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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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ABSTRACT

Objectives To explore whether the physical activity (PA) environment (walkability, greenspace and recreational facilities) surrounding regional primary schools is associated with children's PA levels, active transport and weight status. Limited research on this topic has been conducted outside of major cities.

Design Cross-sectional ecological study using baseline data from two large-scale obesity prevention interventions.

Setting Eighty (n=80) primary schools across two regional areas in Victoria, Australia.

Participants Students aged 8–13 years (n=2144) attending participating primary schools.

Outcome measures Measured weight status (body mass index z-score, proportion overweight/obese) and self-reported PA behaviours (meeting PA recommendations and active travel behaviour).

Results When adjusted for student and school demographics, students had significantly increased odds of using active transport to or from school when the school neighbourhood was more walkable (OR 1.21 (95% CI 1.09 to 1.35), had a greater number of greenspaces (OR 1.35 (95% CI 1.20 to 1.53)) and a greater number of recreational facilities (OR 1.18 (95% CI 1.07 to 1.31)). A higher cumulative PA environment score was also associated with a higher proportion of children using active transport (OR 1.33 (95% CI 1.28 to 1.51)). There were no significant associations between the PA environment measures and either weight status or meeting the PA recommendations in adjusted models.

Conclusions This study is the first of its kind exploring school neighbourhood environments and child weight status and PA in regional areas of Australia. It highlights the potential of the environment surrounding primary schools in contributing to students' active travel to and from school. Further research with the use of objective PA measurement is warranted in regional areas that have been under-researched.

Trial registration number Australian New Zealand Clinical Trials Registry (ANZCTR.org.au) identifier 12616000980437; Results.

Strengths and limitations of this study

- ► There has been limited research conducted on environmental drivers of physical inactivity and obesity in children outside of major cities, particularly in areas surrounding schools.
- ► Multilevel linear and logistic regressions were used to assess associations between elements of the school neighbourhood physical activity (PA) environment and students' weight status and PA behaviours.
- ► Comparisons were made between PA environments of school neighbourhoods surrounding high and low socioeconomic position schools and between inner and outer regional areas.
- ► Strengths of the study include the use of measured student height and weight from large studies with high participation rates and objectively measured PA environments.
- ► Study limitations include the use of self-reported PA behaviour data and the inability to determine how far children lived from the schools.

BACKGROUND

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

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

Limited research has been conducted on the PA environment outside of major cities in Australia and internationally.[17–19] Australian data indicate that overweight and obesity prevalence have significantly increased outside of major city areas since 2010, whereas it appears to have plateaued in major cities.[20] Compared with children living in major cities, children living outside of major cities have been reported to be more physically active overall,[21] although have lower levels of active transport.[20 22] Several major city-based studies have reported that key determinants of whether a child uses active forms of transport to and from school include distance to school,[17 23 24] population density[19] and street connectivity,[25] which are all aspects of the environment that are likely to differ between major cities and regional and remote areas.

Reviews including primarily children in major cities have found that increased availability of greenspace,[26] walkability of neighbourhoods[27] and availability of sport facilities[27] were associated with increased levels of PA. Evidence also suggests that the presence of walking or bike paths and overall neighbourhood walkability are associated with increased active transportation to and from school.[19 23 25] Children who use active forms of transport to and from school have been found to have higher overall levels of PA;[15 16] however, there are mixed results for the association of this behaviour with weight status.[16 28] It is unclear how PA environments may impact on variation in activity levels and weight status in students outside of major city areas.

Given lower population densities, regional students may typically need to travel greater distances to school and it could be hypothesised that these children will be more reliant on motorised transport. More work is needed to understand the relationship between PA environments surrounding schools in regional areas and PA patterns and weight status among students.

In this study, we aimed to quantify the relationships between PA environments surrounding primary schools and (1) students' weight status, (2) PA levels, (3) active transport, in regional areas of Victoria, Australia. Findings from this study may aid in the prioritisation and targeting of policies and programmes to improve PA environments around schools, so that all children have the opportunity to engage in PA, regardless of where they live.

