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Large-scale investment in green space as an intervention for physical activity, mental and cardiometabolic health: Study protocol for a quasi-experimental evaluation of a natural experiment

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ABSTRACT

Introduction

'Green spaces' such as public parks are increasingly regarded as important determinants of physical recreation, mental and cardiometabolic health, but evidence from epidemiological studies tends to be based upon cross-sectional designs. To build more robust evidence in this area, this study will evaluate a large-scale investment in approximately 5,280 hectares of green space stretching 27km north to south in Western Sydney, Australia.

Methods and analysis

A Geographic Information System was used to identify 7,272 participants in the 45 and Up Study baseline data (2006-2008) living within 5km of the Western Sydney Parklands and some of the features that have been constructed since 2009, such as the locations of public access points, advertising billboards, walking and cycle tracks, BBQ stations, and children's playgrounds. These data were linked to information on a range of health outcomes, health-related behaviour and possible confounders, with the second wave of data collection initiated in 2012 and expected to be completed by 2014. Multilevel models to analyse indicators of physical activity, weight status, social networking, mental

and cardiometabolic health within a closed sample of residentially stable participants. Comparisons between persons with contrasting proximities to different areas of the Parklands (e.g. an area with versus an area without a BBQ station) will provide ‘treatment’ and ‘control’ groups within a ‘quasi-experimental’ study design.

Ethics and dissemination

Ethical approval was obtained for the 45 and Up Study from the University of New South Wales Human Research Ethics Committee. Ethics approval for this study was obtained from the University of Western Sydney Ethics Committee. Findings will be disseminated through partner organisations (the Western Sydney Parklands and the National Heart Foundation of Australia), as well as to policy makers in parallel with scientific papers and conference presentations.

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ARTICLE SUMMARY

Article focus: Epidemiological evidence on the relationship between green space and health has been largely based upon cross-sectional study designs. This article reports on the study protocol for a quasi-experimental evaluation of a major investment in green space in Western Sydney, Australia.

Key messages: Analysis of natural experiments using existing data sources are a cost-effective and valuable means to evaluate the impacts of new green space provision within communities of significant health need.

Strengths and limitations of this study: A key strength of this study is the longitudinal design that leverages a major local change in green space provision. The study is limited by self-report outcome data and that participants are aged 45 years and older, so future work focussing on younger people is also warranted.

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3 **MAIN TEXT**
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6
7 **Introduction**
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10 'Green spaces' such as public parks are increasingly regarded as important
11 correlates of cardiovascular health by the scientific community.¹ This is based
12 upon mounting evidence not only from small-scale experiments (e.g. ^{2 3}), but
13 also large observational studies (e.g. ⁴⁻⁶). As a result, there is also rising interest
14 among urban planning and health policy decision makers in the opportunities
15 for constructing and targeting green spaces to make more 'liveable'
16 neighbourhoods that actively promote mental and cardiometabolic health,
17 physical recreation, and overall quality of life.^{7 8}
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33 A challenge with this wave of optimism, however, is the quality of the
34 observational evidence underpinning it.⁹ The vast majority of studies have
35 been cross-sectional, which means that putative interventions, such as an
36 increase in the quantity or quality of green space available locally, cannot be
37 rigorously evaluated for their impact on health. Even with multivariate
38 adjustment for income and other factors which determine where a person can
39 choose to live, unmeasured(able) variables such as a person's preference for
40 living in a greener neighbourhood cannot be ruled out. This may lead to the
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reporting of inaccurate (or even spurious) associations with health and inappropriate policy recommendations.

The observational evidence on green space and health is at a crossroads. More emphasis is required from studies using designs that harness temporal as well as spatial dimensions in order to provide insights on how much and/or what type of green space matters for what (i.e. participation in physical activity), when (i.e. at what period in the lifecourse) and for whom (i.e. particular socio-demographic groups).⁹ A one-size-fits-all prescription of green space seems unlikely and both scientific research and policy needs to engage with that potentially inconvenient level of complexity. In particular, the evaluation of natural experiments and controlled trials in order to enhance the quality of evidence available for decision makers is needed.¹⁰ Such longitudinal studies should (i) measure the association between a change in exposure to green space on a change in health outcome and (ii) have more rigorous controls for possible confounding, such as the restriction of a sample to people whose exposure changes around them, rather than as a result of relocation that is likely to be highly entwined with health selection.¹¹

To build more robust evidence in this area, investigators at the University of Western Sydney (Australia) formed a partnership with the Western Sydney Parklands Trust and obtained funding from the National Heart Foundation of

Australia (ID 100161) to devise the ‘Western Sydney Parklands Longitudinal Study’ (WSPLS). In Western Sydney, a socioeconomically and culturally diverse region of Australia home to over 2 million residents, the New South Wales (NSW) Government invested in the development of approximately 5,280 hectares of green space stretching 27km north to south and spanning 3 Local Government Areas (LGA): Blacktown, Fairfield and Liverpool from 2009 onwards. Communities living across this area are known to experience significant levels of socioeconomic disadvantage and poorer health, such as a high risk of type 2 diabetes mellitus¹² and psychological distress.¹³ The ‘Western Sydney Parklands’ will become the largest urban parkland in Australia and among the largest globally. Much of the land in 2009 comprised residential or vacant land-use. It is intended that the investment will change this composition to approximately 40% dedicated bushland, 25% sport and recreation, 22% long-term infrastructure (e.g. water storage), 10% urban farming, 2% business hubs, and 1% tourism. The development of the Western Sydney Parklands is an example of a large-scale investment in green space that could be potentially regarded as an intervention for physical activity, mental and cardiometabolic health within proximity to communities with significant health need. In this paper, we outline a study protocol used for a quasi-experimental design to evaluate the health impacts of this natural experiment.

Methods and analysis

Data

A Geographic Information System (GIS) comprising geocoded land-use data was provided to the investigator team by the Western Sydney Parklands. This included the grounds of the Western Sydney Parklands and some of the features that have been constructed since 2009, such as the locations of public access points, advertising billboards, walking and cycle tracks, BBQ stations, and children's playgrounds. These data were linked to information on a range of health outcomes, health-related behaviour and possible confounders reported by participants in the 45 and Up Study baseline survey. Detailed information on the development of the 45 and Up Study is published elsewhere.¹⁴ In brief, 267,102 persons aged 45 to 106 years (mean age=62.8, standard deviation=11.2) responded to a self-complete baseline questionnaire that was delivered between 2006 and 2008. Participants had been randomly selected from the Medicare Australia database (the national provider of universal health insurance), with a response of 18%. While this response is low and there was greater participation among more socioeconomic advantaged persons, previous work has suggested that findings from the 45 and Up Study

compare favourably with more representative population health surveys.¹⁵

The 45 and Up Study has been previously used to analyse a range of health and behavioural outcomes in relation to green space exposure,^{5 16-20} as well as other spatial phenomena.^{12 21-26} The second wave of data collection was initiated in 2012 with a follow-up questionnaire mailed to over 40,000 participants and a further 86,250 contacted by late 2013. All other remaining participants will be re-surveyed in 2014 and 2015. The University of New South Wales Human Research Ethics Committee approved The 45 and Up Study.

