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# BMJ Open

## Associations between the physical activity environment surrounding regional primary schools and physical activity behaviours and weight status in Victoria, Australia

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3 1 **Title: Associations between the physical activity environment surrounding regional**  
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5 2 **primary schools and physical activity behaviours and weight status in Victoria,**  
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7 3 **Australia**  
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## 21 ABSTRACT

22 **Objectives:** To explore whether the physical activity environment (walkability, green space  
23 and recreational facilities) surrounding regional primary schools is associated with children's  
24 physical activity levels, active transport, and weight status. Limited research on this topic has  
25 been conducted outside of metropolitan areas.

26 **Design:** Cross-sectional ecological study using baseline data from two large-scale obesity  
27 prevention interventions

28 **Setting:** 39 primary schools across two regional areas in Victoria, Australia

29 **Participants:** Students aged 9 – 12 years (n=1794) attending participating primary schools.

30 **Outcome Measures:** Measured weight status and self-reported physical activity behaviours  
31 (meeting physical activity recommendations and active travel behaviour)

32 **Results:** A higher proportion of students used active transport to or from school when the  
33 school neighbourhood was more walkable ( $\beta = 0.041$  (95% CI:0.019 – 0.062),  $p < 0.01$ ), had a  
34 greater number of green spaces ( $\beta = 0.051$  (95% CI:0.028 – 0.075),  $p < 0.01$ ) and a greater  
35 number of recreational facilities ( $\beta = 0.023$  (95% CI:0.002 – 0.044),  $p = 0.03$ ). A higher  
36 cumulative physical activity environment score was associated with a higher proportion of  
37 children using active transport ( $\beta = 0.064$  (95% CI:0.037 – 0.091),  $p < 0.01$ ), but a higher  
38 proportion of students with overweight and obesity ( $\beta = 0.017$  (95% CI:0.001-0.034),  
39  $p = 0.04$ ).

40 **Conclusions:** This study is the first of its kind exploring school neighbourhood environments  
41 and child weight status and physical activity in regional areas of Australia. It highlights the  
42 potential of the environment surrounding primary schools in contributing to students' active  
43 travel to and from school. Further research with larger sample sizes and the use of objective

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3 44 physical activity measurement is warranted in regional and rural areas which have been  
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5 45 under-researched.  
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## 10 11 47 **Article Summary**

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14 48 There has been limited research conducted on environmental drivers of physical inactivity  
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16 49 and obesity in children outside of metropolitan areas, particularly within school  
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19 50 neighbourhoods.

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22 51 Strengths of the study include the use of measured student height and weight from large  
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24 52 studies with high participations rates and objectively measured physical activity environment.

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27 53 Study limitations include the low sample size once analysed at the school level, the use of  
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29 54 self-report physical activity behaviour data and not being able to determine how far children  
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31 55 lived from the schools.

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40 58 **Keywords:** Physical activity, obesity, active transport, walkability, greenspace, recreational  
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43 59 facilities, rurality  
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## 60 **BACKGROUND**

61 Built and natural environments significantly impact children's behaviours, particularly levels  
62 of physical activity.[1] Inadequate physical activity is a key risk factor for the development of  
63 childhood obesity,[2] as well as many other chronic conditions.[3] Nationally representative  
64 Australian surveys show that approximately a quarter of children aged 5 - 17 have overweight  
65 or obesity,[4] and only a quarter of 5 - 14 year olds meet the recommended levels of daily  
66 physical activity,[5] a figure reflected internationally.[6]

67 Research into environmental influences on children's physical activity and weight status has  
68 typically focused either on the neighbourhoods around children's homes[7-9] or the  
69 characteristics of the environment within school grounds.[10-13] Children spend a significant  
70 portion of their time both at school and in transit to and from school. Environments  
71 surrounding schools provide important physical activity opportunities, and potential settings  
72 for interventions to increase the physical activity levels of children. School neighbourhoods  
73 may also provide a useful proxy for activity centres within communities, within which  
74 children may have opportunities to participate in sports and other physically active recreation  
75 before or after school. An Australian study[14] found that organised sport accounted for only  
76 a small portion of student's overall physical activity levels indicating that other forms of  
77 physical activity, such as active transport and informal play are important contributors.[15,  
78 16]

79 Limited research has been conducted on the physical activity environment outside of  
80 metropolitan areas in Australia and internationally.[17-19] Australian data indicates that  
81 overweight and obesity prevalence has significantly increased in non-metropolitan areas since  
82 2010, whereas it appears to have plateaued in metropolitan areas.[20] Compared to children  
83 living in metropolitan areas, regional and rural children have been reported to be more overall  
84 more physically active,[21] although have lower levels of active transport.[20, 22] Several

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3 85 metropolitan based studies reported that key determinants of whether a child uses active  
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5 86 forms of transport to and from school include distance to school,[17, 23, 24] population  
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7 87 density[19] and street connectivity[25], which are all aspects of the environment that are  
8  
9 88 likely to differ between metropolitan and non-metropolitan areas.

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13 89 Reviews including primarily metropolitan children have found that increased availability of  
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15 90 green space,[26] walkability of neighbourhoods[27] and availability of sports facilities[27]  
16  
17 91 were associated with increased levels of physical activity. Evidence also suggests that the  
18  
19 92 presence of walking or bike paths and overall neighbourhood walkability are associated with  
20  
21 93 increased active transportation to and from school.[19, 23, 25] Children who use active forms  
22  
23 94 of transport to and from school have been found to have higher overall levels of physical  
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25 95 activity,[15, 16] however there are mixed results for the association of this behaviour with  
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27 96 weight status.[16, 28] It is unclear how physical activity environments may impact on  
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29 97 variation in activity levels and weight status in students outside of metropolitan areas.

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34 98 Given lower population densities, regional students may typically need to travel greater  
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36 99 distances to school and, it could be hypothesised that these children will be more reliant on  
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38 100 motorised transport. More work is needed to understand the relationship between physical  
39  
40 101 activity environments surrounding schools in regional areas and physical activity patterns and  
41  
42 102 weight status among students. This exploratory paper set out to investigate whether the  
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44 103 physical activity environment surrounding primary schools (walkability, green space, and  
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46 104 recreational facilities) is associated with students' weight status, physical activity and active  
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48 105 transport, in regional areas of Victoria, Australia.

## 53 106 **METHODS**

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56 107 The methods section is written to address the Strengthening the Reporting of Observational  
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58 108 Studies in Epidemiology (STROBE) Statement.[29]  
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3 109 *Study design:* This study used a cross-sectional ecological design to assess the associations  
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5 110 between school-neighbourhood physical activity environments and the aggregate levels of  
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7 111 physical activity, active transport and weight status among primary school students.  
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12 113 *Setting:* The study was conducted across two regional areas in Victoria, Australia. This  
13  
14 114 covers nine local government areas in the South-West and Goulburn Valley regions, with a  
15  
16 115 total population of 225,895[30] and includes a number of moderately-sized regional towns  
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18 116 (e.g. 10,000 to 30,000 people) and 142 government, Catholic and independent primary  
19  
20 117 schools. Data were collected between April 2015 and September 2016.  
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27 119 *Participants:* Child-level data used in this study were collected as part of the baseline  
28  
29 120 measurements for two large-scale systems-based obesity prevention interventions.[31] The  
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31 121 evaluations have been described previously,[32] [33] and were conducted in the same way in  
32  
33 122 both study regions. In brief, all government and independent primary schools in each study  
34  
35 123 region were invited to participate in 2015 and 2016. In participating schools, all students in  
36  
37 124 years 2 (aged approximately 7-8 years), 4 (aged approximately 9-10 years) and 6 (aged  
38  
39 125 approximately 11-12 years) were invited to participate via an opt-out recruitment approach.  
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46 127 *Weight Status:* Anthropometric measures of height and weight were taken by trained staff  
47  
48 128 according to a standardised protocol. Height was measured to the nearest 0.1cm and weight  
49  
50 129 the nearest 0.05kg. All students were measured twice and where the two initial measures  
51  
52 130 differed, by more than 0.5cm or 0.1kg for height and weight respectively, a third  
53  
54 131 measurement was taken. An average of these height and weight measures was used to  
55  
56 132 calculate body mass index (BMI) z-scores according to the WHO Child Growth Reference  
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3 133 [34], and weight status categories were derived using the following cut-offs, as recommended  
4  
5 134 by the WHO; overweight:  $>+1SD$  to  $\leq+2SD$ , obese:  $>+2SD$ . Both mean BMI z-score and  
6  
7 135 proportion of overweight or obese students within each school were analysed.  
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14 137 *Physical Activity Behaviours and Demographic questions:* Students completed an electronic  
15  
16 138 self-report questionnaire in class time on tablet computers, with guidance from a trained  
17  
18 139 supervisor. Students in Year 4 and 6 self-reported their gender, date-of-birth, language  
19  
20 140 usually spoken at home, Aboriginal and/or Torres Strait Islander background, residential  
21  
22 141 postcode, and country of birth. The physical activity components of the questionnaire used  
23  
24 142 for this study were the demographic information and the Core Indicators and Measures of  
25  
26 143 Youth Health – Physical Activity & Sedentary Behaviour Module,[35] which has been shown  
27  
28 144 to be reliable in this age-group.[35, 36]  
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31  
32 145 Physical activity was assessed as proportion of students within each school who participated  
33  
34 146 in at least 60 minutes of moderate to vigorous physical activity (MVPA) on 5 school days  
35  
36 147 (Monday – Friday), consistent with the National Physical Activity Guidelines.[37] Students'  
37  
38 148 usual mode of transport to and from school was categorised as either active (walking, cycling,  
39  
40 149 public bus, other active) or non-active (car, school bus, other inactive). Proportion of students  
41  
42 150 within each school who use active transport to or from school was calculated for analysis.  
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48  
49 152 *Physical activity environment:* The exposures in this study were three aspects of the physical  
50  
51 153 activity environment in each school's 'neighbourhood'; walkability, green space and  
52  
53 154 recreational facilities.

