BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (http://bmjopen.bmj.com).

If you have any questions on BMJ Open's open peer review process please email info.bmjopen@bmj.com

BMJ Open

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-045785
Article Type:	Original research
Date Submitted by the Author:	12-Oct-2020

Complete List of Authors:	Jacobs, Jane; Deakin University - Geelong Waterfront Campus, Crooks, Nic; Deakin University School of Health and Social Development, Global Obesity Centre Allender, Steven; Deakin University, Faculty of Health Strugnell, Claudia; Deakin University - Geelong Waterfront Campus, WHO Collaborating Centre for Obesity Prevention Backholer, Kathryn; Deakin University, Health and Social Development Nichols, Melanie; Deakin University, Faculty of Health;

Keywords:	PUBLIC HEALTH, Community child health < PAEDIATRICS, SPORTS MEDICINE

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

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

Authors: Jane Jacobs (Corresponding Author)[a], Nicholas Crooks [a], Steven Allender [a], Claudia Strugnell [a], Kathryn Backholer [a], Melanie Nichols [a]

Corresponding author: Jane Jacobs

Email: jane.jacobs@deakin.edu.au

[a]Global Obesity Centre

Deakin University

1 Gheringhap St, Geelong

Victoria, Australia, 3220

Word Count: 3726

ABSTRACT

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

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

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

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

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

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

Conclusions: This study is the first of its kind exploring school neighbourhood environments and child weight status and physical activity 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 larger sample sizes and the use of objective

physical activity measurement is warranted in regional and rural areas which have been under-researched.

Article Summary

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

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

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

Keywords: Physical activity, obesity, active transport, walkability, greenspace, recreational facilities, rurality

BACKGROUND

Built and natural environments significantly impact children's behaviours, particularly levels of physical activity.[1] Inadequate physical activity 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 physical activity,[5] a figure reflected internationally.[6]

Research into environmental influences on children's physical activity 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 physical activity opportunities, and potential settings for interventions to increase the physical activity 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 recreation before or after school. An Australian study[14] found that organised sport accounted for only a small portion of student's overall physical activity levels indicating that other forms of physical activity, such as active transport and informal play are important contributors.[15, 16]

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

Reviews including primarily metropolitan children have found that increased availability of green space,[26] walkability of neighbourhoods[27] and availability of sports facilities[27] were associated with increased levels of physical activity. 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 physical activity,[15, 16] however there are mixed results for the association of this behaviour with weight status.[16, 28] It is unclear how physical activity environments may impact on variation in activity levels and weight status in students outside of metropolitan 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 physical activity environments surrounding schools in regional areas and physical activity patterns and weight status among students. This exploratory paper set out to investigate whether the physical activity environment surrounding primary schools (walkability, green space, and recreational facilities) is associated with students' weight status, physical activity and active transport, in regional areas of Victoria, Australia.

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 physical activity environments and the aggregate levels of physical activity, active transport and 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] and includes a number of moderately-sized regional towns (e.g. 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 systems-based obesity prevention interventions.[31] The evaluations have been described previously,[32] [33] and were conducted in the same way in both study regions. In brief, all government and independent primary schools in each study region were invited to participate in 2015 and 2016. In participating schools, all students in years 2 (aged approximately 7-8 years), 4 (aged approximately 9-10 years) and 6 (aged approximately 11-12 years) were invited to participate via an opt-out recruitment approach.

Weight Status: Anthropometric measures of height and weight were taken by trained staff according to a standardised protocol. Height was measured to the nearest 0.1cm and weight the nearest 0.05kg. All students were measured twice and where the two initial measures differed, by more than 0.5cm or 0.1kg 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

[34], and weight status categories were derived using the following cut-offs, as recommended by the WHO; overweight: >+1SD to ≤+2SD, obese: >+2SD. Both mean BMI z-score and proportion of overweight or obese students within each school were analysed.

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 Year 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 physical activity components of the questionnaire used for this study were the demographic information and the Core Indicators and Measures of Youth Health – Physical Activity & Sedentary Behaviour Module,[35] which has been shown to be reliable in this age-group.[35, 36]

Physical activity was assessed as proportion of students within each school who participated in at least 60 minutes of moderate to vigorous physical activity (MVPA) on 5 school days (Monday – Friday), consistent with the National Physical Activity Guidelines.[37] Students' usual mode of transport to and from school was categorised as either active (walking, cycling, public bus, other active) or non-active (car, school bus, other inactive). Proportion of students within each school who use active transport to or from school was calculated for analysis.

Physical activity environment: The exposures in this study were three aspects of the physical activity environment in each school's 'neighbourhood'; walkability, green space and recreational facilities.