METHODS

The Methods section is written to address the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[29]

Study design

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

Setting

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

Participants

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

Weight status

Anthropometric measures of height and weight were taken by trained staff according to a standardised protocol. Height was measured to the nearest 0.1 cm and weight the nearest 0.05 kg. All students were measured two times and where the two initial measures differed, by more than 0.5 cm or 0.1 kg for height and weight, respectively, a third measurement was taken. An average of these height and weight measures was used to calculate body mass index (BMI) z-scores according to the WHO Child Growth Reference,[35] and weight status categories were derived using the following cut-offs, as recommended by the WHO; overweight: $> +1$ SD to $< +2$ SD, obese: $\geq +2$ SD.

BMI z-score and overweight or obese (yes/no) were included in the analysis.

Physical activity behaviours and demographic questions

Students completed an electronic self-report questionnaire in class time on tablet computers, with guidance from a trained supervisor. Students in years 4 and 6 self-reported their gender, date of birth, language usually spoken at home, Aboriginal and/or Torres Strait Islander background, residential postcode and country of birth. The PA components of the questionnaire used for this study were the demographic information and the Core Indicators and Measures of Youth Health—Physical Activity and Sedentary Behaviour Module,[36] which has been shown to be reliable in this age group.[36 37]

PA was assessed as students participating in at least 60 min of moderate to vigorous PA on five school days (Monday to Friday) (yes/no), consistent with the Australian National Physical Activity Guidelines at the time.[38] Students' usual mode of transport to and from school was categorised as either active (walking, cycling, public bus, other active) or nonactive (car, school bus, other inactive).

PA environment

The exposures in this study were three aspects of the PA environment in each school's 'neighbourhood'; walkability, greenspace and recreational facilities (table 1). A 1 km street network buffer around each school was derived from the 'Neighbourhood Generator' tool through the Australian Urban Research Infrastructure Network (AURIN) Portal[39] to define each school's immediate 'neighbourhood'. This buffer was informed by previous research suggesting that 1 km is a feasible distance that

Table 1 Description of independent, dependent and control variables used in the analysis

Independent variables*			
	Measurement method	**Level of data**	**Data source**
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'[43]
Recreation facilities	Count of recreation facilities Objectively measured	Continuous	datavic 'features of interest'[43]
Total PA environment	Each independent variable broken into tertiles (lowest to highest) and tertiles summed	Continuous	Tertiles created based on above measures
Dependent variables			
	Measurement method	**Level of data**	**Reference for variable definition**
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]
Control variables			
Socio-economic position	ICSEA (school-level SEP)	Continuous	Australian Curriculum Assessment and Reporting Authority[47]
Remoteness	Classified into five levels—major city, inner regional, outer regional, remote, very remote	Categorical	Accessibility/Remoteness Index of Australia[46]
School type	Classified as government, independent, catholic	Categorical	Australian Curriculum Assessment and Reporting Authority[47]

*Within a 1 km walkable distance from the school.
BMI, body mass index; BMI, body mass index; ICSEA, index of community socio-educational advantage; PA, physical activity; SEP, socio-economic position.

children will walk to school.[40] A walkability score for this buffer area and the count of recreational facilities and greenspaces intersecting this buffer were determined for each school. A 50 m trim distance was used around the road centres, to capture greenspace and facilities accessible from the defined street network.

Walkability scores were generated for all primary schools in the study regions, using the 'Walkability Index with gross density for regions' tool through the AURIN portal.[41] Scores are based on standardised scores for population density, land use mix and street connectivity, which have been associated with increased walking.[42] A z-score for each of the three domains is generated for all schools in the included regions, with the sum of these giving an overall walkability score for each school.

