>52</sup> Sperlich et al found  
42  
43 416 a weak association between sitting duration and access to parks and recreation  
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45 417 facilities<sup>53</sup> and suggest that research investigating association between sitting time  
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47 418 and environment should consider the diverse domains of sitting.<sup>53</sup>  
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55 420 Overall, the association between proportion of greenspace and change in physical  
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57 421 activity appeared more prominent in New T2D than No type 2 diabetes. These  
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59 422 findings suggest that greenspace may have more motivating effect on physical  
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3 423 activity among those newly diagnosed with type 2 diabetes. Diabetes Australia  
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5 424 recommends people with T2D start with at least thirty minutes of moderate physical  
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7 425 activity every day or between sixty and ninety minutes every day if they are trying to  
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9 426 lose weight.<sup>54</sup> However, it appears that proximity to greenspace alone may not be  
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11 427 sufficient to meet Diabetes Australia recommendations for those with newly  
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13 428 diagnosed type 2 diabetes.  
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23 431 The strengths of this study include a prospective design and a large population-  
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25 432 based cohort study. Although diagnostic or clinical information was not available to  
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27 433 confirm the diagnosis of T2D among participants, in this sample self-reported  
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29 434 diagnosis of T2D has high sensitivity and specificity compared to hospital  
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31 435 administrative data collections.<sup>31</sup> Having outcome measures at two time points only  
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33 436 over two to five years has limited our ability to track changes in lifestyle behaviours  
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35 437 over longer periods of time.  
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42 439 A few additional limitations apply. We were not able to differentiate between different  
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44 440 domains of MVPA and sitting, such as recreational, transport or occupational  
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46 441 physical activity and sitting. We also don't know whether each activity took place  
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48 442 within the local greenspace. Further, greenspace included state forests and national  
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50 443 parks which may or may not be conducive to walking and MVPA as urban parks and  
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52 444 trails. We also could not categorise greenspace into more usable categories, for  
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54 445 example, sports fields, bushland, presence of picnic facilities, etc., nor do we have  
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56 446 access to the quality of the greenspace. Moreover, although we adjusted for a  
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3 447 number of important potential confounders, there may yet be some residual  
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5 448 confounding. However, we share this limitation with most other published studies on  
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8 449 neighbourhoods and health.  
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## 11 451 Conclusion

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15 452 This study indicates that neighbourhood greenspace is related to active lifestyles  
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17 453 only to a very limited extent among people with newly diagnosed type 2 diabetes.  
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19 454 This is particularly so when there is moderate amount of greenspace (15-20% of the  
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22 455 neighbourhood). Future studies should consider including more comprehensive  
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24 456 environmental measures about greenspace and other environmental attributes (e.g.,  
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26 457 recreational facilities), more specific measures of physical activity and sedentary  
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28 458 behaviour, such as the domain and location of each activity, and the more follow-up  
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30 459 measures over longer period of time.  
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## 34 461 Ethics approval

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37 462 The baseline 45 and Up Study and the SEEF Study were approved by the University  
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39 463 of New South Wales Human Research Ethics Committee and the University of  
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41 464 Sydney Human Research Ethics Committee respectively.  
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49  
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#### 12 13 475 Contributors

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16 476 Shanley Chong participated in the design of the study, carried out the statistical  
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18 477 analyses and drafted the manuscript. Soumya Mazumdar participated in the design  
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20 478 of the study, helped draft the manuscript, helped with the interpretation and revised  
21  
22 479 the manuscript. Ding Ding helped draft the manuscript, helped with the interpretation  
23  
24 480 of the data and revised the manuscript. Geoff Morgan, Elizabeth Comino and Adrian  
25  
26 481 Bauman helped with the interpretation of the data and revised the manuscript. Bin  
27  
28 482 Jalaludin supervised the study, helped draft the manuscript, helped with the  
29  
30 483 interpretation of the data and revised the manuscript.  
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46 488

#### 47 48 489 Competing interests

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51 490 None declared.  
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#### 55 56 57 492 Ethics approval

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3 493 The 45 and Up Study was granted ethical approval by the NSW Population & Health  
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5 494 Services Research Ethic Committee (reference HREC/15/CIOHS/4) and the Cancer  
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8 495 Institute NSW (reference 2015/02/575).  
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13 497 Data sharing statement