Sample

The baseline sample for the WSPLS was selected from participants in the 45 and Up Study who resided up to 5 km Euclidean distance ('as the crow flies') from any point of the Western Sydney Parklands (Figure 1). A total of 7,272 participants were selected. These participants were nested within 624 'Census Collection Districts' (12 participants on average per Census Collector District, ranging from 1 to 156). A GIS was used to classify all participants in the sample by their respective Collection Districts of residence into 1 km proximity bands as the most basic definition of 'exposure' to the Western Sydney Parklands. As is evident from Figure 1, features of the Parklands that could promote certain

health outcomes and health-related behaviours, such as the locations of advertising billboards, walking paths and BBQ stations, are not randomly distributed. As such, definitions of exposure will be modified according to the hypothesised causal pathway being tested. Mental health, for example, may be influenced by living near any part of the Parklands, but especially areas where people can be social, such as BBQ stations. Conversely, the power for green space to influence physical recreation will likely depend on the locations of features that support active lifestyles, such as walking paths. Table 1 reports how the definition of exposure in the baseline sample could be potentially modified accordingly. Approximately 61% of participants who lived within 1km of any part of the Parklands (n=543), for example, lived 10km or more from the nearest Parklands BBQ station.

What outcomes will be measured?

A range of self-reported health outcomes and health-related behaviours at baseline and follow-up will be selected for analysis in line with existing scientific evidence.¹ Health outcomes will include an indicator of psychological wellbeing as measured by the Kessler 10 scale ('K10'), which screens for symptoms of psychological distress experienced over the four weeks prior to

survey completion.²⁷ Questions in the K10 cover feelings of tiredness for no reason, nervous, hopeless, restless, depressed, sad and worthless. Participants had five choices for each of the ten questions (none of the time =1, a little of the time =2, some of the time =3, most of the time =4, all of the time=5) and these will be summed to give the overall score. In line with previous work,^{19 24}²⁸ a binary variable will be constructed with scores of 22 and over identifying participants at high risk of psychological distress.²⁹

Physical functioning will be measured using the Medical Outcomes Study Physical Functioning Scale (MOS-PF).^{30 31} The MOS-PF is a 10-item scale covering vigorous activities (e.g. climbing stairs) to more basic actions related to day to day living (e.g. bathing). Physical health will also be measured using body mass index (BMI), already shown to be related to green space in this data at baseline¹⁶ and derived from self-reported height and weight, with overweight (BMI 25 to 29.9) and obesity (BMI \geq 30) determined by World Health Organization criteria.³² Comparisons between this measure of BMI and an objective measure with a sub-sample of this dataset were favorable.³³ Incidence of doctor-diagnosed cardiometabolic diseases such as hypertension, cardiovascular disease, and diabetes will also be assessed via self-report.

Key mediating variables between green space and mental and cardiometabolic health outcomes are those relating to physical recreation. These behavioural

characteristics include self-reported responses describing walking and participation in moderate and vigorous physical activities, as well as questions on approximate time spent sitting, standing, watching television or computer screens, and sleep duration. Physical activity will be assessed using responses to questions derived from the Active Australia Survey³⁴: *“How many times did you do each of these activities last week?”* Participants could indicate moderate (e.g. gentle swimming) and vigorous (e.g. jogging) forms activity separately, as well as walking. The Active Australia Survey has been shown to have a satisfactory level of test-retest reliability³⁵ and cross-sectional analysis of baseline data has previously shown association between the derived variables and an objective measure of green space exposure.¹⁷

Improvements in green space provision may also stimulate enhancements in social networking.³⁶ Three out of four items will be selected from the shortened version of the Duke Social Support Index³⁷ in this regard: *“How many times in the last week did you... (i) spend time with friends or family who do not live with you”; (ii) “you go to meetings of social clubs, religious groups or other groups you belong to?”; and (iii) “How many people outside your home, but within one hour of travel, do you feel you can depend on or feel very close to?”* The fourth question on telephone conversations is less relevant and, therefore, will be considered as a form of negative control.³⁸

Descriptive analyses reported in Tables 2 and 3 show that there were virtually no significant differences in the distribution of any of these outcomes with respect to proximity to any part of the Western Sydney Parklands in the baseline sample. This can be expected as all of the enhancements occurred from 2009 onwards; after people participated in the 45 and Up Study baseline.

Epidemiological study design specifications to minimise confounding

The major source of confounding will include health selective migration.¹¹ This is when persons who are already healthier and more likely to use green space for health-enhancing reasons purposefully move to neighbourhoods located within close proximity of the Western Sydney Parklands, in order to benefit from the convenience of easy access to nature. Multiple specifications will be made to minimise this form of bias. First, the prospective design will focus attention exclusively upon persons who lived close to the Parklands before investment and enhancements began. Tracking health outcomes and health-related behaviours among this ‘closed’ sample through time will, therefore, help identify the impacts of changes in the green space located nearby. Second, drawing comparisons between persons with contrasting proximities to different areas of the Parklands (e.g. an area with versus an area without a

BBQ station) will provide 'treatment' and 'control' groups that mimic a controlled trial; a 'quasi-experimental' study design.¹⁰

It is possible that some people will have invested in a move to a neighbourhood near the Parklands based upon knowledge that the enhancements would be made in the future. Multivariate adjustment for factors known to be associated with where a person can choose to live will be used to account for this selective migration. These factors include age, gender, country of birth, whether a person is in a couple (i.e. married, civil partnership, or cohabiting) or single, annual household income, employment status and highest educational qualification. In addition, the level of socioeconomic deprivation within a neighbourhood will be taken into account using the Australian Bureau of Statistics 'Socio Economic Index For Areas' scale of relative advantage and disadvantage.³⁹ The distributions of these possible confounders are reported in Table 4. Unlike the health outcomes and health-related behaviours at baseline, many of these potential confounders were differentially patterned according to proximity. People living nearer the Parklands tended to be younger, born in Australia, living in a couple and with higher annual household incomes. Neighbourhoods near the Parklands also tended to be less socioeconomically deprived. All Census Collection Districts

covered in the sample are classified as ‘major city’ in the Accessibility-Remoteness Index of Australia (ARIA).⁴⁰