Features of interest (FOI) data were accessed via the Victorian Government data website (Layer: VMFEAT_FOI_POLYGON) and are produced by the Department of Environment, Land, Water and Planning.[43] FOI data are projected as polygons and used to determine the presence of facilities that may be used by students for PA. For the purpose of this study, we limited the categories of features to three key feature types; recreational resources (eg, skate parks), sporting facilities (eg, tennis court, netball courts, golf course, sporting complexes) and reserves (eg, public parks and gardens). For this analysis, recreational resources and sporting facilities were combined and termed 'recreational facilities' and reserves termed 'greenspace'. Recreational facilities and greenspace were counted as being within a school's neighbourhood if any part of the feature intersected with the walkability buffers (ie, they were within 1 km walking distance of the school). If a reserve contained recreational facilities, it was counted as both recreational facility and greenspace.

Manual verification of locations of recreational facilities and greenspace were conducted on a convenience sample of three schools (two inner regional and one outer regional) by authors JJ and NC. Following this process, a number of reserves in the FOI data set were observed to be inappropriate for PA (eg, inaccessible fields behind locked gates, nature strips on roadside). Subsequently, all reserves were checked and verified using Google Maps satellite view to verify useability, a technique that has been used increasingly in environmental studies.[44]

Remoteness

Remoteness classification for each school was determined according to the five categories of the Accessibility/Remoteness Index for Australia; major cities, inner regional, outer regional, remote and very remote.[45] Classification is based on a continuous variable derived from the area's access to services, measured as distance by road, and the population of the closest centre.[46] All schools included in this study fall into the inner regional and outer regional categories.

Socioeconomic position

Socioeconomic position (SEP) of the school was determined using the index of community socioeducational advantage (ICSEA) scores, obtained from the Australian curriculum, assessment and reporting authority 'My School' website.[47] Scores are derived from a combination of reported parental occupation, parental income, geographic location and proportion of indigenous students to provide an overall indication of the school community's relative SEP. ICSEA scores for each participating school were included as a continuous variable in the regression models but were dichotomised for comparison of descriptive statistics, categorising school into either equal to or above (≥1000) or below (<1000) the national mean.

Data analysis

Only year 4 and 6 student data were used as year 2 students did not complete the behaviour questionnaires. Data collected in 2015 and 2016 were combined as one cohort for analysis.

School neighbourhoods (street network buffers) were imported from the AURIN results into ArcMap (ArcGIS Desktop, V.10.7.1 ESRI, Redlands, California).[48] The FOI data, which included greenspace and recreation facility locations projected as polygons, were also imported into ArcMap. Within ArcMap, the intersect tool was used to produce an attribute table including all recreational facilities and greenspaces that were within, or intersected with, the 1 km walkable neighbourhood around included primary schools. Duplicates were removed within school neighbourhood (where a polygon intersected with the buffer multiple times). This table was exported to Stata SE V.15 (StataCorp, College Station, Texas)[49] for analysis.

Demographics at the school level were tabulated according to remoteness and SEP (low/high), as measured by ISCEA, as aspects of the PA environment have been shown to vary by these factors.[50] Two sample t-tests and proportion tests were used to determine differences between groups.

Multilevel mixed effects logistic regression were fitted to test the association between independent variables: (1) the count of recreational facilities within, or intersecting with, the 1 km walkability buffer, (2) the count of greenspaces within, or intersecting with, the 1 km walkability buffer, (3) the school walkability score and each of three dependent variables; (1) weight status (overweight or obese) (yes/no), (2) adherence to PA guidelines (yes/no) and (3)use of active transport(yes/no) as separate regressions. Multilevel linear regression models were fitted to test the associations between all three PA environment independent variables and the dependent variable of BMI z-score. For all models, clustering was accounted for at the school level. Initial models (model 1) did not include any adjustment for covariates. In model 2, adjustments were made for school-level SEP (measured by ICSEA), student's gender and age (in years) and school type (government, Catholic, independent). A third regression model (model 3) included all independent variables related to the PA environment. Geographical location (according to remoteness) is a direct input into the calculation of ICSEA. Correlation analysis shows that the two variables are collinear in this sample (pairwise correlation $p<0.05$) and, therefore, remoteness was not adjusted for any of the models. A p value <0.05 for all associations was considered significant.