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56 155 A 1km street network buffer around each school was derived from the 'Neighbourhood  
57  
58 156 Generator' tool through the Australian Urban Research Infrastructure Network (AURIN)  
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3 157 Portal[38] to define each school's immediate 'neighbourhood'. This buffer was informed by  
4  
5 158 previous research suggesting that 1km is a feasible distance that children will walk to  
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7  
8 159 school.[39] A walkability score and the count of recreational facilities and green spaces  
9  
10 160 intersecting this buffer was determined for each school. A 50m trim distance was used around  
11  
12 161 the road centres, to capture green space and facilities accessible from the defined street  
13  
14  
15 162 network.

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17  
18 163 Walkability scores were generated for all primary schools in the study regions, using the  
19  
20 164 'Walkability Index with gross density for regions' tool through the AURIN portal.[40] Scores  
21  
22 165 are based on standardised scores for population density, land use mix and street connectivity,  
23  
24 166 which have been associated with increased walking. A z-score for each of the three domains  
25  
26  
27 167 is generated for all schools in the included regions, with the sum of these giving an overall  
28  
29 168 walkability score for each school.

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31  
32 169 Features of Interest (FOI) data were accessed via the Victorian Government data website  
33  
34 170 (Layer: VMFEAT\_FOI\_POLYGON) and are produced by the Department of Environment,  
35  
36  
37 171 Land, Water and Planning.[41] FOI data are projected as polygons and used to determine the  
38  
39 172 presence of facilities which may be used by students for physical activity. For the purpose of  
40  
41 173 this study we limited the categories of features to three key feature types; recreational  
42  
43 174 resources (e.g. skate parks), sporting facilities (e.g. tennis court, netball courts, golf course,  
44  
45 175 sporting complexes), and reserves (e.g. public parks and gardens). For this analysis,  
46  
47  
48 176 recreational resources and sporting facilities were combined and termed 'recreational  
49  
50 177 facilities' and reserves termed 'green space'. Recreational facilities and green space were  
51  
52 178 counted as part of a school's neighbourhood if any part of the feature intersected with the  
53  
54 179 walkability buffers (that is, they were within 1km walking distance of the school). If a reserve  
55  
56 180 contained recreational facilities it was counted as both recreational facility and green space.  
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3 181 Manual verification of locations of recreational facilities and green space was conducted on a  
4  
5 182 convenience sample of three schools (two inner regional and one outer regional) by authors JJ  
6  
7  
8 183 and NC. Following this process a number of reserves in the FOI dataset were observed to be  
9  
10 184 inappropriate for physical activity (e.g. inaccessible fields behind locked gates, nature strips  
11  
12 185 on roadside). Therefore all reserves were checked and verified using Google Maps satellite  
13  
14  
15 186 view to verify useability.  
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20 188 *Remoteness:* Remoteness classification for each school was determined according to the five  
21  
22 189 categories of the Accessibility/Remoteness Index for Australia (ARIA+); Major Cities, Inner  
23  
24 190 Regional, Outer Regional, Remote and Very Remote.[42] Classification is based on a  
25  
26 191 continuous variable derived from the area's access to services, measured as distance by road,  
27  
28 192 and the population of the closest centre.[43]  
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34 194 *Socioeconomic position:* Socioeconomic position (SEP) of the school was determined using  
35  
36 195 the Index of Community Socio-Educational Advantage (ICSEA) scores, obtained from the  
37  
38 196 Australian Curriculum, Assessment and Reporting Authority 'My School' website[44].  
39  
40 197 Scores are derived from a combination of reported parental occupation, parental income,  
41  
42 198 geographic location and proportion of indigenous students to provide an overall indication of  
43  
44 199 the school community's relative socio-economic position. ICSEA scores for each  
45  
46 200 participating school were dichotomised, categorising school into either equal to or above  
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48 201 ( $\geq 1000$ ) or below ( $< 1000$ ) the national median.  
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55 203 *Data Analysis:* School neighbourhoods (street network buffers) and FOI data were imported  
56  
57 204 into ArcMap (ArcGIS Desktop, version 10.7.1 ESRI, Redlands, CA).[45] An attribute table  
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3 205 was developed including all recreational facilities and green spaces that were within or  
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5 206 intersected with the 1km walkable neighbourhood around included primary schools. This was  
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8 207 exported to Stata SE Version 15 (StataCorp, College Station, TX)[46] for analysis.  
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10  
11 208 The unit of analysis was the school, and student-level outcome data were aggregated within  
12  
13 209 each school. Only year 4 and 6 student data were used as year 2 students did not complete  
14  
15 210 behaviour questionnaires. Schools with data on fewer than 20 students in years 4 and 6  
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17 211 (combined) were excluded from analysis to ensure valid estimates of school level means and  
18  
19 212 proportions.  
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22

23 213 Demographics at the school level were tabulated according to remoteness and SEP, as  
24  
25 214 measured by ISCEA, as aspects of the physical activity environment has been shown to vary  
26  
27 215 by these factors.[47] Two sample t-tests were used to indicate difference between groups.  
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30 216 Univariable ordinary least squares regressions were fitted to test the association between 1)  
31  
32 217 the count of recreational facilities within, or intersecting with, the 1km walkability buffer, 2)  
33  
34 218 the count of green spaces intersecting with the 1km walkability buffer, 3) the school  
35  
36 219 walkability score, and each of four outcome measures; weight status (mean BMI z-score and  
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38 220 proportion of students overweight or obese in each school) and physical activity behavioural  
39  
40 221 outcomes (adherence to physical activity guidelines and use of active transport) as separate  
41  
42 222 regressions. Adjustment was made for school SEP as measured by ICSEA in a multivariable  
43  
44 223 model. Geographical location (according to remoteness) is included in the ICSEA  
45  
46 224 calculation, and therefore was not adjusted for separately. A p-value  $\leq 0.05$  was considered  
47  
48 225 significant.  
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54 226 A secondary analysis was conducted to assess the impact of the total physical activity  
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56 227 environment by creating a composite score. Each of the three exposure variables were coded  
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3 228 into tertiles (low = 0, moderate = 1, high = 2), then summed for each school and used as the  
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5 229 exposure for analysis (range 0 to 6).  
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11 231 *Patient and public involvement*

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15 232 *At what stage in the research process were patients/the public first involved in the research*  
16  
17 233 *and how?* The public were involved in the development of the research project and provided  
18  
19 234 support in collecting the child level outcome measures.  
20  
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22  
23 235 *How were the research question(s) and outcome measures developed and informed by their*  
24  
25 236 *priorities, experience, and preferences?* The initial research questions came directly from  
26  
27 237 local health organisations determining this area as a priority in their region.  
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30  
31 238 *How were patients/the public involved in the design of this study?* The local health  
32  
33 239 organisation within these communities were involved in designing the study and the measures  
34  
35 240 used.  
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39 241 *How were they involved in the recruitment to and conduct of the study?* Key local agencies  
40  
41 242 including health services, education departments and primary care partnerships contributed  
42  
43 243 recruitment of participants to the study via the school system. Further, local health services  
44  
45 244 and primary care partnership staff assisted in the collection of data among school children.  
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49 245 *How were (or will) they be involved in your plans to disseminate the study results to*  
50  
51 246 *participants and relevant wider patient communities (e.g. by choosing what*  
52  
53 247 *information/results to share, when, and in what format)?* The study management committee  
54  
55 248 and local implementation committee in consultation with community members have been  
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58 249 involved in planning dissemination of the study results.  
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## RESULTS

Data were collected from 66% (85/129) of schools for two large-scale systems-based obesity prevention interventions, with 79% (3,476/4,386) of eligible students within those schools participating in the study. For this exploratory analysis, 44 schools had complete data for fewer than 20 students in grades 4 and 6 and were excluded. Two additional schools were excluded as the year 4 and 6 students were located on separate campuses, resulting in 39 schools being included in the final analysis. These schools included 1,794 students with complete measures (mean 46 students per school, median 36 students per school).

Descriptive statistics of the participating schools are presented in Table 1, stratified by remoteness and ICSEA. There were a number of differences between schools in inner and outer regional area, with less green space, lower walkability scores and lower total physical activity environment scores in outer compared to inner regional areas. A lower proportion of students used active forms of transport in outer compared to inner regional areas.

Stratification by ICSEA shows significantly more recreational facilities, higher mean walkability scores and higher total physical activity environment scores surrounding lower compared to higher SEP schools.

273 **Table 1:** Descriptive Statistics of Schools and Students

	Inner Regional	Outer Regional	Low SEP	High SEP	All schools
Schools (n)	32	7	29	10	39
Students (n)	1565	229	1404	390	1794
Min students	20	20	20	20	20
Max student	121	64	121	83	121
Mean (SD) age (years)	10.8	10.82	10.81	10.8	10.8
Proportion female	0.5	0.48	0.5	0.49	0.49
<b>Exposures</b>					
<i>Recreational Facilities</i>					
Mean (SD) features per school neighbourhood	4.03 (3.32)	2.86 (2.12)	4.48 (3.3)	1.9 (1.45)*	3.82 (3.14)
Range	0 -11	0 -5	0-11	0 -5	0 -11
<i>Green Space</i>					
Mean (SD) features per school neighbourhood	3.28 (2.33)	1.29 (0.95)*	3.21 (2.16)	2.1 (2.5)	2.92 (2.28)
Range	0 -8	0 -3	0-8	0-8	0 -8
<i>Walkability</i>					
Mean score (SD)	1.03 (2.57)	-1.91 (1.79)*	1.02 (2.76)	0 (1.83)*	0.51 (2.68)
Range	-3.91 - 6.96	-3.77 - 0.48	-3.91 - 6.96	-3.6 - 1.21	-3.91 - 6.96
<i>Total PA score</i>					
Mean score (SD)	3.03 (2.07)	1.14 (1.21)*	3.21 (1.99)	1.2 (1.55)*	2.69 (2.07)
Range	0 - 6	0 - 3	0 - 6	0 -4	0 -6
Mean (SD) proportion meeting PA guideline 5 school days	0.27 (0.11)	0.20 (0.13)	0.25 (0.12)	0.28 (0.10)	0.25 (0.12)
Mean (SD) proportion using AT to or from school	0.33 (0.19)	0.14 (0.13)*	0.33 (0.18)	0.22 (0.22)	0.30 (0.20)
<b>Outcomes</b>					
Mean (SD) BMI z-score	0.65 (0.25)	0.64 (0.20)	0.66 (0.26)	0.62 (0.19)	0.65 (0.24)
Mean (SD) proportion overweight or obese	0.37 (0.09)	0.38 (0.12)	0.38 (0.09)	0.35 (0.11)	0.37 (0.10)

274

275 \*Significant t-test result (&lt;0.05) for difference between inner and outer regional schools, and

276 difference between high and low SEP schools scores

277 Low SEP = ICSEA&lt;1000; High SEP = ICSEA≥1000

278 PA = physical activity; AT = active transport; SD = standard deviation; BMI = body mass index



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3 279 Table 2 shows results of the ordinary least squares regressions. The analysis did not show any  
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5 280 significant associations between any of the three individual features of the schools' physical  
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7 281 activity environments and either students' weight status or the proportion of students meeting  
8  
9 282 physical activity guidelines.