Statistical analysis

Further use of GIS will be applied to refine and adapt measures of exposure and to define relevant ‘control’ groups according to the hypothesis being tested. The design is necessarily ‘Intention To Treat’ (ITT) as information in the 45 and Up Study on whether people specifically visit the Parklands is not known. Multilevel models⁴¹ will be the primarily mode of analysis used to quantify associations between changes in green space and changes in health outcomes and health-related behaviours. These types of models are ideally suited to longitudinal data analysis⁴² as they are able to take into account and explicitly model variance in outcome variables as people age, such as the estimation of ‘growth curves’.⁴³ These models will be fit in purpose-developed statistical software such as MLWIN⁴⁴ and estimated using relevant methods, such as Markov Chain Monte Carlo (MCMC).⁴⁵

Ethics and dissemination

All participants in the 45 and Up Study consented to the use of their questionnaire data and to data linkage. Ethical approval was obtained for the 45 and Up Study from the University of New South Wales Human Research Ethics Committee. Ethics approval for this study was obtained from the University of Western Sydney Ethics Committee. Findings will be disseminated through partner organisations (the Western Sydney Parklands and the National Heart Foundation of Australia), as well as to health and urban planning policy makers in parallel with scientific papers and conference presentations.

Conclusion

Using a large source of existing data and a quasi-experimental study design, the WSPLS will provide cost-effective and valuable insights on the health impact of a major investment in one of the largest urban green spaces in Australia. The findings from this natural experiment will provide information for future green space developments, health policy makers and land-use planners on 'what works' in communities with significant health need.

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Competing interests statement

The authors have no competing interests to declare.

Contributorship Statement

Conceived and designed the experiments: TAB, with support from XF and GSK. Performed the experiments: TAB, XF. Analyzed the data: TAB, XF, GSK. Wrote the paper: TAB, XF, GSK.

Data Sharing Statement

Data is not available.

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Figure 1: Western Sydney Parklands, park features and proximity of Census Collection Districts

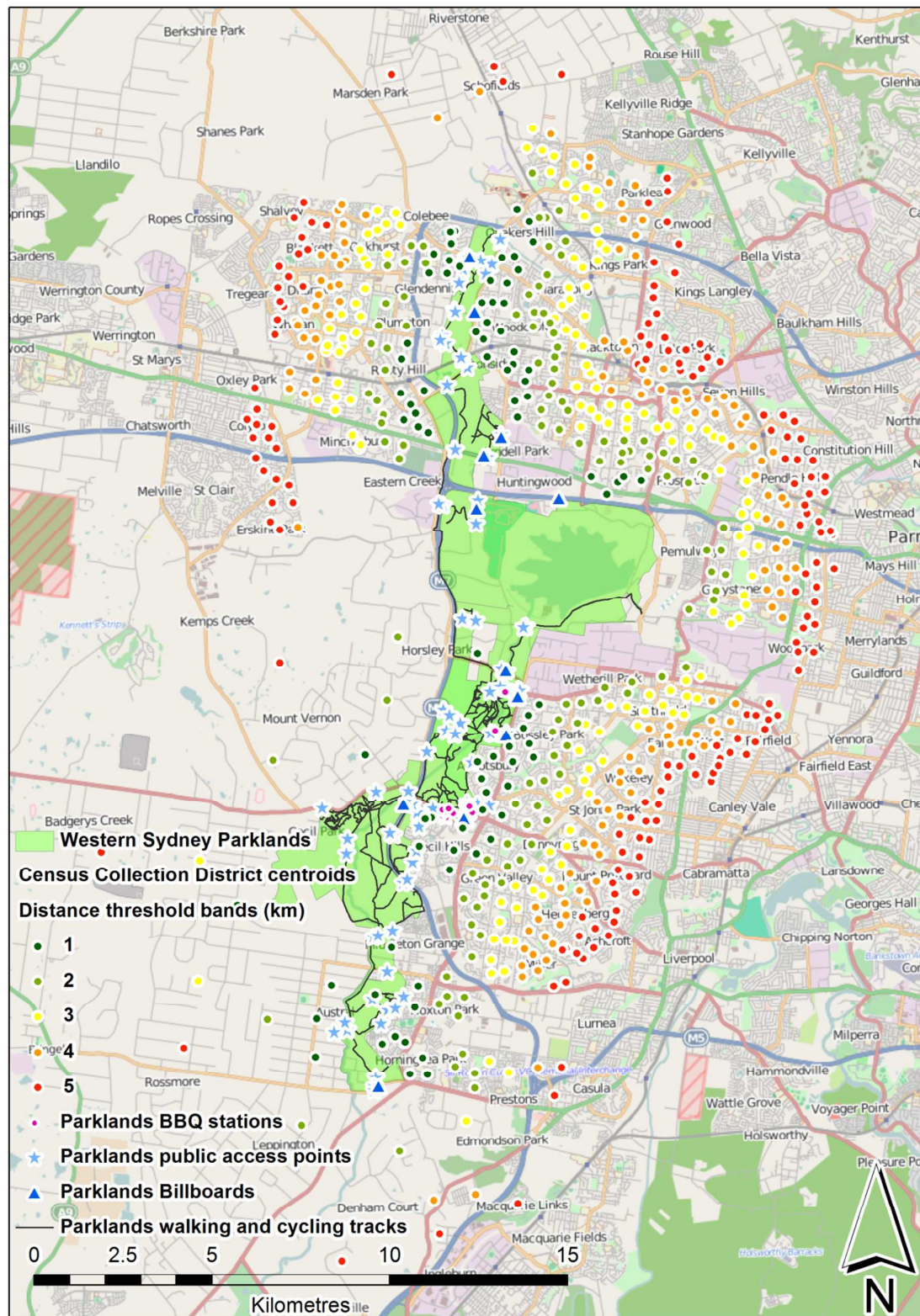


Table 1: Proximity to selected features which are part of the Western Sydney Parklands