A secondary analysis was conducted to assess the impact of the total PA environment by creating a composite score. Each of the three exposure variables was coded into tertiles (low=1, moderate=2, high=3), then summed for each school. This total PA environment score was used as the independent variable for analysis with each of the weight and PA behaviour outcomes.

Patient and public involvement

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

The outcome measurements (weight and health behaviours) were developed in conjunction with community-based organisations (eg, health services, primary care partnerships) due to an absence of locally available data on the prevalence of childhood obesity and associated modifiable behaviours.

RESULTS

Data were collected from 65% (84/129) of eligible schools for two large-scale system-based obesity prevention interventions, with 79% (3476/4386) of eligible students within those schools participating in the study. Of these eligible students, 2269 were in years 4 and 6. For this analysis, three special development schools were excluded due to not being assigned an ICSEA score and one further school did not have complete data on any year 4 or 6 students. This resulted in 80 schools being in the final analysis. These schools included 2144 students with complete measures (94% of eligible year 4 and 6 students). There was some variation in gender and year level within the excluded students (n=72 boys, n=53 girls; n=74 year 6s, n=51 year 4s).

Descriptive statistics of the participating schools are presented in table 2, stratified by school-level SEP (ICSEA) and remoteness classification. Stratification by ICSEA shows a significantly greater number of recreation facilities and greenspaces and higher mean walkability scores in low compared with high SEP school neighbourhoods. A significantly higher proportion of students attending low SEP schools used active transport to or from school, but a higher proportion of students attending high SEP schools met the PA guidelines, and students attending high SEP schools had a lower mean BMI z-score.

There were a number of differences between schools in inner and outer regional areas, with a lower number of recreation facilities and greenspaces, lower walkability scores and lower total PA environment scores in outer compared with inner regional areas. Furthermore, a lower proportion of students used active forms of transport in outer compared with inner regional areas.

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

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

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

DISCUSSION

This study assessed associations between the PA environment of 80 primary schools, and child weight status and PA behaviours, in regional Australia. There were significantly higher odds of students using active transport to and/or from school with increasing number of greenspaces and recreational facilities in the school neighbourhood and with increasing school neighbourhood walkability scores. Students also had significantly higher odds of using active transport with increasing total PA environment score of their school neighbourhood. No significant associations were found between individual features of the PA environment surrounding schools and weight status or PA levels in adjusted models.

Strengths of this study include the use of measured height and weight data from large regional studies with a very high student participation rate (79%).[33 51] This high student participation rate, using an opt-out recruitment approach, is likely to reduce the impact of measurement error introduced through nonparticipation bias on estimates of behaviours and overweight and obesity.[34] Additionally, manually verifying the recreational facilities and greenspaces within the 1 km walkable neighbourhood of a sample of participating schools improved the validity of our environmental data and allowed refinements of the

Table 2 Descriptive statistics of schools (n=80) and students (n=2144)

	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
Exposures					
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
Outcomes					
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)

Low SEP=ICSEA<1000; high SEP=ICSEA≥1000.
*Significant t-test or proportion test result (p<0.05) for difference between inner and outer regional schools, or difference between high and low SEP schools scores.
AT, active transport; BMI, body mass index; ICSEA, index of community socio-educational advantage; PA, physical activity; ; SEP, socio-economic position.

classification methods for greenspaces and recreation facilities for analysis.

Using a 1 km walkable neighbourhood is more accurate than other approaches such as the Euclidean distance to measure the environment[52] as it uses existing road networks that are likely to be used for active transport, reflecting actual transport routes. By contrast, Euclidean buffers do not account for road networks and access, and simply reflect the density, but not accessibility, of environmental features within a given area. The 1 km neighbourhood also represents a distance that has been shown to be realistic for children to travel before or after school.[40 53]

There were also a number of limitations with this study. Inherent issues exist with the use of self-report measures of PA, particularly among children. These include recall and social-desirability biases and challenges with accurate comprehension and reporting.[54] The use of objective measures (such as accelerometry) to gain more accurate assessment of PA would be beneficial in future studies. Additionally, the exclusion of Special Development schools due to these schools not being assigned a school-level SEP measure may impact the generalisability of the results, in particular, regarding applicability of the results to students attending these schools.