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13 283 Significant associations were found between the number of green spaces and the number of  
14  
15 284 recreational facilities in the school neighbourhood and proportion of students using active  
16  
17 285 transport to or from school. After adjusting for ICSEA, for every additional green space and  
18  
19 286 recreational facility there was a 5.1% point (95% CI: 2.8% - 7.5%) and 2.3% point (95% CI:  
20  
21 287 0.2% - 4.4%) increase in the proportion of children using active transport to or from school,  
22  
23 288 respectively. Similarly, significant associations were found between walkability scores and  
24  
25 289 the proportion of children using active transport, indicating a 4.1% point (95% CI 1.9% -  
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27 290 6.2%) increase in the proportion of children using active transport for every 1 point increase  
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29 291 in the walkability score.

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34 292 In the secondary analysis, significant associations were found between the summed 'total  
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36 293 physical activity environment' score and the proportion of students with overweight or  
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38 294 obesity, with a 1.7% point (95% CI 0.1% - 3.4%) increase in the proportion of students with  
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40 295 overweight or obesity for every one point increase in the total physical activity environment  
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42 296 score. This analysis also found a 6.4% point (95% CI 3.7% - 9.1%) increase in the proportion  
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44 297 of children using active transport for every 1 point increase in the total physical activity  
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46 298 environment score.

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303 **Table 2:** Associations Between Physical Activity Environment, Weight and Behavioural  
 304 Outcomes

		Model 1		Model 2	
		$\beta$ coef	95% CI	$\beta$ coef	95% CI
<i>Recreational Facilities</i>					
Outcome	Proportion meeting PA guidelines 5 school days	-0.002	-0.015 - 0.010	-0.001	-0.014 - 0.013
	Proportion using AT $\geq$ 1 trip	0.026	0.007 - 0.045 **	0.023	0.002 - 0.044 *
	BMI z-score	0.010	-0.016 - 0.035	0.009	-0.019 - 0.036
	Proportion overweight/obese	0.009	-0.001 - 0.019	0.008	-0.002 - 0.019
<i>Green Space</i>					
Outcome	Proportion meeting PA guidelines 5 school days	-0.003	-0.020 - 0.014	-0.002	-0.020 - 0.016
	Proportion using AT $\geq$ 1 trip	0.054	0.031 - 0.076 **	0.051	0.028 - 0.075 **
	BMI z-score	0.028	-0.007 - 0.062	0.027	-0.008 - 0.062
	Proportion overweight/obese	0.013	-0.000 - 0.027	0.013	-0.001 - 0.027
<i>Walkability</i>					
Outcome	Proportion meeting PA guidelines 5 school days	-0.007	-0.021 - 0.008	-0.006	-0.021 - 0.01
	Proportion using AT $\geq$ 1 trip	0.042	0.022 - 0.062 **	0.041	0.019 - 0.062 **
	BMI z-score	0.022	-0.007 - 0.051	0.022	-0.009 - 0.053
	Proportion overweight/obese	0.011	-0.000 - 0.023	0.011	-0.001 - 0.023
<i>Total PA environment score</i>					
Outcome	Proportion meeting PA guidelines 5 school days	-0.009	-0.028 - 0.009	-0.008	-0.029 - 0.013
	Proportion using AT $\geq$ 1 trip	0.062	0.038 - 0.086 **	0.064	0.037 - 0.091 **
	BMI z-score	0.032	-0.005 - 0.070	0.035	-0.007 - 0.077
	Proportion overweight/obese	0.017	0.002 - 0.031 *	0.017	0.001 - 0.034 *

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306 Model 1: Unadjusted; Model 2: Adjusted for ICSEA. \*  $p < 0.05$ , \*\* $p < 0.01$  PA = physical activity; AT  
 307 = active transport; BMI = body mass index

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## 309 **DISCUSSION**

310 This exploratory study assessed associations between the physical activity environment of 39  
311 primary schools, and weight status and physical activity behaviours, in regional Australia.

312 Significant associations were found between the proportion of students using active forms of  
313 transport to and/or from school and the number of green spaces, the number of recreational  
314 facilities and neighbourhood walkability scores. The total physical activity environment score  
315 was also associated with the proportion of students with overweight or obesity, although not  
316 in the expected direction. No significant associations were found between individual features  
317 of the physical activity environment surrounding the schools and weight status or physical  
318 activity levels.

319 Strengths of this study include the use of measured height and weight data from large  
320 regional studies with a very high student participation rate (79%).[32, 33] This high student  
321 participation rate is likely to reduce the impact of measurement error introduced through non-  
322 participation bias on estimates of behaviours and overweight and obesity.[48] Additionally,  
323 manually verifying the recreational facilities and green spaces within the 1km walkable  
324 neighbourhood of a sample of participating schools improved the validity of our  
325 environmental data and allowed refinements of the classification methods for green spaces  
326 and recreation facilities for analysis.

327 Using a 1km walkable neighbourhood is more accurate than other approaches such as the  
328 Euclidean distance to measure the environment[49] as it uses existing road networks that are  
329 likely to be used for active transport, reflecting actual transport routes. By contrast, Euclidean  
330 buffers do not account for road networks and access, and simply reflect the density of  
331 environmental features within a given area. The 1km neighbourhood also represents a  
332 distance that has been shown to be realistic for children to travel before or after school.[39,  
333 50]

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3 334 There were also a number of limitations with this study. As this is an exploratory study, the  
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5 335 sample size of schools was small, limiting the power of the statistical models used.

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7 336 Additionally, inherent issues exist with the use of self-report measures of physical activity,  
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10 337 particularly among children. These include recall and social-desirability biases and  
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12 338 challenges with accurate comprehension and reporting.[51] The use of objective measures  
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14 339 (such as accelerometry) to gain more accurate measures of physical activity would be  
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16 340 beneficial in future studies.

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20 341 Due to the cross-sectional study design, we are unable to determine causation between the  
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22 342 physical activity environment and the outcomes explored. Self-selection into a particular  
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24 343 area, in this instance by a child's parents, may also influence the results, particularly  
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26 344 considering those of higher SEP may be less likely to be obese, and choose environments  
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28 345 more conducive to physical activity.[52] However, in this study, more recreational facilities  
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30 346 and higher walkability scores were found in areas surrounding schools classified as lower  
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32 347 compared to higher SEP.

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36 348 Another limitation is that we did not have data on the distance that the children lived from the  
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38 349 school which may particularly influence the active transport outcome. These data would  
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40 350 enhance the analysis, however, we hypothesise that the school neighbourhood may act as a  
41  
42 351 proxy for the community physical activity environment, where children may play before and  
43  
44 352 after school, as well as an area that could enhance active transportation.

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46 353 The potential impact of residual confounding by other factors which were not able to be  
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48 354 controlled for also needs to be considered. These may include individual socio-economic  
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50 355 factors, parent's perception of the neighbourhood or safety, family car ownership and  
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52 356 distance to school.  
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3 357 A lack of association between the individual physical activity environment measures  
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5 358 surrounding schools and physical activity levels or weight status in students may be due to  
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7 359 lack of heterogeneity in our sample of those environmental characteristics that are  
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10 360 deterministic of behaviour, a lack of genuine associations between environments and these  
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12 361 outcomes, or insufficient power to detect differences. In regards to weight status, there are  
13  
14 362 many complex determinants of weight,[53] of which physical activity is only one. Other  
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16 363 environmental factors such as the food environment and individual factors also play a role,  
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18 364 but are beyond the scope of this study. While associations were found between the  
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20 365 environment and active transport, it has been suggested that active transport alone may not  
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22 366 result in sufficient energy expenditure to impact on obesity levels.[54]  
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27 367 Our finding of the significant association between the total physical activity environment  
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29 368 score and the proportion of students with high weight status was in the opposite direction to  
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31 369 our hypothesis and may reflect type II error. Further research with a larger sample is required  
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33 370 to unpack this finding. This impact of the overall physical activity environment warrants  
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35 371 further study, with more standardised measures that take in multiple aspects of the physical  
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37 372 activity environment, as is done to calculate walkability scores.  
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41 373 The walkability score used in this study included connectivity, land-use mix and population  
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43 374 density measures. Combining different aspects of the environment into a composite score is a  
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45 375 common approach to assess walkability.[55, 56] Reviews looking at individual components  
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47 376 of walkability have found more diverse land-use mix,[27, 57] population density[27, 58] and  
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49 377 street connectivity[25, 58, 59] to be associated with increased physical activity levels, or  
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51 378 active travel in children and adolescents. However a majority of published studies have been  
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53 379 conducted in metropolitan settings. The impact and relative importance of each of these  
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55 380 measures may differ for regional compared to metropolitan communities. To elicit  
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57 381 differences between regional and metropolitan environments, it may be useful to look at these