Proximity to any part of the Western Sydney Parklands (km)					
	≤ 1	2	3	4	5
N	891	1525	1516	1596	1724
N (%)					
Proximity to public access points (km)					
1	661 (74.2%)	13 (0.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
3	200 (22.4%)	1159 (76.0%)	767 (50.6%)	16 (1.0%)	0 (0.0%)
5	30 (3.4%)	162 (10.6%)	442 (29.2%)	1092 (68.4%)	707 (41.0%)
≥ 10	0 (0.0%)	191 (12.5%)	307 (20.3%)	488 (30.6%)	1017 (59.0%)
Proximity to walking and cycling tracks (km)					
1	613 (68.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
3	253 (28.4%)	1328 (87.1%)	1062 (70.1%)	0 (0.0%)	0 (0.0%)
5	25 (2.8%)	197 (12.9%)	417 (27.5%)	1386 (86.8%)	991 (57.5%)
≥ 10	0 (0.0%)	0 (0.0%)	37 (2.4%)	210 (13.2%)	733 (42.5%)
Proximity to BBQ stations (km)					
1	186 (20.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
3	101 (11.3%)	396 (26.0%)	160 (10.6%)	0 (0.0%)	0 (0.0%)
5	61 (6.8%)	77 (5.0%)	145 (9.6%)	420 (26.3%)	180 (10.4%)
≥ 10	543 (60.9%)	1052 (69.0%)	1211 (79.9%)	1176 (73.7%)	1544 (89.6%)
Proximity to advertising billboards (km)					
1	302 (33.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
3	520 (58.4%)	1120 (73.4%)	404 (26.6%)	0 (0.0%)	0 (0.0%)
5	66 (7.4%)	353 (23.1%)	874 (57.7%)	1088 (68.2%)	363 (21.1%)
≥ 10	3 (0.3%)	52 (3.4%)	238 (15.7%)	508 (31.8%)	1361 (78.9%)

Table 2: Patterning of health outcomes at baseline, by proximity to the Parklands

		Proximity to any part of the Western Sydney Parklands (km)				
		≤ 1	2	3	4	5
N		891	1525	1516	1596	1724
	Mean					
				Odds Ratio (95% CI)		
K10 ≥ 22	17%		0.9 (0.7, 1.1)	1.0 (0.8, 1.2)	1.2 (1.0, 1.5)	1.1 (0.9, 1.4)
% missing	2.69		3.21	3.03	3.57	3.54
Self-rated quality of life	3%		1.4 (0.8, 2.3)	0.9 (0.5, 1.6)	1.6 (0.9, 2.6)	1.3 (0.8, 2.2)
% missing	6.51		7.15	8.64	8.58	6.9
Overweight and obese	68%		0.9 (0.8, 1.1)	0.9 (0.8, 1.1)	1.1 (0.9, 1.3)	1.0 (0.8, 1.2)
% missing	8.08		8.33	9.04	9.15	9.05
Diabetes	13%		0.9 (0.7, 1.1)	1.1 (0.9, 1.4)	1.3 (1.0, 1.6) *	1.2 (1.0, 1.6)
% missing	0		0	0	0	0
High blood pressure	37%		0.9 (0.8, 1.1)	1.1 (0.9, 1.3)	1.2 (1.0, 1.5) *	1.1 (0.9, 1.2)
% missing	0		0	0	0	0
CVD	11%		0.8 (0.6, 1.0)	1.0 (0.8, 1.3)	1.1 (0.9, 1.4)	1.3 (1.0, 1.7) *
% missing	0		0	0	0	0
				Rate Ratio (95% CI)		
Physical functioning	17.86		1.0 (0.8, 1.2)	1.0 (0.8, 1.2)	1.2 (1.0, 1.5) *	1.2 (1.0, 1.4) *
% missing	19.98		20.98	22.82	23.37	24.42 *

* p < 0.05; ** p < 0.01; *** p < 0.001; from distance to Parklands < 1 km

95% CI: 95% Confidence Interval

Table 3: Patterning of health-related behaviours at baseline, by proximity to the Parklands

		Proximity to any part of the Western Sydney Parklands (km)				
		≤ 1	2	3	4	5
N		891	1525	1516	1596	1724
		Mean	Rate Ratio (95% CI)			
Walk		5.44	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	1.0 (1.0, 1.1)	1.0 (0.9, 1.1)
% missing		6.29	7.02	7.85	8.21	8.18
Moderate PA		4.36	0.9 (0.8, 1.0)	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)
% missing		12.91	11.8	13.65	14.29	13.98
Vigorous PA		1.48	1.2 (1.0, 1.5)	1.1 (0.9, 1.3)	1.1 (0.9, 1.3)	0.9 (0.7, 1.1)
% missing		18.97	19.54	21.11	22.12	21.46
Screen time (hours)		4.38	1.0 (0.9, 1.0)	1.0 (1.0, 1.1)	1.0 (0.9, 1.0)	1.0 (0.9, 1.0)
% missing		4.71	4.59	5.28	5.76	5.51
Social visits		3.95	0.9 (0.9, 1.0)	1.1 (1.0, 1.1)	1.1 (1.0, 1.2) **	1.1 (1.0, 1.2) *
% missing		3.82	4.33	4.22	5.01	4.58
Social groups		1.47	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	1.1 (0.9, 1.2)
% missing		6.4	6.62	6.79	8.15	8
People I can depend on		6.51	1.0 (1.0, 1.1)	1.0 (0.9, 1.1)	1.0 (0.9, 1.0)	1.0 (0.9, 1.1)
% missing		5.95	5.38	4.55	6.58	6.15
		Coefficient (95% CI)				
Sitting time (hours)		5.76	-0.2 (-0.5, 0.1)	0.1 (-0.2, 0.3)	-0.2 (-0.5, 0.1)	0.0 (-0.3, 0.2)
% missing		7.86	8.07	9.56	11.34 *	9.45
Standing time (hours)		4.82	-0.1 (-0.4, 0.2)	-0.2 (-0.5, 0.1)	-0.1 (-0.4, 0.2)	-0.1 (-0.4, 0.2)
% missing		11	10.95	13.65	14.97 *	13.98 *
		Odds Ratio (95% CI)				
6 hours sleep or less		84%	1.0 (0.8, 1.2)	1.0 (0.8, 1.2)	1.0 (0.8, 1.2)	0.9 (0.8, 1.1)
% missing		4.26	3.41	3.63	4.7	4.47

* p < 0.05; ** p < 0.01; *** p < 0.001; from distance to Parklands < 1 km
95% CI: 95% Confidence Interval

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Large-scale investment in green space as an intervention for physical activity, mental and cardiometabolic health: Study protocol for a quasi-experimental evaluation of a natural experiment

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Large-scale investment in green space as an intervention for physical activity, mental and cardiometabolic health: Study protocol for a quasi-experimental evaluation of a natural experiment

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ABSTRACT

Introduction

'Green spaces' such as public parks are regarded as determinants of health, but evidence from tends to be based upon cross-sectional designs. This protocol describes a study that will evaluate a large-scale investment in approximately 5,280 hectares of green space stretching 27km north to south in Western Sydney, Australia.

Methods and analysis

A Geographic Information System was used to identify 7,272 participants in the 45 and Up Study baseline data (2006-2008) living within 5km of the Western Sydney Parklands and some of the features that have been constructed since 2009, such as public access points, advertising billboards, walking and cycle tracks, BBQ stations, and children's playgrounds. These data were linked to information on a range of health and behavioural outcomes, with the second wave of data collection initiated by the Sax Institute in 2012 and expected to be completed by 2015. Multilevel models will be used to analyse potential change in physical activity, weight status, social contacts, mental and cardiometabolic health within a closed sample of residentially stable

participants. Comparisons between persons with contrasting proximities to different areas of the Parklands will provide ‘treatment’ and ‘control’ groups within a ‘quasi-experimental’ study design. In line with expectations, baseline results prior to the enhancement of the Western Sydney Parklands indicated virtually no significant differences in the distribution of any of the outcomes with respect to proximity to green space pre-intervention.