A 1km street network buffer around each school was derived from the 'Neighbourhood Generator' tool through the Australian Urban Research Infrastructure Network (AURIN)

Portal[38] to define each school's immediate 'neighbourhood'. This buffer was informed by previous research suggesting that 1km is a feasible distance that children will walk to school.[39] A walkability score and the count of recreational facilities and green spaces intersecting this buffer was determined for each school. A 50m trim distance was used around the road centres, to capture green space 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.[40] Scores are based on standardised scores for population density, land use mix and street connectivity, which have been associated with increased walking. 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.[41] FOI data are projected as polygons and used to determine the presence of facilities which may be used by students for physical activity. For the purpose of this study we limited the categories of features to three key feature types; recreational resources (e.g. skate parks), sporting facilities (e.g. tennis court, netball courts, golf course, sporting complexes), and reserves (e.g. public parks and gardens). For this analysis, recreational resources and sporting facilities were combined and termed 'recreational facilities' and reserves termed 'green space'. Recreational facilities and green space were counted as part of a school's neighbourhood if any part of the feature intersected with the walkability buffers (that is, they were within 1km walking distance of the school). If a reserve contained recreational facilities it was counted as both recreational facility and green space.

Manual verification of locations of recreational facilities and green space was 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 dataset were observed to be inappropriate for physical activity (e.g. inaccessible fields behind locked gates, nature strips on roadside). Therefore all reserves were checked and verified using Google Maps satellite view to verify useability.

Remoteness: Remoteness classification for each school was determined according to the five categories of the Accessibility/Remoteness Index for Australia (ARIA+); Major Cities, Inner Regional, Outer Regional, Remote and Very Remote.[42] 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.[43]

Socioeconomic position: Socioeconomic position (SEP) of the school was determined using the Index of Community Socio-Educational Advantage (ICSEA) scores, obtained from the Australian Curriculum, Assessment and Reporting Authority 'My School' website[44]. 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 socio-economic position. ICSEA scores for each participating school were dichotomised, categorising school into either equal to or above (≥1000) or below (<1000) the national median.

Data Analysis: School neighbourhoods (street network buffers) and FOI data were imported into ArcMap (ArcGIS Desktop, version 10.7.1 ESRI, Redlands, CA).[45] An attribute table was developed including all recreational facilities and green spaces that were within or intersected with the 1km walkable neighbourhood around included primary schools. This was exported to Stata SE Version 15 (StataCorp, College Station, TX)[46] for analysis.

The unit of analysis was the school, and student-level outcome data were aggregated within each school. Only year 4 and 6 student data were used as year 2 students did not complete behaviour questionnaires. Schools with data on fewer than 20 students in years 4 and 6 (combined) were excluded from analysis to ensure valid estimates of school level means and proportions.

Demographics at the school level were tabulated according to remoteness and SEP, as measured by ISCEA, as aspects of the physical activity environment has been shown to vary by these factors.[47] Two sample t-tests were used to indicate difference between groups.

Univariable ordinary least squares regressions were fitted to test the association between 1) the count of recreational facilities within, or intersecting with, the 1km walkability buffer, 2) the count of green spaces intersecting with the 1km walkability buffer, 3) the school walkability score, and each of four outcome measures; weight status (mean BMI z-score and proportion of students overweight or obese in each school) and physical activity behavioural outcomes (adherence to physical activity guidelines and use of active transport) as separate regressions. Adjustment was made for school SEP as measured by ICSEA in a multivariable model. Geographical location (according to remoteness) is included in the ICSEA calculation, and therefore was not adjusted for separately. A p-value ≤0.05 was considered significant.

A secondary analysis was conducted to assess the impact of the total physical activity environment by creating a composite score. Each of the three exposure variables were coded into tertiles (low = 0, moderate = 1, high = 2), then summed for each school and used as the exposure for analysis (range 0 to 6).

Patient and public involvement

At what stage in the research process were patients/the public first involved in the research and how? The public were involved in the development of the research project and provided support in collecting the child level outcome measures.

How were the research question(s) and outcome measures developed and informed by their priorities, experience, and preferences? The initial research questions came directly from local health organisations determining this area as a priority in their region.

How were patients/the public involved in the design of this study? The local health organisation within these communities were involved in designing the study and the measures used.

How were they involved in the recruitment to and conduct of the study? Key local agencies including health services, education departments and primary care partnerships contributed recruitment of participants to the study via the school system. Further, local health services and primary care partnership staff assisted in the collection of data among school children.

How were (or will) they be involved in your plans to disseminate the study results to participants and relevant wider patient communities (e.g. by choosing what information/results to share, when, and in what format)? The study management committee and local implementation committee in consultation with community members have been involved in planning dissemination of the study results.

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.

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
Exposures					
Recreational Facilities					
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
Green Space					
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
Walkability					
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
Total PA score					
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)
Outcomes					
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)

*Significant t-test result (<0.05) for difference between inner and outer regional schools, and difference between high and low SEP schools scores

Low SEP = ICSEA<1000; High SEP = ICSEA≥1000

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

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

Significant associations were found between the number of green spaces and the number of recreational facilities in the school neighbourhood and proportion of students using active transport to or from school. After adjusting for ICSEA, for every additional green space and recreational facility there was a 5.1% point (95% CI: 2.8% - 7.5%) and 2.3% point (95% CI: 0.2% - 4.4%) increase in the proportion of children using active transport to or from school, respectively. Similarly, significant associations were found between walkability scores and the proportion of children using active transport, indicating a 4.1% point (95% CI 1.9% - 6.2%) increase in the proportion of children using active transport for every 1 point increase in the walkability score.