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16 498 This research was completed using data collected through the 45 and Up Study  
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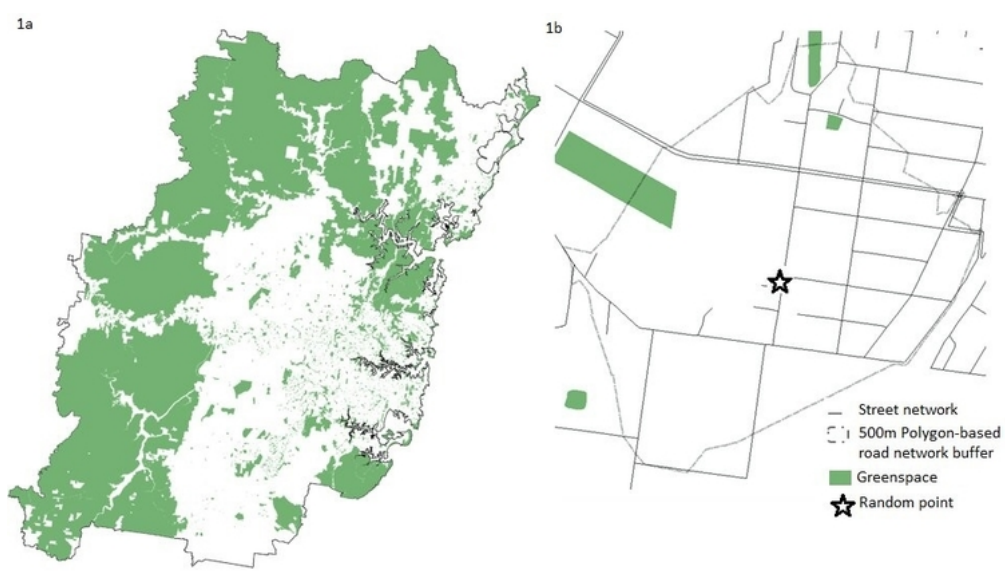
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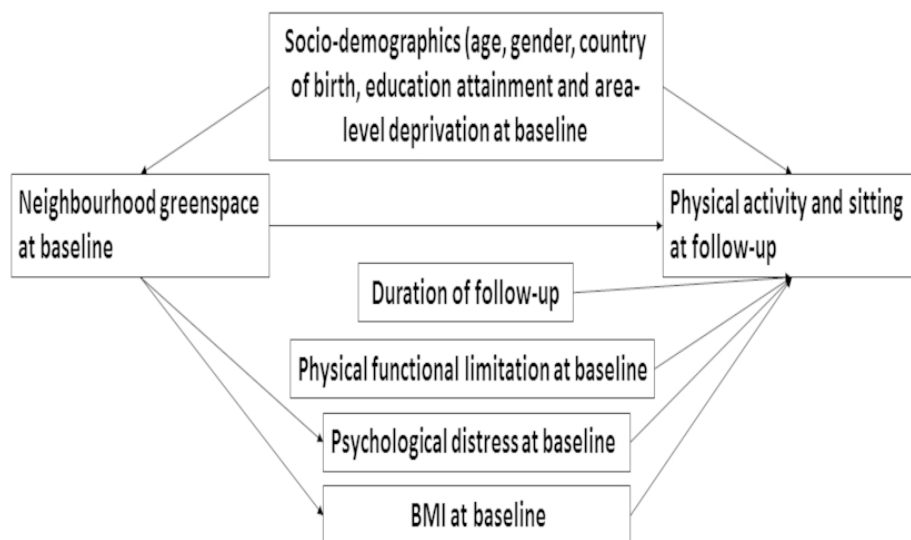
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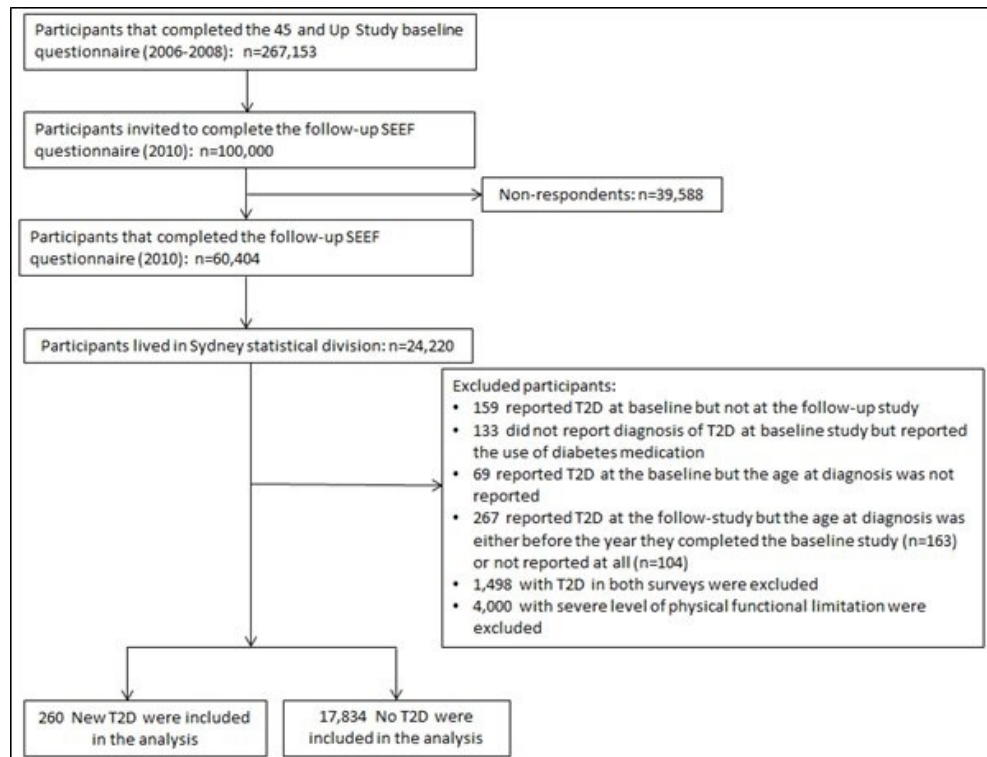