Ethics and dissemination

Ethical approval was obtained for the 45 and Up Study from the University of New South Wales Human Research Ethics Committee. Ethics approval for this study was obtained from the University of Western Sydney Ethics Committee. Findings will be disseminated through partner organisations (the Western Sydney Parklands and the National Heart Foundation of Australia), as well as to policy makers in parallel with scientific papers and conference presentations.

ARTICLE SUMMARY

Strengths and limitations of this study:

- A key strength of this study is the longitudinal design that leverages a major local change in green space provision.
- Another important strength is the range of health and behaviour variables that can be examined within a large sample of participants.
- The study is limited by self-report outcome data and that participants are aged 45 years and older, so future research that focusses on younger adults, youths and children within the same context is also warranted.

MAIN TEXT

Introduction

‘Green spaces’ such as public parks are increasingly regarded as important correlates of cardiovascular health by the scientific community.¹ This is based upon mounting evidence not only from small-scale experiments (e.g.^{2 3}), but also large observational studies (e.g.⁴⁻⁶). As a result, there is also rising interest among urban planning and health policy decision makers in the opportunities for constructing and targeting green spaces to make more ‘liveable’ neighbourhoods that actively promote mental and cardiometabolic health, physical recreation, and overall quality of life.^{7 8}

A challenge with this wave of optimism, however, is the quality of the observational evidence underpinning it.⁹ The vast majority of studies have been cross-sectional, which means that putative interventions, such as an increase in the quantity or quality of green space available locally, cannot be rigorously evaluated for their impact on health. Even with multivariate adjustment for income and other factors which determine where a person can choose to live, unmeasured(able) variables such as a person’s preference for living in a greener neighbourhood cannot be ruled out. This may lead to the

reporting of inaccurate (or even spurious) associations with health and inappropriate policy recommendations.

The observational evidence on green space and health is at a crossroads. More emphasis is required from studies using designs that harness temporal as well as spatial dimensions in order to provide insights on how much and/or what type of green space matters for what (i.e. participation in physical activity), when (i.e. at what period in the lifecourse) and for whom (i.e. particular socio-demographic groups).⁹ A one-size-fits-all prescription of green space seems unlikely and both scientific research and policy needs to engage with that potentially inconvenient level of complexity. In particular, the evaluation of natural experiments and controlled trials in order to enhance the quality of evidence available for decision makers is needed.¹⁰ Such longitudinal studies should (i) measure the association between a change in exposure to green space on a change in health outcome and (ii) have more rigorous controls for possible confounding, such as the restriction of a sample to people whose exposure changes around them (e.g. ¹¹), rather than as a result of relocation that is likely to be highly entwined with health selection.¹²

To build more robust evidence in this area, investigators at Western Sydney University and the University of Wollongong (Australia) formed a partnership with the Western Sydney Parklands Trust and obtained funding from the

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National Heart Foundation of Australia (ID 100161) to devise the ‘Western Sydney Parklands Longitudinal Study’ (WSPLS). The aim of the WSPLS is to assess, longitudinally, the extent that cardiovascular risk factors among middle-to-older aged adults are influenced by enhanced local green space provision.

In Western Sydney, a socioeconomically and culturally diverse region of Australia home to over 2 million residents, the New South Wales (NSW) Government invested in the development of approximately 5,280 hectares of green space stretching 27km north to south and spanning 3 Local Government Areas (LGA): Blacktown, Fairfield and Liverpool from 2009 onwards. Communities living across this area are known to experience significant levels of socioeconomic disadvantage and poorer health, such as a high risk of type 2 diabetes mellitus¹³ and psychological distress.¹⁴ The ‘Western Sydney Parklands’ will become the largest urban parkland in Australia and among the largest globally. Much of the land in 2009 comprised residential or vacant land-use. It is intended that the investment will change this composition to approximately 40% dedicated bushland, 25% sport and recreation, 22% long-term infrastructure (e.g. water storage), 10% urban farming, 2% business hubs, and 1% tourism. The development of the Western Sydney Parklands is an example of a large-scale investment in green space that could be potentially

regarded as an intervention for physical activity, mental and cardiometabolic health within proximity to communities with significant health need. In this paper, we outline a study protocol used for a quasi-experimental design to evaluate the health impacts of this natural experiment.

Methods and analysis

Data

A Geographic Information System (GIS) comprising geocoded land-use data was provided to the investigator team by the Western Sydney Parklands. This included the grounds of the Western Sydney Parklands and some of the features that have been constructed since 2009, such as the locations of public access points, advertising billboards, walking and cycle tracks, BBQ stations, and children's playgrounds. These data were linked to information on a range of health outcomes, health-related behaviour and possible confounders reported by participants in the 45 and Up Study baseline survey. Detailed information on the development of the 45 and Up Study is published elsewhere.¹⁵ In brief, 267,102 persons aged 45 to 106 years (mean age=62.8, standard deviation=11.2) responded to a self-complete baseline questionnaire that was delivered between 2006 and 2008. Participants had been randomly

selected from the Medicare Australia database (the national provider of universal health insurance), with a response of 18%. While this response is low and there was greater participation among more socioeconomic advantaged persons, previous work has suggested that findings from the 45 and Up Study compare favourably with more representative population health surveys.¹⁶ The 45 and Up Study has been previously used to analyse a range of health and behavioural outcomes in relation to green space exposure,^{5 17-21} as well as other spatial phenomena.^{11 13 22-26} The second wave of data collection was initiated in 2012 with a follow-up questionnaire mailed to over 40,000 participants and a further 86,250 contacted by late 2013. All other remaining participants will be re-surveyed in 2014 and 2015. The University of New South Wales Human Research Ethics Committee approved The 45 and Up Study.