In the secondary analysis, significant associations were found between the summed 'total physical activity environment' score and the proportion of students with overweight or obesity, with a 1.7% point (95% CI 0.1% - 3.4%) increase in the proportion of students with overweight or obesity for every one point increase in the total physical activity environment score. This analysis also found a 6.4% point (95% CI 3.7% - 9.1%) increase in the proportion of children using active transport for every 1 point increase in the total physical activity environment score.

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

		Model 1			Model 2		
		β coef	**95% CI**		**β coef**	**95% CI**	
Recreational Facilities							
Outcome	Proportion meeting PA guidelines 5 school days	-0.002	-0.015 - 0.010		-0.001	-0.014 - 0.013	
	Proportion using AT ≥ 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	
Green Space							
Outcome	Proportion meeting PA guidelines 5 school days	-0.003	-0.020 - 0.014		-0.002	-0.020 - 0.016	
	Proportion using AT ≥ 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	
Walkability							
Outcome	Proportion meeting PA guidelines 5 school days	-0.007	-0.021 - 0.008		-0.006	-0.021 - 0.01	
	Proportion using AT ≥ 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	
Total PA environment score							
Outcome	Proportion meeting PA guidelines 5 school days	-0.009	-0.028 - 0.009		-0.008	-0.029 - 0.013	
	Proportion using AT ≥ 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	*

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

DISCUSSION

This exploratory study assessed associations between the physical activity environment of 39 primary schools, and weight status and physical activity behaviours, in regional Australia. Significant associations were found between the proportion of students using active forms of transport to and/or from school and the number of green spaces, the number of recreational facilities and neighbourhood walkability scores. The total physical activity environment score was also associated with the proportion of students with overweight or obesity, although not in the expected direction. No significant associations were found between individual features of the physical activity environment surrounding the schools and weight status or physical activity levels.

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%).[32, 33] This high student participation rate is likely to reduce the impact of measurement error introduced through non-participation bias on estimates of behaviours and overweight and obesity.[48] Additionally, manually verifying the recreational facilities and green spaces within the 1km walkable neighbourhood of a sample of participating schools improved the validity of our environmental data and allowed refinements of the classification methods for green spaces and recreation facilities for analysis.

Using a 1km walkable neighbourhood is more accurate than other approaches such as the Euclidean distance to measure the environment[49] 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 of environmental features within a given area. The 1km neighbourhood also represents a distance that has been shown to be realistic for children to travel before or after school.[39, 50]

334 There were also a number of limitations with this study. As this is an exploratory study, the sample size of schools was small, limiting the power of the statistical models used. Additionally, inherent issues exist with the use of self-report measures of physical activity, particularly among children. These include recall and social-desirability biases and challenges with accurate comprehension and reporting.[51] The use of objective measures (such as accelerometry) to gain more accurate measures of physical activity would be beneficial in future studies.

Due to the cross-sectional study design, we are unable to determine causation between the physical activity 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 physical activity.[52] However, in this study, more recreational facilities and higher walkability scores were found in areas surrounding schools classified as lower compared to higher SEP.

Another limitation is that we did not have data on the distance that the children lived from the school which may 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 physical activity 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 which 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.

A lack of association between the individual physical activity environment measures surrounding schools and physical activity 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,[53] of which physical activity 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.[54]

Our finding of the significant association between the total physical activity environment score and the proportion of students with high weight status was in the opposite direction to our hypothesis and may reflect type II error. Further research with a larger sample is required to unpack this finding. This impact of the overall physical activity environment warrants further study, with more standardised measures that take in multiple aspects of the physical activity 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.[55, 56] Reviews looking at individual components of walkability have found more diverse land-use mix,[27, 57] population density[27, 58] and street connectivity[25, 58, 59] to be associated with increased physical activity levels, or active travel in children and adolescents. However a majority of published studies have been conducted in metropolitan settings. The impact and relative importance of each of these measures may differ for regional compared to metropolitan communities. To elicit differences between regional and metropolitan 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, 59, 60] 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.[61, 62] With increasing rurality, 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 to 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 which considered active transport for children who live within walking distance of their school (defined as 1.6km) found much higher rates (up to 67%) of active transport.[63]

We have used a 1km buffer from primary schools in line with other research regarding the distances that children would walk.[39] 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.[64] In the food environment literature there is some evidence that a larger buffers should be used,[65, 66] Additionally, it may be that a larger buffer is more relevant in regional and rural 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 physical activity 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 larger sample sizes and the use of objective physical activity measurement is warranted in regional and rural areas to further our understanding of the broader healthy school environment.