Another limitation is the cross-sectional study design, which meant we were unable to determine causation between the PA environment and the outcomes explored. Self-selection into a particular area, in this instance, by a child's parents, may also influence the results, particularly considering those of higher SEP may be less likely to be obese and choose environments more conducive to PA.[55] However, in this study, more recreational facilities and greenspaces and higher walkability scores were found in areas surrounding schools classified as lower compared with higher SEP. There have been similar findings in other studies examining associations between area-level SEP and greenspace,[56–58] recreational facilities[59–62] and walkability[63] where lower SEP areas have had more facilities or higher walkability scores compared with higher SEP areas. These results highlight the complexity of these relationships, with factors such as quality and accessibility also playing important roles.

A further limitation is that we did not have data on the distance that the children lived from the school that may

Table 3 Associations between PA environment, weight and behavioural outcomes (students n=2144)

	Model 1		Model 2		Model 3	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Meeting PA guidelines						
Recreational facilities	0.97	0.92 to 1.02	0.98	0.93 to 1.04	1.00	0.93 to 1.07
Greenspace	0.96	0.89 to 1.04	0.98	0.91 to 1.06	1.00	0.90 to 1.11
Walkability	0.96	0.90 to 1.02	0.97	0.92 to 1.04	0.98	0.90 to 1.07
Total PA environment	0.94	0.87 to 1.00	0.95	0.87 to 1.04	–	–
Using AT 1+trip						
Recreational facilities	1.23†	1.11 to 1.37	1.18†	1.07 to 1.31	1.05	0.94 to 1.18
Greenspace	1.41†	1.24 to 1.61	1.35†	1.20 to 1.53	1.30†	1.09 to 1.54
Walkability	1.26†	1.14 to 1.41	1.21†	1.09 to 1.35	1.01	0.87 to 1.17
Total PA environment	1.40†	1.23 to 1.58	1.33†	1.28 to 1.51	–	–
Overweight/obese						
Recreational facilities	1.03	1.00 to 1.06	1.01	0.98 to 1.04	1.01	0.97 to 1.04
Greenspace	1.04*	1.00 to 1.09	1.03	0.99 to 1.07	1.03	0.97 to 1.08
Walkability	1.03	0.99 to 1.07	1.01	0.98 to 1.05	1.00	0.95 to 1.04
Total PA environment	1.05*	1.00 to 1.10	1.03	0.99 to 1.08	–	–
	Beta‡	*95%* CI	Beta‡	*95%* CI	Beta‡	*95%* CI
BMI z-score						
Recreational facilities	0.01	−0.01 to 0.29	0.00	−0.02 to 0.02	0.00	−0.03 to 0.02
Greenspace	0.03*	0.00 to 0.05	0.02	−0.01 to 0.04	0.03	−0.01 to 0.06
Walkability	0.01	−0.01 to 0.03	0.00	−0.02 to 0.02	−0.01	−0.04 to 0.02
Total PA environment	0.03*	0.00 to 0.06	0.01	−0.01 to 0.04	–	–

Model 1: unadjusted; model 2: adjusted for age (years), gender, school type and ICSEA (school-level SEP); model 3: adjusted for age (years), gender, school type, ICSEA (school-level SEP) and other independent variables.
*p<0.05.
†p<0.01.
‡Mean change in BMI z-score.
AT, active transport; BMI, body mass index; ICSEA, index of community socio-educational advantage; PA, physical activity; SEP, socio-economic position.

particularly influence the active transport outcome. These data would enhance the analysis; however, we hypothesise that the school neighbourhood may act as a proxy for the community PA environment, where children may play before and after school as well as an area that could enhance active transportation.

The potential impact of residual confounding by other factors that were not able to be controlled for also needs to be considered. These may include individual socio-economic factors, parent's perception of the neighbourhood or safety, family car ownership and distance to school. Additionally, although multiple tests have been conducted, consistent associations with active transport and the PA environment are found, and results remain consistent with adjustment of the p value threshold to <0.01.