Sample

The baseline sample for the WSPLS was initially selected from participants in the 45 and Up Study who resided up to 5 km Euclidean distance ('as the crow flies') from any point of the Western Sydney Parklands (Figure 1). As appropriate data becomes available, this sampling may be modified to take into account road and footpath network distance to the Western Sydney

Parklands, as this is likely to be more indicative of the journeys people will take to access the green space. A total of 7,272 participants were selected. These participants were nested within 624 'Census Collection Districts' (12 participants on average per Census Collector District, ranging from 1 to 156). A GIS was used to classify all participants in the sample by their respective Collection Districts of residence into 1 km proximity bands as the most basic definition of 'exposure' to the Western Sydney Parklands. As is evident from Figure 1, features of the Parklands that could promote certain health outcomes and health-related behaviours, such as walking paths and BBQ stations, are not randomly distributed. Similarly, there is a spatial patterning of features that offer no direct health benefit but may be effect measure modifiers through influencing the odds of whether participants visit the Western Sydney Parklands or not, such as the locations of advertising billboards. As such, definitions of exposure will be modified according to the hypothesised causal pathway being tested. Mental health, for example, may be influenced by living near any part of the Parklands, but especially areas where people can be social, such as BBQ stations, picnic tables and playgrounds. Conversely, the power for green space to influence physical recreation will likely depend on the locations of features that support active lifestyles, such as walking paths. Table 1 reports how the definition of exposure in the baseline sample could be potentially

modified accordingly. Approximately 61% of participants who lived within 1km of any part of the Parklands (n=543), for example, lived 10km or more from the nearest Parklands BBQ station. Proximity to other potentially health-relevant sites within the Western Sydney Parklands such as picnic tables, playgrounds, gardens and walking and cycling tracks will also be measured.

What outcomes will be measured?

A range of self-reported health outcomes and health-related behaviours at baseline and follow-up will be selected for analysis in line with existing scientific evidence.¹ Health outcomes will include an indicator of psychological wellbeing as measured by the Kessler 10 scale ('K10'), which screens for symptoms of psychological distress experienced over the four weeks prior to survey completion.²⁷ Questions in the K10 cover feelings of tiredness for no reason, nervous, hopeless, restless, depressed, sad and worthless. Participants had five choices for each of the ten questions (none of the time =1, a little of the time =2, some of the time =3, most of the time =4, all of the time=5) and these will be summed to give the overall score. In line with previous work,^{20 24}²⁸ a binary variable will be constructed with scores of 22 and over identifying participants at high risk of psychological distress.²⁹

Physical functioning will be measured using the Medical Outcomes Study Physical Functioning Scale (MOS-PF).^{30 31} The MOS-PF is a 10-item scale covering vigorous activities (e.g. climbing stairs) to more basic actions related to day to day living (e.g. bathing). Physical health will also be measured using body mass index (BMI), already shown to be related to green space in this data at baseline¹⁷ and derived from self-reported height and weight, with overweight (BMI 25 to 29.9) and obesity (BMI ≥ 30) determined by World Health Organization criteria.³² Comparisons between this measure of BMI and an objective measure with a sub-sample of this dataset were favorable.³³ Incidence of doctor-diagnosed cardiometabolic diseases such as hypertension, cardiovascular disease, and diabetes will also be assessed via self-report.

Key mediating variables between green space and mental and cardiometabolic health outcomes are those relating to physical recreation. These behavioural characteristics include self-reported responses describing walking and participation in moderate and vigorous physical activities, as well as questions on approximate time spent sitting, standing, watching television or computer screens, and sleep duration. Physical activity will be assessed using responses to questions derived from the Active Australia Survey³⁴: *"How many times did you do each of these activities last week?"* Participants could indicate moderate (e.g. gentle swimming) and vigorous (e.g. jogging) forms of activity

separately, as well as walking. The Active Australia Survey has been shown to have a satisfactory level of test-retest reliability³⁵ and cross-sectional analysis of baseline data has previously shown association between the derived variables and an objective measure of green space exposure.¹⁸

Improvements in green space provision may also stimulate enhancements in social networking.³⁶ Three out of four items will be selected from the shortened version of the Duke Social Support Index³⁷ in this regard: *“How many times in the last week did you... (i) spend time with friends or family who do not live with you”; (ii) “you go to meetings of social clubs, religious groups or other groups you belong to?”; and (iii) “How many people outside your home, but within one hour of travel, do you feel you can depend on or feel very close to?”* The fourth question on telephone conversations is less relevant and, therefore, will be considered as a form of negative control.³⁸

Descriptive analyses reported in Tables 2 and 3 show that there were virtually no significant differences in the distribution of any of these outcomes with respect to proximity to any part of the Western Sydney Parklands in the baseline sample. This can be expected as all of the enhancements occurred from 2009 onwards; after people participated in the 45 and Up Study baseline.

Epidemiological study design specifications to minimise confounding

The major source of confounding will include health selective migration.¹² This is when persons who are already healthier and more likely to use green space for health-enhancing reasons purposefully move to neighbourhoods located within close proximity of the Western Sydney Parklands, in order to benefit from the convenience of easy access to nature. Multiple specifications will be made to minimise this form of bias. First, the prospective design will focus attention exclusively upon persons who lived close to the Parklands before investment and enhancements began. Tracking health outcomes and health-related behaviours among this 'closed' sample through time will, therefore, help identify the impacts of changes in the green space located nearby. Second, drawing comparisons between persons with contrasting proximities to different areas of the Parklands (e.g. an area with versus an area without a BBQ station) will provide 'treatment' and 'control' groups that mimic a controlled trial; a 'quasi-experimental' study design.¹⁰

It is possible that some people will have invested in a move to a neighbourhood near the Parklands based upon knowledge that the enhancements would be made in the future. Multivariate adjustment for factors known to be associated with where a person can choose to live will be used to account for this selective migration. These factors include age, gender,

country of birth, whether a person is in a couple (i.e. married, civil partnership, or cohabiting) or single, annual household income, employment status and highest educational qualification. In addition, the level of socioeconomic deprivation within a neighbourhood will be taken into account using the Australian Bureau of Statistics 'Socio Economic Index For Areas' scale of relative advantage and disadvantage.³⁹ The distributions of these possible confounders are reported in Table 4. Unlike the health outcomes and health-related behaviours at baseline, many of these potential confounders were differentially patterned according to proximity. People living nearer the Parklands tended to be younger, born in Australia, living in a couple and with higher annual household incomes. Neighbourhoods near the Parklands also tended to be less socioeconomically deprived. All Census Collection Districts covered in the sample are classified as 'major city' in the Accessibility-Remoteness Index of Australia (ARIA).⁴⁰

Statistical analysis

Further use of GIS will be applied to refine and adapt measures of exposure and to define relevant 'control' groups according to the hypothesis being tested. The design is necessarily 'Intention To Treat' (ITT) as information in the

45 and Up Study on whether people specifically visit the Parklands is not known. Multilevel models⁴¹ will be the primary mode of analysis used to quantify associations between changes in green space and changes in health outcomes and health-related behaviours. These types of models are ideally suited to longitudinal data analysis⁴² as they are able to take into account and explicitly model variance in outcome variables as people age, such as the estimation of 'growth curves'.⁴³ These models will be fit in purpose-developed statistical software such as MLWIN⁴⁴ and estimated using relevant methods, such as Markov Chain Monte Carlo (MCMC).⁴⁵

Ethics and dissemination

All participants in the 45 and Up Study consented to the use of their questionnaire data and to data linkage. Ethical approval was obtained for the 45 and Up Study from the University of New South Wales Human Research Ethics Committee. Ethics approval for this study was obtained from the Western Sydney University Ethics Committee. Findings will be disseminated through partner organisations (the Western Sydney Parklands and the National Heart Foundation of Australia), as well as to health and urban planning policy makers in parallel with scientific papers and conference presentations.