Abbreviations:

ARIA: Accessibility/Remoteness Index for Australia

AT: Active transport

AURIN: Australian Urban Research Infrastructure Network

BMI: Body Mass Index

FOI: features of interest

ICSEA: Index of Community Socio-Educational Advantage

MVPA: Moderate to vigorous physical activity

PA: physical activity

SEP: Socio-Economic Position

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

WHO: World Health Organisation

Declarations

Ethics approval and consent to participate: This study received ethical approval from the Deakin University Human Research Ethics Committee (DUHREC 2014–279), the Victorian Department of Education and Training (DET 2015_002622). 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 (e.g. only survey) as desired.

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests

Funding: This study was supported by funding from the Goulburn Valley's Primary Care Partnership, Western Alliance, and a NHMRC Partnership Project Grant tiled Whole of System Trial of Prevention Strategies for childhood obesity: WHO STOPS childhood obesity (APP1114118). NC, CS, MN, KB, JJ and SA are researchers within a NHMRC Centre for Research Excellence in Obesity Policy and Food Systems (APP1041020). SA would like to acknowledge funding support from VicHealth, the Australian National Health and Medical Research Council (GNT1151572; GNT1133090; GNT114118), the Western Alliance and the NSW Health Translational Research Grants Scheme.

Author contributions: JJ, NC and MN conceptualised the study and initial hypothesis and collated environmental data. SA and CS conceived the WHOSTOP 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

Acknowledgements: Not applicable

REFERENCES

1. Smith M, Hosking J, Woodward A, et al. Systematic literature review of built environment effects on physical activity and active transport - an update and new findings on health equity. *Int J Behav Nutr Phys Act,* 2017, 14:158.
2. Rowlands AV Physical Activity, Inactivity, and Health During Youth. *Pediatr Exerc Sci,* 2016, 28:19-22.
3. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* 2012, 380:219-229.
4. National Health Survey: First Results, 2017-18, Cat no. 4364.0.55.001 [http://www.abs.gov.au/ausstats/abs@.nsf/mf/4364.0.55.001]. Accessed Nov 2019
5. Australia's Health 2014. Australia's health series no. 14. Cat. no. AUS 178 [https://www.aihw.gov.au/reports/australias-health/australias-health-2014/] Accessed Nov 2019
6. Tremblay MS, Gray CE, Akinroye K et al. Physical activity of children: a global matrix of grades comparing 15 countries. *J Phys Act Health* 2014, 11 Suppl 1:S113-125.
7. Villanueva K, Badland H, Kvalsvig A, et al Can the Neighborhood Built Environment Make a Difference in Children's Development? Building the Research Agenda to Create Evidence for Place-Based Children's Policy. *Acad pediatr* 2016, 16:10-19.
8. Timperio A, Crawford D, Ball K, et al. Typologies of neighbourhood environments and children's physical activity, sedentary time and television viewing. *Health Place* 2017, 43:121-127.
9. Timperio A, Reid J, Veitch J: Playability: Built and Social Environment Features That Promote Physical Activity Within Children. *Curr Obes Rep* 2015, 4:460-476.
10. Morton KL, Atkin AJ, Corder K, et al. The school environment and adolescent physical activity and sedentary behaviour: a mixed-studies systematic review. *Obes Rev.* 2016, 17:142-158.

11. de Vet E, de Ridder DT, de Wit JB: Environmental correlates of physical activity and dietary behaviours among young people: a systematic review of reviews. *Obes Rev* 2011, 12:e130-142.
12. Black IE, Menzel NN, Bungum TJ. The Relationship Among Playground Areas and Physical Activity Levels in Children. *J Pediatr Health Car* 2015, 29(2):156-168.
13. Button B, Trites S, Janssen I. Relations between the school physical environment and school social capital with student physical activity levels. *BMC Public Health* 2013, 13:1191.
14. Koorts H, Timperio A, Arundell L, et al. Is sport enough? Contribution of sport to overall moderate- to vigorous-intensity physical activity among adolescents. *J Sci Med Sport* 2019, 22:1119-1124.
15. Denstel KD, Broyles ST, Larouche R, *et al* Active school transport and weekday physical activity in 9-11-year-old children from 12 countries. *Int J Obes Supp*2015, 5(Suppl 2):S100-106.
16. Larouche R, Saunders TJ, Faulkner G, et al. Associations between active school transport and physical activity, body composition, and cardiovascular fitness: a systematic review of 68 studies. *J Phys Act Health* 2014, 11(1):206-227.
17. Panter JR, Jones AP, van Sluijs EM: Environmental determinants of active travel in youth: A review and framework for future research. I*nt J Behav Nutr Phys Act* 2008, 5(1):34.
18. Abbott RA, Macdonald D, Nambiar S, et al. The association between walking to school, daily step counts and meeting step targets in 5- to 17-year-old Australian children. *Pediatr Exerc Sci* 2009, 21(4):520-532.
19. D'Haese S, Vanwolleghem G, Hinckson E, et al. Cross-continental comparison of the association between the physical environment and active transportation in children: a systematic review. I*nt J Behav Nutr Phys Act* 2015, 12:145.
20. Hardy LL, Mihrshahi, S., Drayton, B.A., et al. NSW Schools Physical Activity and Nutrition Survey (SPANS) 2015, Sydney: NSW Department of Health.
21. Bell L, Ullah S, Olds T, et al. Prevalence and socio-economic distribution of eating, physical activity and sedentary behaviour among South Australian children in urban and rural communities: baseline findings from the OPAL evaluation. *Public Health* 2016, 140:196-205.
22. Merom D, Tudor-Locke C, Bauman A, et al. Active commuting to school among NSW primary school children: implications for public health. *Health Place* 2006, 12:678-687.
23. Pont K, Ziviani J, Wadley D, et al. Environmental correlates of children's active transportation: a systematic literature review. *Health Place* 2009, 15:827-840.
24. Gutierrez-Zornoza M, Sanchez-Lopez M, Garcia-Hermoso A, et al. Active commuting to school, weight status, and cardiometabolic risk in children from rural areas: the Cuenca study. *Health Educ Behav* 2015, 42:231-239.
25. Giles-Corti B, Wood G, Pikora T, et al. School site and the potential to walk to school: the impact of street connectivity and traffic exposure in school neighborhoods. *Health Place* 2011, 17:545-550.
26. McCrorie PR, Fenton C, Ellaway A: Combining GPS, GIS, and accelerometry to explore the physical activity and environment relationship in children and young people - a review. I*nt J Behav Nutr Phys Act* 2014, 11:93.
27. Ding D, Sallis JF, Kerr J, et al. Neighborhood environment and physical activity among youth a review. *Am J Prev Med* 2011, 41:442-455.