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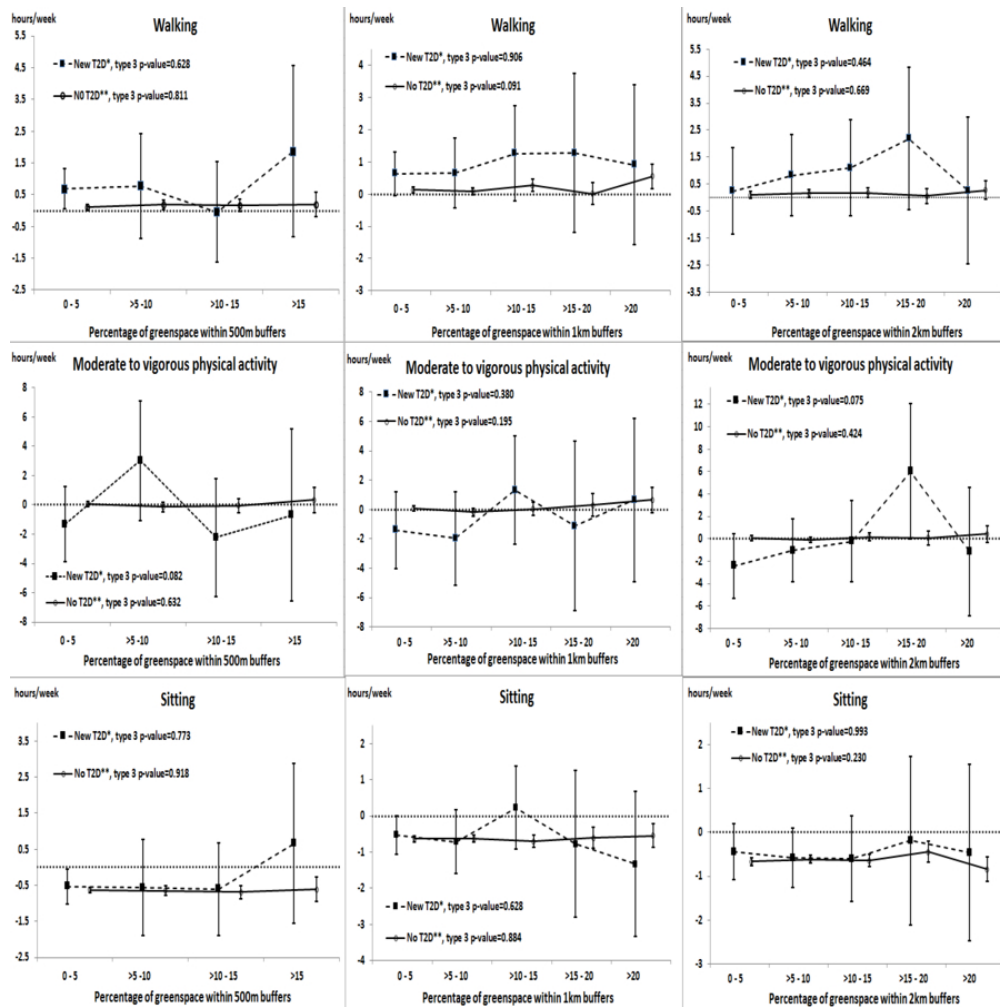




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