A lack of association between the individual PA environment measures surrounding schools and PA levels or weight status in students may be due to lack of heterogeneity in our sample of those environmental characteristics that are deterministic of behaviour, a lack of genuine associations between environments and these outcomes or insufficient power to detect differences. In regards to weight status, there are many complex determinants of weight,[64] of which PA is only one. Other environmental factors such as the food environment and individual factors also play a role but are beyond the scope of this study. While associations were found between the environment and active transport, it has been suggested that active transport alone may not result in sufficient energy expenditure to impact on obesity levels.[65]

This impact of the overall PA environment warrants further study, with more standardised measures that take in multiple aspects of the PA environment, as is done to calculate walkability scores.

The walkability score used in this study included connectivity, land-use mix and population density measures. Combining different aspects of the environment into a composite score is a common approach to assess walkability.[42 66] Reviews looking at individual components of walkability have found more diverse land-use mix,[27 67] population density[27 68] and street connectivity[25 68 69] to be associated with increased PA levels or active travel in children and adolescents. However, a majority of published studies have been conducted in major city settings. The impact and relative importance of each of these measures may differ for regional compared with major city communities. To elicit differences between regional and major city environments, it may be useful to look at these components separately in a broader cross-section of environments, with further heterogeneity in levels of remoteness (from major cities to very remote).

Our findings on the association between walkability scores of school neighbourhoods and active transport are in line with other studies[25 69 70] but represents one of very few studies focused on regional areas. Distance to school has been shown to be an important factor in the choice or ability to use active forms of transport for school commutes.[71 72] With increasing remoteness, distances travelled to school tend to increase, thus impacting active transport levels. This is supported by our results showing a significantly greater proportion of children from inner regional schools actively commuted to school compared with those in outer regional schools, a result reflected in other Australian studies.[20] While walkability was associated with a greater proportion of students using active forms of transport for their journeys to and from school, the overall number of children actively commuting remained below one quarter in our sample. A Canadian study that considered active transport for children who live within walking distance of their school (defined as 1.6 km) found much higher rates (up to 67%) of active transport.[73]

We have used a 1 km buffer from primary schools in line with other research regarding the distances that children would walk.[40] However, there is debate regarding the optimal walking distance to use to define the local neighbourhood and to reflect accessible environments for children where they are likely to access services and recreational opportunities.[74] In the food environment literature, there is some evidence that a larger buffers should be used,[75 76] Additionally, it may be that a larger buffer is more relevant in regional locations, where there is a greater reliance on cars, less public transport and greater distances between homes and schools.

CONCLUSIONS

This study is the first of its kind exploring school neighbourhood environments and child weight status and PA behaviours in regional areas of Australia. It highlights the importance of the environment surrounding primary schools in contributing to students' active travel to and from school. Further research with the use of objective PA measurement is warranted in regional and remote areas to further our understanding of the broader healthy school environment.

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Contributors JJ, NC and MN conceptualised the study and initial hypothesis and collated environmental data. SA and CS conceived the WHOSTOPs study and underlying design. JJ conducted analysis and interpretation, with assistance from KB and MN. JJ prepared the manuscript. JJ, MN, NC, CS, KB and SA provided intellectual input, contributed to the development of the manuscript and have read and approved the final manuscript.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not required.

Ethics approval This study received ethical approval from the Deakin University Human Research Ethics Committee (DUHREC 2014-279 and 2014-289), the Victorian Department of Education and Training (DET 2015-002622) and the Catholic Archdiocese of Sandhurst and Ballarat. Students enrolled in participating schools were invited to take part in the study through the distribution of a plain language statement and opt-out form. Students were considered to have provided informed consent unless an opt-out form signed by their parents or guardians was returned to the school or verbal assent was not given by the student at the time of measurement. Students were also able to participate in as much (e.g. all measurements) or as little (eg, only survey) as desired.

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