28. Sarmiento OL, Lemoine P, Gonzalez SA, *et al* Relationships between active school transport and adiposity indicators in school-age children from low-, middle- and high-income countries. *Int J Obes Supp* 2015, 5(Suppl 2):S107-114.

29. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg* 2014, 12:1495-1499.

30. Australian Bureau of Statistics: Population - Local Government Area, Victoria, TableBuilder. Findings based on use of ABS TableBuilder data. 2016.

31. Allender S, Millar L, Hovmand P, et al Whole of Systems Trial of Prevention Strategies for Childhood Obesity: WHO STOPS Childhood Obesity. Int J Environ Res Public Health 2016, 13(11).

32. Crooks N, Strugnell C, Bell C, et al. Establishing a sustainable childhood obesity monitoring system in regional Victoria. Health Promot J Austr 2017, 28(2):96-102.

33. Morrissey B, Allender S, Strugnell C: Dietary and Activity Factors Influence Poor Sleep and the Sleep-Obesity Nexus among Children. Int J Environ Res Public Health 2019, 16(10):1778.

34. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J: Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007, 85(9):660-667.

35. Card A, Manske, S., Mammen, G., et al Core Indicators and Measures of Youth Health Physical Activity & Sedentary Behaviour Module: Indicators and Questions to use with Youth Respondents and/or School Setting Assessments. St. John's, Newfoundland and Labrador: Memorial University of Newfoundland. . In.; 2012.

36. Wong SL, Leatherdale ST, Manske SR: Reliability and validity of a school-based physical activity questionnaire. *Med Sci Sports Exerc* 2006, 38:1593-1600.

37. Australian Government: Australia's Physical Activity and Sedentary Behaviour Guidelines and the Australian 24-Hour Movement Guidelines. The Department of Health, Canberra; 2019.

38. Australian Urban Research Infrastructure Network. Neighbourhood Generator [https://docs.aurin.org.au/portal-help/analysing-your-data/walkability-tools/walkability001-points-to-regions/]Accessed Jan 2020

39. Panter J, Corder K, Griffin SJ, et al. Individual, socio-cultural and environmental predictors of uptake and maintenance of active commuting in children: longitudinal results from the SPEEDY study. I*nt J Behav Nutr Phys Act* 2013, 10:83.

40. Australian Urban Research Infrastructure Network. Walkability Index with Gross Density (Regions) [https://docs.aurin.org.au/portal-help/analysing-your-data/walkability-tools/walkability003-gross-density/] Accessed Oct 2019

41. Victorian State Government. data.vic.gov.au [http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803003642&publicId=guest&extractionProviderId=1#tab1] Accessed Oct 2019

42. Australian Bureau of Statistics. Australian Statistical Geography Standard (ASGS). [http://www.abs.gov.au/websitedbs/D3310114.nsf/home/remoteness+structure]Accessed Nov 2019

43. Australian Population and Migration Research Centre. ARIA (Accessibility/Remoteness Index of Australia) [https://www.adelaide.edu.au/apmrc/research/projects/category/about_aria.html] Accessed Nov 2019

44. Australian Curriculum: Assessment and Reporting Authority My Schools [https://www.myschool.edu.au/] Accessed Jan 2020

45. ESRI: ArcGIS 10.2.2 for Desktop. In. Redlands, CA: Environmental Systems Research Institute, ; 2014.

46. StataCorp. 2017. Stata Statistical Software: Release 15. College Station TSL.

47. Jacobs J, Alston L, Needham C, et al. Variation in the physical activity environment according to area-level socio-economic position-A systematic review. *Obes Rev* 2019, 20(5):686-700.