Conclusion

Using a large source of existing data and a quasi-experimental study design, the WSPLS will provide cost-effective and valuable insights on the health impact of a major investment in one of the largest urban green spaces in Australia. The findings from this natural experiment will provide information for future green space developments, health policy makers and land-use planners on ‘what works’ in communities with significant health need.

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Contributorship statement

Conceived and designed the experiments: TAB, with support from XF and GSK.

Performed the experiments: TAB, XF.

Analyzed the data: TAB, XF.

Wrote the paper: TAB, XF, GSK.

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Competing interests

No, there are no competing interests.

For peer review only

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Competing interests statement

The authors have no competing interests to declare.

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Figure 1: Western Sydney Parklands, park features and proximity of Census Collection Districts

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Table 1: Proximity to selected features which are part of the Western Sydney Parklands

Proximity to any part of the Western Sydney Parklands (km)					
	≤ 1	2	3	4	5
N	891	1525	1516	1596	1724
N (%)					
Proximity to public access points (km)					
1	661 (74.2%)	13 (0.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
3	200 (22.4%)	1159 (76.0%)	767 (50.6%)	16 (1.0%)	0 (0.0%)
5	30 (3.4%)	162 (10.6%)	442 (29.2%)	1092 (68.4%)	707 (41.0%)
≥ 10	0 (0.0%)	191 (12.5%)	307 (20.3%)	488 (30.6%)	1017 (59.0%)
Proximity to walking and cycling tracks (km)					
1	613 (68.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
3	253 (28.4%)	1328 (87.1%)	1062 (70.1%)	0 (0.0%)	0 (0.0%)
5	25 (2.8%)	197 (12.9%)	417 (27.5%)	1386 (86.8%)	991 (57.5%)
≥ 10	0 (0.0%)	0 (0.0%)	37 (2.4%)	210 (13.2%)	733 (42.5%)
Proximity to BBQ stations (km)					
1	186 (20.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
3	101 (11.3%)	396 (26.0%)	160 (10.6%)	0 (0.0%)	0 (0.0%)
5	61 (6.8%)	77 (5.0%)	145 (9.6%)	420 (26.3%)	180 (10.4%)
≥ 10	543 (60.9%)	1052 (69.0%)	1211 (79.9%)	1176 (73.7%)	1544 (89.6%)
Proximity to advertising billboards (km)					
1	302 (33.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
3	520 (58.4%)	1120 (73.4%)	404 (26.6%)	0 (0.0%)	0 (0.0%)
5	66 (7.4%)	353 (23.1%)	874 (57.7%)	1088 (68.2%)	363 (21.1%)
≥ 10	3 (0.3%)	52 (3.4%)	238 (15.7%)	508 (31.8%)	1361 (78.9%)

Table 2: Patterning of health outcomes at baseline, by proximity to the Parklands

	Proximity to any part of the Western Sydney Parklands (km)				
	≤ 1	2	3	4	5
N	891	1525	1516	1596	1724
	Mean	Odds Ratio (95% CI)			
K10 ≥ 22	17%	0.9 (0.7, 1.1)	1.0 (0.8, 1.2)	1.2 (1.0, 1.5)	1.1 (0.9, 1.4)
% missing	2.69	3.21	3.03	3.57	3.54
Self-rated quality of life	3%	1.4 (0.8, 2.3)	0.9 (0.5, 1.6)	1.6 (0.9, 2.6)	1.3 (0.8, 2.2)
% missing	6.51	7.15	8.64	8.58	6.9
Overweight and obese	68%	0.9 (0.8, 1.1)	0.9 (0.8, 1.1)	1.1 (0.9, 1.3)	1.0 (0.8, 1.2)
% missing	8.08	8.33	9.04	9.15	9.05
Diabetes	13%	0.9 (0.7, 1.1)	1.1 (0.9, 1.4)	1.3 (1.0, 1.6) *	1.2 (1.0, 1.6)
% missing	0	0	0	0	0
High blood pressure	37%	0.9 (0.8, 1.1)	1.1 (0.9, 1.3)	1.2 (1.0, 1.5) *	1.1 (0.9, 1.2)
% missing	0	0	0	0	0
CVD	11%	0.8 (0.6, 1.0)	1.0 (0.8, 1.3)	1.1 (0.9, 1.4)	1.3 (1.0, 1.7) *
% missing	0	0	0	0	0
		Rate Ratio (95% CI)			
Physical functioning	17.86	1.0 (0.8, 1.2)	1.0 (0.8, 1.2)	1.2 (1.0, 1.5) *	1.2 (1.0, 1.4) *
% missing	19.98	20.98	22.82	23.37	24.42 *

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; from distance to Parklands < 1 km
95% CI: 95% Confidence Interval

Table 3: Patterning of health-related behaviours at baseline, by proximity to the Parklands

	Proximity to any part of the Western Sydney Parklands (km)				
	≤ 1	2	3	4	5
N	891	1525	1516	1596	1724
	Mean	Rate Ratio (95% CI)			
Walk	5.44	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	1.0 (1.0, 1.1)	1.0 (0.9, 1.1)
% missing	6.29	7.02	7.85	8.21	8.18
Moderate PA	4.36	0.9 (0.8, 1.0)	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)
% missing	12.91	11.8	13.65	14.29	13.98
Vigorous PA	1.48	1.2 (1.0, 1.5)	1.1 (0.9, 1.3)	1.1 (0.9, 1.3)	0.9 (0.7, 1.1)
% missing	18.97	19.54	21.11	22.12	21.46
Screen time (hours)	4.38	1.0 (0.9, 1.0)	1.0 (1.0, 1.1)	1.0 (0.9, 1.0)	1.0 (0.9, 1.0)
% missing	4.71	4.59	5.28	5.76	5.51
Social visits	3.95	0.9 (0.9, 1.0)	1.1 (1.0, 1.1)	1.1 (1.0, 1.2) **	1.1 (1.0, 1.2) *
% missing	3.82	4.33	4.22	5.01	4.58
Social groups	1.47	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)	1.1 (0.9, 1.2)
% missing	6.4	6.62	6.79	8.15	8
People I can depend on	6.51	1.0 (1.0, 1.1)	1.0 (0.9, 1.1)	1.0 (0.9, 1.0)	1.0 (0.9, 1.1)
% missing	5.95	5.38	4.55	6.58	6.15
		Coefficient (95% CI)			
Sitting time (hours)	5.76	-0.2 (-0.5, 0.1)	0.1 (-0.2, 0.3)	-0.2 (-0.5, 0.1)	0.0 (-0.3, 0.2)
% missing	7.86	8.07	9.56	11.34 *	9.45
Standing time (hours)	4.82	-0.1 (-0.4, 0.2)	-0.2 (-0.5, 0.1)	-0.1 (-0.4, 0.2)	-0.1 (-0.4, 0.2)
% missing	11	10.95	13.65	14.97 *	13.98 *
		Odds Ratio (95% CI)			
6 hours sleep or less	84%	1.0 (0.8, 1.2)	1.0 (0.8, 1.2)	1.0 (0.8, 1.2)	0.9 (0.8, 1.1)
% missing	4.26	3.41	3.63	4.7	4.47