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3 382 components separately in a broader cross-section of environments, with further heterogeneity  
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5 383 in levels of remoteness (from major cities to very remote).  
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8 384 Our findings on the association between walkability scores of school neighbourhoods and  
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10 385 active transport are in line with other studies,[25, 59, 60] but represents one of very few  
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12 386 studies focused on regional areas. Distance to school has been shown to be an important  
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14 387 factor in the choice or ability to use active forms of transport for school commutes.[61, 62]  
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16 388 With increasing rurality, distances travelled to school tend to increase, thus impacting active  
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18 389 transport levels. This is supported by our results showing a significantly greater proportion of  
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20 390 children from inner regional schools actively commuted to school compared to those in outer  
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22 391 regional schools, a result reflected in other Australian studies.[20] While walkability was  
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24 392 associated with a greater proportion of students using active forms of transport for their  
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26 393 journeys to and from school, the overall number of children actively commuting remained  
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28 394 below one quarter in our sample. A Canadian study which considered active transport for  
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30 395 children who live within walking distance of their school (defined as 1.6km) found much  
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32 396 higher rates (up to 67%) of active transport.[63]  
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39 397 We have used a 1km buffer from primary schools in line with other research regarding the  
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41 398 distances that children would walk.[39] However, there is debate regarding the optimal  
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43 399 walking distance to use to define the local neighbourhood and to reflect accessible  
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45 400 environments for children where they are likely to access services and recreational  
46  
47 401 opportunities.[64] In the food environment literature there is some evidence that a larger  
48  
49 402 buffers should be used,[65, 66] Additionally, it may be that a larger buffer is more relevant in  
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51 403 regional and rural locations, where there is a greater reliance on cars, less public transport and  
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53 404 greater distances between homes and schools.  
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3 405 **Conclusions:** This study is the first of its kind exploring school neighbourhood  
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5 406 environments and child weight status and physical activity in regional areas of Australia. It  
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7 407 highlights the importance of the environment surrounding primary schools in contributing to  
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9 408 students' active travel to and from school. Further research with larger sample sizes and the  
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11 409 use of objective physical activity measurement is warranted in regional and rural areas to  
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13 410 further our understanding of the broader healthy school environment.  
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20 412 **Abbreviations:**

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23 413 ARIA: Accessibility/Remoteness Index for Australia

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26 414 AT: Active transport

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29 415 AURIN: Australian Urban Research Infrastructure Network

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32 416 BMI: Body Mass Index

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35 417 FOI: features of interest

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38 418 ICSEA: Index of Community Socio-Educational Advantage

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41 419 MVPA: Moderate to vigorous physical activity

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44 420 PA: physical activity

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47 421 SEP: Socio-Economic Position

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50 422 STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

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53 423 WHO: World Health Organisation

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3 426 **Declarations**  
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6 427 **Ethics approval and consent to participate:** This study received ethical approval from the  
7  
8 428 Deakin University Human Research Ethics Committee (DUHREC 2014–279), the Victorian  
9  
10 429 Department of Education and Training (DET 2015\_002622). Students enrolled in  
11  
12 430 participating schools were invited to take part in the study through the distribution of a plain  
13  
14 431 language statement and opt-out form. Students were considered to have provided informed  
15  
16 432 consent unless an opt-out form signed by their parents or guardians was returned to the  
17  
18 433 school or verbal assent was not given by the student at the time of measurement. Students  
19  
20 434 were also able to participate in as much (e.g. all measurements) or as little (e.g. only survey)  
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22 435 as desired.  
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27 436  
28 437 **Availability of data and materials:** The datasets used and/or analysed during the current  
29  
30 438 study are available from the corresponding author on reasonable request.  
31  
32

33 439 **Competing interests:** The authors declare that they have no competing interests  
34  
35

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37  
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39  
40 442 System Trial of Prevention Strategies for childhood obesity: WHO STOPS childhood obesity  
41  
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43  
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45  
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47  
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49  
50 447 NSW Health Translational Research Grants Scheme.  
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54  
55 448 **Author contributions:** JJ, NC and MN conceptualised the study and initial hypothesis and  
56  
57 449 collated environmental data. SA and CS conceived the WHOSTOP study and underlying  
58  
59 450 design. JJ conducted analysis and interpretation, with assistance from KB and MN. JJ  
60



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3 451 prepared the manuscript. JJ, MN, NC, CS, KB and SA provided intellectual input,  
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5 452 contributed to the development of the manuscript and have read and approved the final  
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8 453 manuscript  
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For peer review only



## Associations between the physical activity environment surrounding regional primary schools and physical activity behaviours and weight status in Victoria, Australia

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Check (section, page, lines)
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Abstract Pg 2, line 26
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract Pg 2-3, lines 22 - 44
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Background Pg 4- 5, lines 62 – 106
Objectives	3	State specific objectives, including any prespecified hypotheses	Background Pg 5, lines 103 - 106
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	Methods Pg 6, lines 110 - 112
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods Pg 6, lines 110-118
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Methods: Pg 6, lines 120 - 126
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Methods: Outcomes: pg 6-7; lines 128 – 151 Exposures: pg 7-8; lines 153 – 187 Confounders: pg 9; lines 189 - 202
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Methods: Outcomes: pg 6-7; lines 128 – 151 Exposures: pg 7-8; lines 153 – 187 Confounders: pg 9; lines 189 - 202
Bias	9	Describe any efforts to address potential sources of bias	Methods: Pg 10; lines 223 - 226
Study size	10	Explain how the study size was arrived at	Methods: Pg 10; lines 209 - 213
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Methods: Groupings: pg 6-9; lines 128 – 202; pg 10-11, lines 227 - 230 Variables in analyses – pg 9 -11; Lines 204 - 230
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Methods: Pg 9 – 10; lines 204 - 226
		(b) Describe any methods used to examine	Methods:

## Associations between the physical activity environment surrounding regional primary schools and physical activity behaviours and weight status in Victoria, Australia

		subgroups and interactions	Pg 10 -11; lines 227 - 230
		(c) Explain how missing data were addressed	n/a
		(d) If applicable, describe analytical methods taking account of sampling strategy	n/a
		(e) Describe any sensitivity analyses	n/a
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Results: Pg 12; lines 252 - 258
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results: Pg 12; lines 259 – 266 Pg 13; Table 1
		(b) Indicate number of participants with missing data for each variable of interest	n/a
Outcome data	15*	Report numbers of outcome events or summary measures	Pg 13; Table 1
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Results: Pg 14: Lines 279 – 291 Pg 15 - Table 2 Confounder adjusted: Model 2 – indicated in table legend
		(b) Report category boundaries when continuous variables were categorized	Pg 15 - Table 2
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Results: Pg 14, lines 292 – 298 Pg 15 - Table 2
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	Discussion: Pg 16, lines 310- 318
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion: Pg 17, lines 334 - 356
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations,	Discussion: Pg 18-19; lines 357 - 404

## Associations between the physical activity environment surrounding regional primary schools and physical activity behaviours and weight status in Victoria, Australia

		multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion: Pg 19, 397 – 404
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Pg 21, lines 440 - 447

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).



# BMJ Open

## Is the physical activity environment surrounding primary schools associated with students' weight status, physical activity or active transport, in regional areas of Victoria, Australia? A cross-sectional study.

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Secondary Subject Heading:	Epidemiology, Sports and exercise medicine
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3 1 **Title:** *Is the physical activity environment surrounding primary schools associated with*  
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5 2 *students' weight status, physical activity or active transport, in regional areas of Victoria,*  
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7 3 *Australia? A cross-sectional study.*  
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10 4 **Authors:** Jane Jacobs (Corresponding Author)<sup>a</sup>, Nicholas Crooks <sup>a</sup>, Steven Allender <sup>a</sup>,  
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3 20 **ABSTRACT**  
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5 21 **Objectives:** To explore whether the physical activity (PA) environment (walkability,  
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7 greenspace and recreational facilities) surrounding regional primary schools is associated  
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10 23 with children's PA levels, active transport, and weight status. Limited research on this topic  
11  
12 24 has been conducted outside of major cities.

15 25 **Design:** Cross-sectional ecological study using baseline data from two large-scale obesity  
16  
17 prevention interventions  
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20 27 **Setting:** Eighty (n= 80) primary schools across two regional areas in Victoria, Australia  
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22

23 28 **Participants:** Students aged 8 – 13 years (n=2,144) attending participating primary schools.  
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26 29 **Outcome Measures:** Measured weight status [Body Mass Index (BMI) z-score, proportion  
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28 overweight/obese] and self-reported PA behaviours (meeting PA recommendations and  
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30 active travel behaviour)  
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33 32 **Results:** When adjusted for student and school demographics, students had significantly  
34  
35 increased odds of using active transport to or from school when the school neighbourhood  
36  
37 was more walkable (OR 1.21 (95%CI 1.09, 1.35), had a greater number of greenspaces (OR  
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39 1.35 (95%CI 1.20, 1.53)) and a greater number of recreational facilities (OR 1.18 (95% CI  
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41 1.07, 1.31)). A higher cumulative PA environment score was also associated with a higher  
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43 proportion of children using active transport (OR 1.33 (95%CI 1.28, 1.51)). There were no  
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45 significant associations between the PA environment measures and either weight status, or  
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47 meeting the PA recommendations in adjusted models.  
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53 40 **Conclusions:** This study is the first of its kind exploring school neighbourhood environments  
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55 and child weight status and PA in regional areas of Australia. It highlights the potential of the  
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57 environment surrounding primary schools in contributing to students' active travel to and  
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3 43 from school. Further research with the use of objective PA measurement is warranted in  
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5 44 regional areas which have been under-researched.  
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## 10 11 46 **Strengths and Limitations**