48. Strugnell C, Orellana L, Hayward J et al. Active (Opt-In) Consent Underestimates Mean BMI-z and the Prevalence of Overweight and Obesity Compared to Passive (Opt-Out) Consent. Evidence from the Healthy Together Victoria and Childhood Obesity Study. Int J Environ Res Public Health 2018, 15.

49. Boscoe FP, Henry KA, Zdeb MS: A Nationwide Comparison of Driving Distance Versus Straight-Line Distance to Hospitals. *Prof. Geogr* 2012, 64:10. 1080/00330124.00332011.00583586.

50. Rodríguez-López C, Salas-Fariña ZM, Villa-González E, et al. The Threshold Distance Associated With Walking From Home to School. *Health Educ Behav* 2017, 44:857-866.

51. Sharman SJ, Skouteris H, Powell MB et al. Factors Related to the Accuracy of Self-Reported Dietary Intake of Children Aged 6 to 12 Years Elicited with Interviews: A Systematic Review. *J Acad Nutr Diet* 2016, 116(1):76-114.

52. Boone-Heinonen J, Gordon-Larsen P, Guilkey DK, et al. Environment and Physical Activity Dynamics: The Role of Residential Self-selection. *Psychol Sport Exerc* 2011, 12(1):54-60.

53. Lee BY, Bartsch SM, Mui Y, et al. A systems approach to obesity. *Nutr Rev* 2017, 75(suppl 1):94-106.

54. Meron D, Rissel C, Reinten-Reynolds T, Hardy LL: Changes in active travel of school children from 2004 to 2010 in New South Wales, Australia. *Prev Med* 2011, 53:408-410.

55. Leslie E, Coffee N, Frank L, et al. Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes. *Health Place,* 2007, 13:111-122.

56. Frank LD, Sallis JF, Saelens BE, et al. The development of a walkability index: application to the Neighborhood Quality of Life Study. *Br J Sports Med* 2010, 44:924-933.

57. Carver A, Panter JR, Jones AP, et al. Independent mobility on the journey to school: A joint cross-sectional and prospective exploration of social and physical environmental influences. *J Transp Health* 2014, 1:25-32.

58. Giles-Corti B, Kelty SF, Zubrick SR, et al. Encouraging walking for transport and physical activity in children and adolescents: how important is the built environment? *Sports Med,* 2009, 39:995-1009.

59. Trapp GS, Giles-Corti B, Christian HE, Bulsara M, Timperio AF, McCormack GR, Villaneuva KP: Increasing children's physical activity: individual, social, and environmental factors associated with walking to and from school. Health Educ Behav 2012, 39:172-182.

60. Gustat J, Richards K, Rice J, Andersen L, Parker-Karst K, Cole S: Youth Walking and Biking Rates Vary by Environments Around 5 Louisiana Schools. *J School Health* 2015, 85:36-42.

61. Harten N, Olds T: Patterns of active transport in 11-12 year old Australian children. *Aust N Z J Public Health* 2004, 28(2):167-172.

62. Su JG, Jerrett M, McConnell R, et al. Factors influencing whether children walk to school. *Health Place* 2013, 22:153-161.

63. Rothman L, To T, Buliung R, et al. Influence of social and built environment features on children walking to school: an observational study. *Prev Med* 2014, 60:10-15.
64. van Loon J, Frank LD, Nettlefold L, et al. Youth physical activity and the neighbourhood environment: Examining correlates and the role of neighbourhood definition. *Soc Sci Med* 2014, 104:107-115.
65. Kerr J, Frank L, Sallis JF, Saelens B, Glanz K, Chapman J: Predictors of trips to food destinations. I*nt J Behav Nutr Phys Act* 2012, 9:58.
66. Thornton LE, Crawford DA, Lamb KE, Ball K: Where do people purchase food? A novel approach to investigating food purchasing locations. *Int J Health Geogr* 2017, 16:9.

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)
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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
Discussion			
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
Other information			
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.

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.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-045785.R1
Article Type:	Original research
Date Submitted by the Author:	19-May-2021
Complete List of Authors:	Jacobs, Jane; Deakin University - Geelong Waterfront Campus, Crooks, Nic; Deakin University School of Health and Social Development, Global Obesity Centre Allender, Steven; Faculty of Health Strugnell, Claudia; Deakin University - Geelong Waterfront Campus, WHO Collaborating Centre for Obesity Prevention Backholer, Kathryn; Deakin University, Health and Social Development Nichols, Melanie; Deakin University, Faculty of Health;
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Sports and exercise medicine
Keywords:	PUBLIC HEALTH, Community child health < PAEDIATRICS, SPORTS MEDICINE

Title: *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.*

Authors: Jane Jacobs (Corresponding Author)[a], Nicholas Crooks [a], Steven Allender [a], Claudia Strugnell [a], Kathryn Backholer [a], Melanie Nichols [a]

Corresponding author: Jane Jacobs

Email: jane.jacobs@deakin.edu.au

[a]Global Obesity Centre

Deakin University

1 Gheringhap St, Geelong

Victoria, Australia, 3220

Word Count: 4,011

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=2,144) attending participating primary schools.