* p < 0.05; ** p < 0.01; *** p < 0.001; from distance to Parklands < 1 km
95% CI: 95% Confidence Interval

Table 4: Patterning of possible confounders at baseline, by proximity to the Parklands

	Proximity to any part of the Western Sydney Parklands (km)				
	≤ 1	2	3	4	5
N	891	1525	1516	1596	1724
	Mean	Coefficient (95% CI)			
Age	58.95	1.1 (0.2, 1.9) *	2.0 (1.1, 2.8) ***	3.2 (2.3, 4.1) ***	3.7 (2.8, 4.6) ***
% missing	0	0.07	0.07	0.06	0.12
		Odds Ratio (95% CI)			
Women	54%	0.9 (0.8, 1.0)	0.9 (0.8, 1.1)	1.0 (0.8, 1.1)	1.0 (0.8, 1.1)
% missing	0	0	0	0	0
Country of birth	45%	1.0 (0.9, 1.2)	1.2 (1.0, 1.5) *	1.3 (1.1, 1.5) **	1.5 (1.3, 1.8) ***
% missing	0	0	0	0	0
Not in a couple	25%	0.7 (0.6, 0.9) **	0.9 (0.7, 1.1)	1.2 (1.0, 1.5) *	1.4 (1.1, 1.6) ***
% missing	1.01	0.52	0.86	0.75	0.7
Income ≤ \$20k	28%	1.0 (0.8, 1.3)	1.2 (1.0, 1.5)	1.7 (1.4, 2.0) ***	1.6 (1.3, 1.9) ***
% missing	25.36	27.48	26.12	27.38	25.58
Unemployed or limiting long-term illness	8%	1.1 (0.8, 1.6)	1.0 (0.7, 1.3)	1.5 (1.1, 2.0) **	1.1 (0.8, 1.5)
% missing	0.67	0.79	0.73	1.5	1.39
No educational qualifications	20%	0.7 (0.6, 0.9) **	0.9 (0.7, 1.1)	1.0 (0.8, 1.2)	1.0 (0.8, 1.2)
% missing	1.8	1.77	1.65	3.13	2.2
Lowest SEIFA tertile	21%	1.4 (1.2, 1.7) ***	1.5 (1.2, 1.8) ***	3.0 (2.5, 3.6) ***	2.8 (2.3, 3.4) ***
% missing	0	0	0	0	0

* p < 0.05; ** p < 0.01; *** p < 0.001; from distance to Parklands < 1 km
 95% CI: 95% Confidence Interval
 SEIFA: Socio Economic Index For Areas (relative advantage/disadvantage scale)

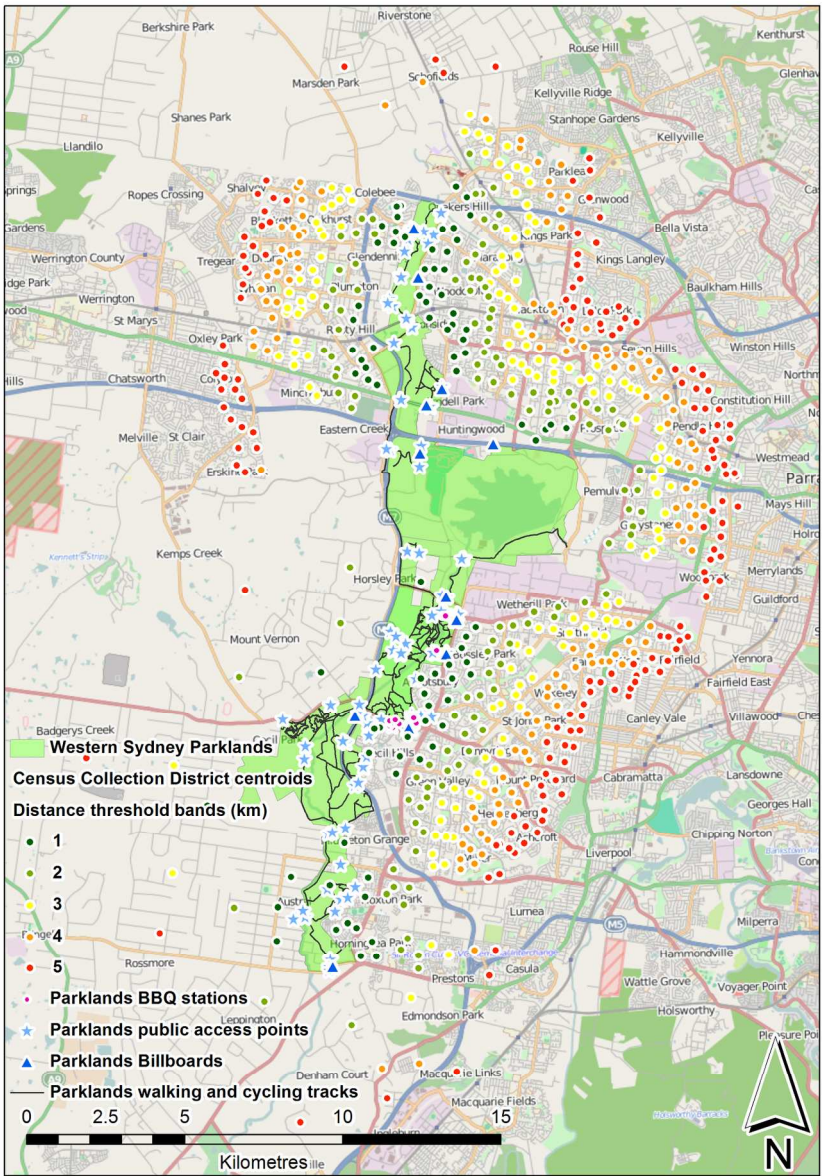


Figure 1
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