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14 47 • There has been limited research conducted on environmental drivers of physical  
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16 48 inactivity and obesity in children outside of major cities, particularly in areas  
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18 49 surrounding schools.
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21 50 • Multi-level linear and logistic regressions were used to assess associations between  
22  
23 51 elements of the school neighbourhood physical activity environment and students'  
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25 52 weight status and physical activity behaviours.
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27 53 • Comparisons were made between PA environments of school neighbourhoods  
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29 54 surrounding high and low socio-economic position schools and between inner and  
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31 55 outer regional areas.
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33 56 • Strengths of the study include the use of measured student height and weight from  
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35 57 large studies with high participations rates and objectively measured physical activity  
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37 58 environments.
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39 59 • Study limitations include the use of self-report physical activity behaviour data and  
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41 60 the inability to determine how far children lived from the schools.  
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53 63 **Keywords:** Physical activity, obesity, active transport, walkability, greenspace, recreational  
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55 64 facilities, rurality, school environment, children  
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## 65 BACKGROUND

66 Built and natural environments significantly impact children's behaviours, particularly levels  
67 of physical activity (PA).[1] Inadequate PA is a key risk factor for the development of  
68 childhood obesity,[2] as well as many other chronic conditions.[3] Nationally representative  
69 Australian surveys show that approximately a quarter of children aged 5 - 17 have overweight  
70 or obesity,[4] and only a quarter of 5 - 14 year olds meet the recommended levels of daily  
71 PA,[5] a figure reflected internationally.[6]

72 Research into environmental influences on children's PA and weight status has typically  
73 focused either on the neighbourhoods around children's homes[7-9] or the characteristics of  
74 the environment within school grounds.[10-13] Children spend a significant portion of their  
75 time both at school and in transit to and from school. Environments surrounding schools  
76 provide important PA opportunities, and potential settings for interventions to increase the  
77 PA levels of children. School neighbourhoods may also provide a useful proxy for activity  
78 centres within communities, within which children may have opportunities to participate in  
79 sports and other physically active behaviours before or after school. An Australian study[14]  
80 found that organised sport accounted for only a small portion of student's overall PA levels  
81 indicating that other forms of PA, such as active transport and informal play are important  
82 contributors.[15, 16]

83 Limited research has been conducted on the PA environment outside of major cities in  
84 Australia and internationally.[17-19] Australian data indicates that overweight and obesity  
85 prevalence has significantly increased outside of major cities areas since 2010, whereas it  
86 appears to have plateaued in major cities.[20] Compared to children living in major cities,  
87 children living outside of major cities have been reported to be more physically active  
88 overall,[21] although have lower levels of active transport.[20, 22] Several major city based  
89 studies have reported that key determinants of whether a child uses active forms of transport

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3 90 to and from school include distance to school,[17, 23, 24] population density[19] and street  
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5 91 connectivity,[25] which are all aspects of the environment that are likely to differ between  
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8 92 major cities and regional and remote areas..  
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11 93 Reviews including primarily children in major cities have found that increased availability of  
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13 94 greenspace,[26] walkability of neighbourhoods[27] and availability of sports facilities[27]  
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15 95 were associated with increased levels of PA. Evidence also suggests that the presence of  
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17 96 walking or bike paths and overall neighbourhood walkability are associated with increased  
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19 97 active transportation to and from school.[19, 23, 25] Children who use active forms of  
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21 98 transport to and from school have been found to have higher overall levels of PA,[15, 16]  
22  
23 99 however there are mixed results for the association of this behaviour with weight status.[16,  
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25 100 28] It is unclear how PA environments may impact on variation in activity levels and weight  
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27 101 status in students outside of metropolitan areas.  
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32 102 Given lower population densities, regional students may typically need to travel greater  
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34 103 distances to school and, it could be hypothesised that these children will be more reliant on  
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36 104 motorised transport. More work is needed to understand the relationship between PA  
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38 105 environments surrounding schools in regional areas and PA patterns and weight status among  
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40 106 students.  
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45 107 In this study we aimed to quantify the relationships between physical activity environments  
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47 108 surrounding primary schools and i)students' weight status ii) PA levels iii) active transport, in  
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49 109 regional areas of Victoria, Australia. Findings from this study may aid in the prioritisation  
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51 110 and targeting of policies and programs to improve PA environments around schools, so that  
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53 111 all children have the opportunity to engage in PA, regardless of where they live.  
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## 112 **METHODS**

113 The methods section is written to address the Strengthening the Reporting of Observational  
114 Studies in Epidemiology (STROBE) Statement.[29]

115 *Study design:* This study used a cross-sectional ecological design to assess the associations  
116 between school-neighbourhood PA environments and the self-report measures of PA and  
117 active transport and measured weight status among primary school students.

118  
119 *Setting:* The study was conducted across two regional areas in Victoria, Australia. This  
120 covers nine local government areas in the South-West and Goulburn Valley regions, with a  
121 total population of 225,895[30], which includes a number of moderately-sized regional towns  
122 (e.g. 10,000 to 30,000 people) and 142 Government, Catholic and Independent primary  
123 schools. Data were collected between April 2015 and September 2016.

124  
125 *Participants:* Child-level data used in this study were collected as part of the baseline  
126 measurements for two large-scale systems-based obesity prevention interventions.[31, 32]  
127 The evaluations have been described previously,[33] and were conducted in the same way in  
128 both study regions. In brief, in the 2015 (South-West region) and 2016 (Goulburn Valley  
129 region) data collection periods all primary schools (Government, Independent and Catholic)  
130 were invited to participate. In participating schools, all students in year 2 (aged  
131 approximately 7-8 years), year 4 (aged approximately 9-10 years) and year 6 (aged  
132 approximately 11-12 years) were invited to participate via an opt-out recruitment approach.  
133 Catholic schools data were not included in 2015 as approval to use passive (opt-out)  
134 recruitment processes were not granted by Catholic schools in that year, and evidence shows  
135 that opt-in consent can result in up to 5% lower overweight and obese prevalence detection  
136 [34] .



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6 138 *Weight Status:* Anthropometric measures of height and weight were taken by trained staff  
7  
8 139 according to a standardised protocol. Height was measured to the nearest 0.1cm and weight  
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10 140 the nearest 0.05kg. All students were measured twice and where the two initial measures  
11  
12 141 differed, by more than 0.5cm or 0.1kg for height and weight respectively, a third  
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14 142 measurement was taken. An average of these height and weight measures was used to  
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16 143 calculate body mass index (BMI) z-scores according to the World Health Organization  
17  
18 144 (WHO) Child Growth Reference [35], and weight status categories were derived using the  
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20 145 following cut-offs, as recommended by the WHO; overweight:  $>+1SD$  to  $<+2SD$ , obese:  
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22 146  $\geq+2SD$ . BMI z-score and overweight or obese (yes/no) were included in the analysis.  
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30 148 *Physical Activity Behaviours and Demographic questions:* Students completed an electronic  
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32 149 self-report questionnaire in class time on tablet computers, with guidance from a trained  
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34 150 supervisor. Students in years 4 and 6 self-reported their gender, date-of-birth, language  
35  
36 151 usually spoken at home, Aboriginal and/or Torres Strait Islander background, residential  
37  
38 152 postcode, and country of birth. The PA components of the questionnaire used for this study  
39  
40 153 were the demographic information and the Core Indicators and Measures of Youth Health –  
41  
42 154 Physical Activity & Sedentary Behaviour Module,[36] which has been shown to be reliable  
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44 155 in this age-group.[36, 37]  
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49 156 Physical activity was assessed students participating in at least 60 minutes of moderate to  
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51 157 vigorous physical activity (MVPA) on 5 school days (Monday – Friday) (yes/no), consistent  
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53 158 with the Australian National Physical Activity Guidelines at the time.[38] Students' usual  
54  
55 159 mode of transport to and from school was categorised as either active (walking, cycling,  
56  
57 160 public bus, other active) or non-active (car, school bus, other inactive).  
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161

162 *Physical activity environment:* The exposures in this study were three aspects of the PA  
 163 environment in each school's 'neighbourhood'; walkability, greenspace and recreational  
 164 facilities (Table 1). A 1km street network buffer around each school was derived from the  
 165 'Neighbourhood Generator' tool through the Australian Urban Research Infrastructure  
 166 Network (AURIN) Portal[39] to define each school's immediate 'neighbourhood'. This  
 167 buffer was informed by previous research suggesting that 1km is a feasible distance that  
 168 children will walk to school.[40] A walkability score for this buffer area, and the count of  
 169 recreational facilities and greenspaces intersecting this buffer was determined for each  
 170 school. A 50m trim distance was used around the road centres, to capture greenspace and  
 171 facilities accessible from the defined street network.

172

173

174 **Table 1: Description of independent, dependent and control variables used in the**  
 175 **analysis**

<b>Independent variables*</b>			
	<b>Measurement method</b>	<b>Level of data</b>	<b>Data source</b>
Walkability	Population Density + Land-Use Mix + Connectivity. Objectively measured	Continuous	Australian Urban Research Infrastructure Network [41]
Greenspace	Count of greenspaces Objectively measured	Continuous	datavic 'features of interest' [42]
Recreation Facilities	Count of recreation facilities Objectively measured	Continuous	datavic 'features of interest' [42]
Total PA environment	Each independent variable broken into tertiles (lowest to highest) and tertiles summed	Continuous	Tertiles created based on above measures
<b>Dependent variables</b>			
	<b>Measurement method</b>	<b>Level of data</b>	<b>Reference for variable definition</b>
Active travel	Active travel to or from school on typical day Self-report questionnaire	Dichotomous	Australian National Physical Activity Guidelines[38]
Physical activity	Meeting PA guidelines on 5 school days in typical week Self-report questionnaire	Dichotomous	Australian National Physical Activity Guidelines[38]

Weight status	Classified overweight or obese based on WHO growth chart Measured	Dichotomous	WHO growth chart[35]
BMI z-score	Age and gender BMI z-score based on WHO growth chart Measured	Continuous	WHO growth chart[35]
<b>Control variables</b>			
Socio-economic position	ICSEA (School-level SEP)	Continuous	Australian Curriculum Assessment and Reporting Authority [43]
Remoteness	Classified into 5 levels – Major city, Inner Regional, Outer Regional, Remote, Very Remote	Categorical	Accessibility/Remoteness Index of Australia [44]
School type	Classified as Government, Independent, Catholic	Categorical	Australian Curriculum Assessment and Reporting Authority [43]

176 \*within a 1km walkable distance from the school

177 WHO: World Health Organization; ICSEA: Index of Community Socio-Educational  
178 Advantage; SEP: Socio-economic position; BMI: Body Mass Index

179

180 Walkability scores were generated for all primary schools in the study regions, using the  
181 ‘Walkability Index with gross density for regions’ tool through the AURIN portal.[41] Scores  
182 are based on standardised scores for population density, land use mix and street connectivity,  
183 which have been associated with increased walking.[45] A z-score for each of the three  
184 domains is generated for all schools in the included regions, with the sum of these giving an  
185 overall walkability score for each school.