Outcome Measures: Measured weight status [Body Mass Index (BMI) 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, 1.35), had a greater number of greenspaces (OR 1.35 (95%CI 1.20, 1.53)) and a greater number of recreational facilities (OR 1.18 (95% CI 1.07, 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, 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 which have been under-researched.

Strengths and Limitations

- 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.
- Multi-level linear and logistic regressions were used to assess associations between elements of the school neighbourhood physical activity environment and students' weight status and physical activity behaviours.
- Comparisons were made between PA environments of school neighbourhoods surrounding high and low socio-economic 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 participations rates and objectively measured physical activity environments.
- Study limitations include the use of self-report physical activity behaviour data and the inability to determine how far children lived from the schools.

Keywords: Physical activity, obesity, active transport, walkability, greenspace, recreational facilities, rurality, school environment, children

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 indicates that overweight and obesity prevalence has significantly increased outside of major cities areas since 2010, whereas it appears to have plateaued in major cities.[20] Compared to 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 sports 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 metropolitan 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 physical activity environments surrounding primary schools and i)students' weight status ii) PA levels iii) active transport, in regional areas of Victoria, Australia. Findings from this study may aid in the prioritisation and targeting of policies and programs 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 (e.g. 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 systems-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 schools 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 0.1cm and weight the nearest 0.05kg. All students were measured twice and where the two initial measures differed, by more than 0.5cm or 0.1kg 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 World Health Organization (WHO) Child Growth Reference [35], and weight status categories were derived using the following cut-offs, as recommended by the WHO; overweight: >+1SD to <+2SD, obese: ≥+2SD. 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 & Sedentary Behaviour Module,[36] which has been shown to be reliable in this age-group.[36, 37]

Physical activity was assessed students participating in at least 60 minutes of moderate to vigorous physical activity (MVPA) on 5 school days (Monday – 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 non-active (car, school bus, other inactive).

Physical activity 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 1km 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 1km is a feasible distance that children will walk to school.[40] A walkability score for this buffer area, and the count of recreational facilities and greenspaces intersecting this buffer was determined for each school. A 50m trim distance was used around the road centres, to capture greenspace and facilities accessible from the defined street network.

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' [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
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 [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]

*within a 1km walkable distance from the school

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

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.[45] 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.[42] FOI data are projected as polygons and used to determine the presence of facilities which 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 (e.g. skate parks), sporting facilities (e.g. tennis court, netball courts, golf course, sporting complexes), and reserves (e.g. 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 (that is, they were within 1km 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 was 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 dataset were observed to be inappropriate for PA (e.g. 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.[46]

Remoteness: Remoteness classification for each school was determined according to the five categories of the Accessibility/Remoteness Index for Australia (ARIA+); Major Cities, Inner Regional, Outer Regional, Remote and Very Remote.[47] 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.[44] 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 Socio-Educational Advantage (ICSEA) scores, obtained from the Australian Curriculum, Assessment and Reporting Authority 'My School' website[43]. 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 socio-economic position. 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, version 10.7.1 ESRI, Redlands, CA).[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 1km 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 Version 15 (StataCorp, College Station, TX)[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 has 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: i) the count of recreational facilities within, or intersecting with, the 1km walkability buffer, ii) the count of greenspaces within, or intersecting with, the 1km walkability buffer, iii) the school walkability score, and each of three dependent variables; i) weight status (overweight or obese) (yes/no) ,ii)adherence to PA guidelines (yes/no) and iii)use of active transport(yes/no) as separate regressions. Multi-level 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 in 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 were 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 upon for this manuscript involved extensive collaboration with numerous community-based organisations (e.g. 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 (e.g. 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 systems-based obesity prevention interventions, with 79% (3,476/4,386) of eligible students within those schools participating in the study. Of these eligible students, 2,269 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 2,144 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 to 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 to inner regional areas. Further, a lower proportion of students used active forms of transport in outer compared to inner regional areas.

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
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)

*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

Low SEP = ICSEA<1000; High SEP = ICSEA≥1000

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

Table 3 shows 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% 1.20, 1.53). The association between greenspace and active transport also remained when adjusted for the other independent variables (model 3) (OR 1.30, 95% 1.09, 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, 1.51). .