186 Features of Interest (FOI) data were accessed via the Victorian Government data website  
187 (Layer: VMFEAT\_FOI\_POLYGON) and are produced by the Department of Environment,  
188 Land, Water and Planning.[42] FOI data are projected as polygons and used to determine the  
189 presence of facilities which may be used by students for PA. For the purpose of this study we  
190 limited the categories of features to three key feature types; recreational resources (e.g. skate  
191 parks), sporting facilities (e.g. tennis court, netball courts, golf course, sporting complexes),  
192 and reserves (e.g. public parks and gardens). For this analysis, recreational resources and

1  
2  
3 193 sporting facilities were combined and termed ‘recreational facilities’ and reserves termed  
4  
5 194 ‘greenspace’. Recreational facilities and greenspace were counted as being within a school’s  
6  
7  
8 195 neighbourhood if any part of the feature intersected with the walkability buffers (that is, they  
9  
10 196 were within 1km walking distance of the school). If a reserve contained recreational facilities  
11  
12 197 it was counted as both recreational facility and greenspace.

13  
14  
15 198 Manual verification of locations of recreational facilities and greenspace was conducted on a  
16  
17 199 convenience sample of three schools (two inner regional and one outer regional) by authors JJ  
18  
19  
20 200 and NC. Following this process a number of reserves in the FOI dataset were observed to be  
21  
22 201 inappropriate for PA (e.g. inaccessible fields behind locked gates, nature strips on roadside).  
23  
24 202 Subsequently all reserves were checked and verified using Google Maps satellite view to  
25  
26  
27 203 verify useability, a technique that has been used increasingly in environmental studies.[46]  
28  
29

30 204  
31  
32  
33 205 *Remoteness*: Remoteness classification for each school was determined according to the five  
34  
35 206 categories of the Accessibility/Remoteness Index for Australia (ARIA+); Major Cities, Inner  
36  
37 207 Regional, Outer Regional, Remote and Very Remote.[47] Classification is based on a  
38  
39  
40 208 continuous variable derived from the area’s access to services, measured as distance by road,  
41  
42 209 and the population of the closest centre.[44] All schools included in this study fall into the  
43  
44 210 Inner Regional and Outer Regional categories.  
45

46 211  
47  
48  
49 212 *Socioeconomic position*: Socioeconomic position (SEP) of the school was determined using  
50  
51 213 the Index of Community Socio-Educational Advantage (ICSEA) scores, obtained from the  
52  
53 214 Australian Curriculum, Assessment and Reporting Authority ‘My School’ website[43].  
54  
55  
56 215 Scores are derived from a combination of reported parental occupation, parental income,  
57  
58 216 geographic location and proportion of indigenous students to provide an overall indication of  
59  
60

1  
2  
3 217 the school community's relative socio-economic position. ICSEA scores for each  
4  
5 218 participating school were included as a continuous variable in the regression models, but  
6  
7  
8 219 were dichotomised for comparison of descriptive statistics, categorising school into either  
9  
10 220 equal to or above ( $\geq 1000$ ) or below ( $< 1000$ ) the national mean.  
11  
12

221

13  
14  
15 222 *Data Analysis:* Only year 4 and 6 student data were used as year 2 students did not complete  
16  
17 223 the behaviour questionnaires. Data collected in 2015 and 2016 were combined as one cohort  
18  
19  
20 224 for analysis.  
21  
22

23 225 School neighbourhoods (street network buffers) were imported from the AURIN results into  
24  
25 226 ArcMap (ArcGIS Desktop, version 10.7.1 ESRI, Redlands, CA).[48] The FOI data, which  
26  
27 227 included greenspace and recreation facility locations projected as polygons, were also  
28  
29  
30 228 imported into ArcMap. Within ArcMap, the intersect tool was used to produce an attribute  
31  
32 229 table including all recreational facilities and greenspaces that were within, or intersected with,  
33  
34 230 the 1km walkable neighbourhood around included primary schools. Duplicates were removed  
35  
36  
37 231 within school neighbourhood (where a polygon intersected with the buffer multiple times).  
38  
39 232 This table was exported to Stata SE Version 15 (StataCorp, College Station, TX)[49] for  
40  
41 233 analysis.  
42  
43

44 234 Demographics at the school level were tabulated according to remoteness and SEP  
45  
46 235 (low/high), as measured by ISCEA, as aspects of the PA environment has been shown to vary  
47  
48  
49 236 by these factors.[50] Two sample t-tests and proportion tests were used to determine  
50  
51 237 differences between groups.  
52  
53

54 238 Multilevel mixed effects logistic regression were fitted to test the association between  
55  
56 239 independent variables: i) the count of recreational facilities within, or intersecting with, the  
57  
58  
59 240 1km walkability buffer, ii) the count of greenspaces within, or intersecting with, the 1km  
60

1  
2  
3 241 walkability buffer, iii) the school walkability score, and each of three dependent variables; i)  
4  
5 242 weight status (overweight or obese) (yes/no) ,ii)adherence to PA guidelines (yes/no) and  
6  
7 243 iii)use of active transport(yes/no) as separate regressions. Multi-level linear regression  
8  
9 244 models were fitted to test the associations between all three PA environment independent  
10  
11 245 variables and the dependent variable of BMI z-score. For all models, clustering was  
12  
13 246 accounted for at the school level. Initial models (model 1) did not include any adjustment for  
14  
15 247 covariates. In model 2, adjustments were made for school-level SEP (measured by ICSEA),  
16  
17 248 student's gender and age (in years) and school type (Government, Catholic, Independent). A  
18  
19 249 third regression model (model 3) included all independent variables related to the PA  
20  
21 250 environment. Geographical location (according to remoteness) is a direct input into the  
22  
23 251 calculation of ICSEA. Correlation analysis shows that the two variables are collinear in this  
24  
25 252 sample (pairwise correlation  $p < 0.05$ ) and therefore remoteness was not adjusted for in any of  
26  
27 253 the models. A p-value  $< 0.05$  for all associations was considered significant.  
28  
29  
30  
31  
32  
33 254 A secondary analysis was conducted to assess the impact of the total PA environment by  
34  
35 255 creating a composite score. Each of the three exposure variables were coded into tertiles (low  
36  
37 256 = 1, moderate = 2, high = 3), then summed for each school. This total PA environment score  
38  
39 257 was used as the independent variable for analysis with each of the weight and PA behaviour  
40  
41 258 outcomes.  
42  
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### 259 260 *Patient and public involvement*

261 The wider trials from which the baseline data are drawn upon for this manuscript involved  
262 extensive collaboration with numerous community-based organisations (e.g. health services,  
263 primary care partnerships and local councils). Key local agencies contributed to recruitment  
264 and student level data collection.

1  
2  
3 265 The outcome measurements (weight and health behaviours) were developed in conjunction  
4  
5 266 with community-based organisations (e.g. health services, primary care partnerships) due to  
6  
7 267 an absence of locally available data on the prevalence of childhood obesity and associated  
8  
9 268 modifiable behaviours.  
10  
11  
12

13 269

## 16 270 **RESULTS**

17  
18 271 Data were collected from 65% (84/129) of eligible schools for two large-scale systems-based  
19  
20 272 obesity prevention interventions, with 79% (3,476/4,386) of eligible students within those  
21  
22 273 schools participating in the study. Of these eligible students, 2,269 were in years 4 and 6. For  
23  
24 274 this analysis, three special development schools were excluded due to not being assigned an  
25  
26 275 ICSEA score and one further school did not have complete data on any year 4 or 6 students.  
27  
28 276 This resulted in 80 schools being in the final analysis. These schools included 2,144 students  
29  
30 277 with complete measures (94% of eligible year 4 and 6 students). There was some variation in  
31  
32 278 gender and year level within the excluded students (n=72 boys, n=53 girls; n=74 year 6s,  
33  
34 279 n=51 year 4s).

35  
36  
37  
38  
39 280 Descriptive statistics of the participating schools are presented in Table 2, stratified by school  
40  
41 281 level SEP (ICSEA) and remoteness classification. Stratification by ICSEA shows a  
42  
43 282 significantly greater number of recreation facilities and greenspaces, and higher mean  
44  
45 283 walkability scores in low compared to high SEP school neighbourhoods. A significantly  
46  
47 284 higher proportion of students attending low SEP schools used active transport to or from  
48  
49 285 school, but a higher proportion of students attending high SEP schools met the PA guidelines,  
50  
51 286 and students attending high SEP schools had a lower mean BMI z-score.  
52  
53

54  
55  
56 287 There were a number of differences between schools in inner and outer regional areas, with a  
57  
58 288 lower number of recreation facilities and greenspaces, lower walkability scores and lower  
59  
60



289 total PA environment scores in outer compared to inner regional areas. Further, a lower  
 290 proportion of students used active forms of transport in outer compared to inner regional  
 291 areas.

292

293 **Table 2: Descriptive statistics of schools (n=80) and students (n = 2,144)**

	Low SEP	High SEP	Inner Regional	Outer Regional	All schools
Schools (n)	56	24	60	20	80
Students (n)	1616	528	1813	331	2144
Mean (SD) age (years)	10.86 (1.08)	10.95 (1.05)	10.88 (1.07)	10.9 (1.09)	10.88 (1.08)
Proportion female	0.49	0.48	0.49	0.49	0.49
<b>Exposures</b>					
Recreational Facilities Mean (SD) features per neighbourhood	3.71 (2.81)	2.25 (1.75)*	3.40 (2.82)	2.90 (1.86)*	3.28 (2.62)
Range	0-11	0-7	0-11	0-7	0-11
Greenspace Mean (SD) features per neighbourhood	2.40 (1.96)	1.62 (1.86)*	2.43 (2.11)	1.40 (1.10)*	2.18 (1.95)
Range	0-8	0-8	0-8	0-4	0-8
Walkability Mean score (SD)	-0.39 (2.71)	-1.64 (1.56)*	-0.41 (2.69)	-1.84 (1.24)*	-0.76 (2.48)
Range	-3.91 - 6.96	-3.76 - 1.22	-3.91 - 6.96	-3.77 - 0.47	-3.91 - 6.96
Total PA score Mean score (SD)	5.2 (1.93)	4.00 (1.29)	5.10 (1.94)	4.05 (1.19)	4.84 (1.83)
Range	3-9	3-7	3-9	3-6	3-9
<b>Outcomes</b>					
Proportion meeting PA guidelines 5 school days	0.24 (0.42)	0.30 (0.46)*	0.27 (0.44)	0.22 (0.42)	0.26 (0.44)
Proportion using AT to or from school	0.33 (0.47)	0.18 (0.38)*	0.32 (0.47)	0.17 (0.37)*	0.29 (0.46)
Proportion overweight/obese	0.39 (0.49)	0.33 (0.47)	0.38 (0.49)	0.37 (0.48)	0.38 (0.48)
Mean (SD) BMI z- score	0.69 (1.22)	0.59 (1.1)*	0.67 (1.2)	0.65 (1.18)	0.67 (1.19)

294 \*Significant t-test or proportion test result ( $p < 0.05$ ) for difference between inner and outer regional  
 295 schools, or difference between high and low SEP schools scores

296 Low SEP = ICSEA < 1000; High SEP = ICSEA  $\geq$  1000



297 PA = physical activity; AT = active transport; SD = standard deviation; BMI = body mass index

298

299 Table 3 shows the analysis did not find any significant associations between the schools' PA  
300 environment and either students' weight status or the odds of students meeting PA guidelines  
301 once adjusted for demographics of the students and schools.

302 Significant associations were found between each of the independent variables (recreation  
303 facilities, greenspace and walkability) and the odds of a student using active transport to or  
304 from school. When adjusted for age, gender, school SEP and school type (model 2) the  
305 biggest effect size was for greenspace, with every additional greenspace in a school  
306 neighbourhood increasing the odds of a student using active transport to or from school by  
307 35% (OR 1.35: 95% 1.20, 1.53). The association between greenspace and active transport  
308 also remained when adjusted for the other independent variables (model 3) (OR 1.30, 95%  
309 1.09, 1.54).

310 In the secondary analysis, significant associations were found between the summed 'total PA  
311 environment' score and using active transport and weight outcomes in the unadjusted model.  
312 However, in the adjusted model, only a significant result remained for active transport (OR  
313 1.33, 95% CI 1.28, 1.51).

314

315

316 **Table 3: Associations Between Physical Activity Environment, Weight and Behavioural**  
317 **Outcomes (students n = 2,144)**

	Model 1		Model 2		Model 3	
	<i>Odds Ratio</i>	<i>95% CI</i>	<i>Odds Ratio</i>	<i>95% CI</i>	<i>Odds Ratio</i>	<i>95% CI</i>
<b>Meeting PA guidelines</b>						
Recreational Facilities	0.97	0.92, 1.02	0.98	0.93, 1.04	1.00	0.93, 1.07
Greenspace	0.96	0.89, 1.04	0.98	0.91, 1.06	1.00	0.90, 1.11
Walkability	0.96	0.90, 1.02	0.97	0.92, 1.04	0.98	0.90, 1.07

Total PA environment	0.94	0.87, 1.00	0.95	0.87, 1.04	-	-
<b>Using AT 1+ trip</b>						
Recreational Facilities	<b>1.23**</b>	1.11, 1.37	<b>1.18**</b>	1.07, 1.31	1.05	0.94, 1.18
Greenspace	<b>1.41**</b>	1.24, 1.61	<b>1.35**</b>	1.20, 1.53	<b>1.30**</b>	1.09, 1.54
Walkability	<b>1.26**</b>	<b>1.14, 1.41</b>	<b>1.21**</b>	1.09, 1.35	1.01	0.87, 1.17
Total PA environment	<b>1.40**</b>	1.23, 1.58	<b>1.33**</b>	1.28, 1.51	-	-
<b>Overweight/obese</b>						
Recreational Facilities	1.03	1.00, 1.06	1.01	0.98, 1.04	1.01	0.97, 1.04
Greenspace	<b>1.04*</b>	1.00, 1.09	1.03	0.99, 1.07	1.03	0.97, 1.08
Walkability	1.03	0.99, 1.07	1.01	0.98, 1.05	1.00	0.95, 1.04
Total PA environment	<b>1.05*</b>	1.00, 1.10	1.03	0.99, 1.08	-	-
	<i>Beta<sup>^</sup></i>	<i>95% CI</i>	<i>Beta<sup>^</sup></i>	<i>95% CI</i>	<i>Beta<sup>^</sup></i>	<i>95% CI</i>
<b>BMI z-score</b>						
Recreational Facilities	0.01	-0.01, 0.29	0.00	-0.02, 0.02	0.00	-0.03, 0.02
Greenspace	<b>0.03*</b>	0.00, 0.05	0.02	-0.01, 0.04	0.03	-0.01, 0.06
Walkability	0.01	-0.01, 0.03	0.00	-0.02, 0.02	-0.01	-0.04, 0.02
Total PA environment	<b>0.03*</b>	0.00, 0.06	0.01	-0.01, 0.04	-	-

318

319 Model 1: unadjusted; Model 2: adjusted for age (years), gender, school type and ICSEA  
 320 (school-level SEP); Model 3: adjusted for age (years), gender, school type, ICSEA (school-  
 321 level SEP) and other independent variables.

322 \* p<0.05, \*\*p<0.01 PA = physical activity; AT = active transport; BMI = body mass index

323 <sup>^</sup>mean change in BMI z-score

324

325

## 326 DISCUSSION

327 This study assessed associations between the PA environment of 80 primary schools, and  
 328 child weight status and PA behaviours, in regional Australia. There were significantly higher  
 329 odds of students using active transport to and/or from school with increasing number of  
 330 greenspaces and recreational facilities in the school neighbourhood and with increasing  
 331 school neighbourhood walkability scores. Students also had significantly higher odds of using

1  
2  
3 332 active transport with increasing total PA environment score of their school neighbourhood.  
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5 333 No significant associations were found between individual features of the PA environment  
6

7 334 surrounding schools and weight status or PA levels in adjusted models.  
8  
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10 335 Strengths of this study include the use of measured height and weight data from large  
11

12 336 regional studies with a very high student participation rate (79%).[33, 51] This high student  
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15 337 participation rate, using an opt-out recruitment approach, is likely to reduce the impact of  
16

17 338 measurement error introduced through non-participation bias on estimates of behaviours and  
18

19 339 overweight and obesity.[34] Additionally, manually verifying the recreational facilities and  
20  
21

22 340 greenspaces within the 1km walkable neighbourhood of a sample of participating schools  
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24 341 improved the validity of our environmental data and allowed refinements of the classification  
25

26 342 methods for greenspaces and recreation facilities for analysis.  
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28

29 343 Using a 1km walkable neighbourhood is more accurate than other approaches such as the  
30

31 344 Euclidean distance to measure the environment[52] as it uses existing road networks that are  
32  
33

34 345 likely to be used for active transport, reflecting actual transport routes. By contrast, Euclidean  
35

36 346 buffers do not account for road networks and access, and simply reflect the density, but not  
37  
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39 347 accessibility, of environmental features within a given area. The 1km neighbourhood also  
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41 348 represents a distance that has been shown to be realistic for children to travel before or after  
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43 349 school.[40, 53]  
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46 350 There were also a number of limitations with this study. Inherent issues exist with the use of  
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48 351 self-report measures of PA, particularly among children. These include recall and social-  
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50 352 desirability biases and challenges with accurate comprehension and reporting.[54] The use of  
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53 353 objective measures (such as accelerometry) to gain more accurate assessment of PA would be  
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55 354 beneficial in future studies. Additionally, the exclusion of Special Development schools due  
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58 355 to these schools not being assigned a school-level SEP measure may impact the  
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3 356 generalisability of the results, in particular regarding applicability of the results to students  
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5 357 attending these schools.  
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8 358 Another limitation is the cross-sectional study design, which meant we were unable to  
9  
10 359 determine causation between the PA environment and the outcomes explored. Self-selection  
11  
12 360 into a particular area, in this instance by a child's parents, may also influence the results,  
13  
14 361 particularly considering those of higher SEP may be less likely to be obese, and choose  
15  
16 362 environments more conducive to PA.[55] However, in this study, more recreational facilities  
17  
18 363 and greenspaces and higher walkability scores were found in areas surrounding schools  
19  
20 364 classified as lower compared to higher SEP. There have been similar findings in other studies  
21  
22 365 examining associations between area-level SEP and greenspace[56-58], recreational facilities  
23  
24 366 [59-62], and walkability[63] where lower SEP areas have had more facilities or higher  
25  
26 367 walkability scores compared to higher SEP areas. These results highlight the complexity of  
27  
28 368 these relationships, with factors such as quality and accessibility also playing important roles.  
29  
30  
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33  
34 369 A further limitation is that we did not have data on the distance that the children lived from  
35  
36 370 the school which may particularly influence the active transport outcome. These data would  
37  
38 371 enhance the analysis, however, we hypothesise that the school neighbourhood may act as a  
39  
40 372 proxy for the community PA environment, where children may play before and after school,  
41  
42 373 as well as an area that could enhance active transportation.  
43  
44  
45

46 374 The potential impact of residual confounding by other factors which were not able to be  
47  
48 375 controlled for also needs to be considered. These may include individual socio-economic  
49  
50 376 factors, parent's perception of the neighbourhood or safety, family car ownership and  
51  
52 377 distance to school. Additionally, although multiple tests have been conducted, consistent  
53  
54 378 associations with active transport and the PA environment are found, and results remain  
55  
56 379 consistent with adjustment of the p value threshold to <0.01.  
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2  
3 380 A lack of association between the individual PA environment measures surrounding schools  
4  
5 381 and PA levels or weight status in students may be due to lack of heterogeneity in our sample  
6  
7 382 of those environmental characteristics that are deterministic of behaviour, a lack of genuine  
8  
9 383 associations between environments and these outcomes, or insufficient power to detect  
10  
11 384 differences. In regards to weight status, there are many complex determinants of weight,[64]  
12  
13 385 of which PA is only one. Other environmental factors such as the food environment and  
14  
15 386 individual factors also play a role, but are beyond the scope of this study. While associations  
16  
17 387 were found between the environment and active transport, it has been suggested that active  
18  
19 388 transport alone may not result in sufficient energy expenditure to impact on obesity  
20  
21 389 levels.[65]  
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27 390 This impact of the overall PA environment warrants further study, with more standardised  
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29 391 measures that take in multiple aspects of the PA environment, as is done to calculate  
30  
31 392 walkability scores.  
32  
33

34 393 The walkability score used in this study included connectivity, land-use mix and population  
35  
36 394 density measures. Combining different aspects of the environment into a composite score is a  
37  
38 395 common approach to assess walkability.[45, 66] Reviews looking at individual components  
39  
40 396 of walkability have found more diverse land-use mix,[27, 67] population density[27, 68] and  
41  
42 397 street connectivity[25, 68, 69] to be associated with increased PA levels, or active travel in  
43  
44 398 children and adolescents. However a majority of published studies have been conducted in  
45  
46 399 major city settings. The impact and relative importance of each of these measures may differ  
47  
48 400 for regional compared to major city communities. To elicit differences between regional and  
49  
50 401 major city environments, it may be useful to look at these components separately in a broader  
51  
52 402 cross-section of environments, with further heterogeneity in levels of remoteness (from major  
53  
54 403 cities to very remote).  
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2  
3 404 Our findings on the association between walkability scores of school neighbourhoods and  
4  
5 405 active transport are in line with other studies,[25, 69, 70] but represents one of very few  
6  
7 406 studies focused on regional areas. Distance to school has been shown to be an important  
8  
9 407 factor in the choice or ability to use active forms of transport for school commutes.[71, 72]  
10  
11 408 With increasing remoteness, distances travelled to school tend to increase, thus impacting  
12  
13 409 active transport levels. This is supported by our results showing a significantly greater  
14  
15 410 proportion of children from inner regional schools actively commuted to school compared to  
16  
17 411 those in outer regional schools, a result reflected in other Australian studies.[20] While  
18  
19 412 walkability was associated with a greater proportion of students using active forms of  
20  
21 413 transport for their journeys to and from school, the overall number of children actively  
22  
23 414 commuting remained below one quarter in our sample. A Canadian study which considered  
24  
25 415 active transport for children who live within walking distance of their school (defined as  
26  
27 416 1.6km) found much higher rates (up to 67%) of active transport.[73]  
28  
29  
30  
31  
32  
33 417 We have used a 1km buffer from primary schools in line with other research regarding the  
34  
35 418 distances that children would walk.[40] However, there is debate regarding the optimal  
36  
37 419 walking distance to use to define the local neighbourhood and to reflect accessible  
38  
39 420 environments for children where they are likely to access services and recreational  
40  
41 421 opportunities.[74] In the food environment literature there is some evidence that a larger  
42  
43 422 buffers should be used,[75, 76] Additionally, it may be that a larger buffer is more relevant in  
44  
45 423 regional locations, where there is a greater reliance on cars, less public transport and greater  
46  
47 424 distances between homes and schools.  
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52  
53 425 **Conclusions:** This study is the first of its kind exploring school neighbourhood  
54  
55 426 environments and child weight status and PA in regional areas of Australia. It highlights the  
56  
57 427 importance of the environment surrounding primary schools in contributing to students'  
58  
59 428 active travel to and from school. Further research with the use of objective PA measurement  
60

1  
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3 429 is warranted in regional and remote areas to further our understanding of the broader healthy  
4  
5 430 school environment.  
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9 431

10  
11 432 **Abbreviations:**

12  
13  
14 433 ARIA: Accessibility/Remoteness Index for Australia

15  
16  
17 434 AT: Active transport

18  
19  
20 435 AURIN: Australian Urban Research Infrastructure Network

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23 436 BMI: Body Mass Index

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26 437 FOI: features of interest

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29 438 ICSEA: Index of Community Socio-Educational Advantage

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32 439 MVPA: Moderate to vigorous physical activity

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35 440 PA: physical activity

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38 441 SEP: Socio-Economic Position

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41 442 STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

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44 443 WHO: World Health Organisation

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53 446 **Declarations**

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56 447 **Ethics approval and consent to participate:** This study received ethical approval from the  
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58 448 Deakin University Human Research Ethics Committee (DUHREC 2014–279 and 2014-289),  
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3 449 the Victorian Department of Education and Training (DET 2015\_002622) and the Catholic  
4  
5  
6 450 Archdiocese of Sandhurst. Students enrolled in participating schools were invited to take part  
7  
8 451 in the study through the distribution of a plain language statement and opt-out form. Students  
9  
10 452 were considered to have provided informed consent unless an opt-out form signed by their  
11  
12 453 parents or guardians was returned to the school or verbal assent was not given by the student  
13  
14 454 at the time of measurement. Students were also able to participate in as much (e.g. all  
15  
16 455 measurements) or as little (e.g. only survey) as desired.

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19 456  
20 457 **Availability of data and materials:** The datasets used and/or analysed during the current  
21  
22 458 study are available from the corresponding author on reasonable request.

23  
24  
25 459 **Competing interests:** The authors declare that they have no competing interests

26  
27  
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29  
30 461 Partnership, Western Alliance, and a NHMRC Partnership Project Grant titled Whole of  
31  
32 462 System Trial of Prevention Strategies for childhood obesity: WHO STOPS childhood obesity  
33  
34 463 (APP1114118). NC, CS, MN, KB, JJ and SA are researchers within a NHMRC Centre for  
35  
36 464 Research Excellence in Obesity Policy and Food Systems (APP1041020). SA would like to  
37  
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39  
40 466 Research Council (GNT1151572; GNT1133090; GNT114118), the Western Alliance and the  
41  
42 467 NSW Health Translational Research Grants Scheme.

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44  
45 468 **Author contributions:** JJ, NC and MN conceptualised the study and initial hypothesis and  
46  
47 469 collated environmental data. SA and CS conceived the WHOSTOP study and underlying  
48  
49 470 design. JJ conducted analysis and interpretation, with assistance from KB and MN. JJ  
50  
51 471 prepared the manuscript. JJ, MN, NC, CS, KB and SA provided intellectual input,  
52  
53 472 contributed to the development of the manuscript and have read and approved the final  
54  
55 473 manuscript  
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3 474 **Acknowledgements:** Not applicable  
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17 478 **REFERENCES**  
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For peer review only

**Is the physical activity environment surrounding primary schools associated with students' weight status, physical activity or active transport, in regional areas of Victoria, Australia? A cross-sectional study.**

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Check (section, page, lines) (in clean version)
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Title Pg 1, line 1-3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract Pg 2-3, lines 21 - 44
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Background Pg 4- 5, lines 65 – 106
Objectives	3	State specific objectives, including any prespecified hypotheses	Background Pg 5, lines 107 - 111
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	Methods Pg 6, lines 115 - 117
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods Pg 6, lines 119-136
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Methods: Pg 6, lines 119 - 136
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Methods: Outcomes: pg 6-7; lines 138 – 160 Exposures: pg 8-10; lines 162 – 203 Confounders: pg 10-11; lines 205 - 220
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Methods: Outcomes: : pg 6-7; lines 138 – 160 Exposures: pg 8-10; lines 162 – 203 Confounders: pg 10-11; lines 205 – 220 Table 1: page 8-9
Bias	9	Describe any efforts to address potential sources of bias	Methods: Pg 12; lines 247 - 253
Study size	10	Explain how the study size was arrived at	Methods: Pg 10; lines 209 - 213
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Methods: Pg 8, Table 1
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Methods: Pg 11 -12; lines 222 - 258

**Is the physical activity environment surrounding primary schools associated with students' weight status, physical activity or active transport, in regional areas of Victoria, Australia? A cross-sectional study.**

		(b) Describe any methods used to examine subgroups and interactions	n/a
		(c) Explain how missing data were addressed	n/a
		(d) If applicable, describe analytical methods taking account of sampling strategy	Methods: Pg 12, lines 245-246
		(e) Describe any sensitivity analyses	n/a
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Results: Pg 13; lines 271 - 279
		(b) Give reasons for non-participation at each stage	Pg 13; lines 274- 275
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results: Pg 13; lines 280-291 Pg 16; Table 3
		(b) Indicate number of participants with missing data for each variable of interest	n/a
Outcome data	15*	Report numbers of outcome events or summary measures	Pg 16; Table 2
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Results: Pg 15: Lines 299-309 Pg 14-15 - Table 3 Confounder adjusted: Model 2 and model 3 – indicated in table legend
		(b) Report category boundaries when continuous variables were categorized	Pg 15 - Table 3
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Results: Pg 15, lines 310-313 Pg 15-16 - Table 3
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	Discussion: Pg 16-17, lines 327-334
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion: Pg 17-18, lines 350 - 373

**Is the physical activity environment surrounding primary schools associated with students' weight status, physical activity or active transport, in regional areas of Victoria, Australia? A cross-sectional study.**

Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion: Pg 19-20; lines 380 - 424
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion: Pg 18, 355 – 357
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Pg 22, lines 468 - 473

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).