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

	Model 1		**Model 2**		**Model 3**	
	Odds Ratio	*95% CI*	*Odds Ratio*	*95% CI*	*Odds Ratio*	*95% CI*
Meeting PA guidelines						
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	-	-
Using AT 1+ trip						
Recreational Facilities	**1.23****	1.11, 1.37	**1.18****	1.07, 1.31	1.05	0.94, 1.18
Greenspace	**1.41****	1.24, 1.61	**1.35****	1.20, 1.53	**1.30****	1.09, 1.54
Walkability	**1.26****	**1.14, 1.41**	**1.21****	1.09, 1.35	1.01	0.87, 1.17
Total PA environment	**1.40****	1.23, 1.58	**1.33****	1.28, 1.51	-	-
Overweight/obese						
Recreational Facilities	1.03	1.00, 1.06	1.01	0.98, 1.04	1.01	0.97, 1.04
Greenspace	**1.04***	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	**1.05***	1.00, 1.10	1.03	0.99, 1.08	-	-
	*Beta^*	*95% CI*	*Beta^*	*95% CI*	*Beta^*	*95% CI*
BMI z-score						
Recreational Facilities	0.01	-0.01, 0.29	0.00	-0.02, 0.02	0.00	-0.03, 0.02
Greenspace	**0.03***	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	**0.03***	0.00, 0.06	0.01	-0.01, 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 PA = physical activity; AT = active transport; BMI = body mass index

^mean change in BMI z-score

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 non-participation bias on estimates of behaviours and overweight and obesity.[34] Additionally, manually verifying the recreational facilities and greenspaces within the 1km walkable neighbourhood of a sample of participating schools improved the validity of our environmental data and allowed refinements of the classification methods for greenspaces and recreation facilities for analysis.

Using a 1km 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 1km 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 to 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 to 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 which may 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 which 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.[45, 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 to 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 to 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 which considered active transport for children who live within walking distance of their school (defined as 1.6km) found much higher rates (up to 67%) of active transport.[73]

We have used a 1km 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 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.

Abbreviations:

ARIA: Accessibility/Remoteness Index for Australia

AT: Active transport

AURIN: Australian Urban Research Infrastructure Network

BMI: Body Mass Index

FOI: features of interest

ICSEA: Index of Community Socio-Educational Advantage

MVPA: Moderate to vigorous physical activity

PA: physical activity

SEP: Socio-Economic Position

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

WHO: World Health Organisation

Declarations

Ethics approval and consent to participate: 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. 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 (e.g. only survey) as desired.

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests

Funding: This study was supported by funding from the Goulburn Valley's Primary Care Partnership, Western Alliance, and a NHMRC Partnership Project Grant tiled Whole of System Trial of Prevention Strategies for childhood obesity: WHO STOPS childhood obesity (APP1114118). NC, CS, MN, KB, JJ and SA are researchers within a NHMRC Centre for Research Excellence in Obesity Policy and Food Systems (APP1041020). SA would like to acknowledge funding support from VicHealth, the Australian National Health and Medical Research Council (GNT1151572; GNT1133090; GNT114118), the Western Alliance and the NSW Health Translational Research Grants Scheme.

Author contributions: JJ, NC and MN conceptualised the study and initial hypothesis and collated environmental data. SA and CS conceived the WHOSTOP 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

Acknowledgements: Not applicable

REFERENCES

1. Smith M, Hosking J, Woodward A, Witten K, MacMillan A, Field A, Baas P, Mackie H: Systematic literature review of built environment effects on physical activity and active transport - an update and new findings on health equity. *Int J Behav Nutr Phys Act,* 2017, 14(1):158.
2. Rowlands AV: Physical Activity, Inactivity, and Health During Youth. *Pediatr Exerc Sci,* 2016, 28(1):19-22.
3. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT: Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* 2012, 380(9838):219-229.
4. Australian Bureau of Statisitcs. National Health Survey: First Results, 2017-18, Cat no. 4364.0.55.001 [http://www.abs.gov.au/ausstats/abs@.nsf/mf/4364.0.55.001]
5. Australian Institute of Health and Welfare Australia's Health 2014. Australia's health series no. 14. Cat. no. AUS 178 [https://www.aihw.gov.au/reports/australias-health/australias-health-2014/]
6. Tremblay MS, Gray CE, Akinroye K, Harrington DM, Katzmarzyk PT, Lambert EV, Liukkonen J, Maddison R, Ocansey RT, Onywera VO *et al*: Physical activity of children: a global matrix of grades comparing 15 countries. *J Phys Act Health* 2014, 11 Suppl 1:S113-125.
7. Villanueva K, Badland H, Kvalsvig A, O'Connor M, Christian H, Woolcock G, Giles-Corti B, Goldfeld S: Can the Neighborhood Built Environment Make a Difference in Children's Development? Building the Research Agenda to Create Evidence for Place-Based Children's Policy. *Acad Pediatr,* 2016, 16(1):10-19.
8. Timperio A, Crawford D, Ball K, Salmon J: Typologies of neighbourhood environments and children's physical activity, sedentary time and television viewing. *Health Place* 2017, 43:121-127.
9. Timperio A, Reid J, Veitch J: Playability: Built and Social Environment Features That Promote Physical Activity Within Children. *Curr Obes Rep* 2015, 4(4):460-476.
10. Morton KL, Atkin AJ, Corder K, Suhrcke M, van Sluijs EM: The school environment and adolescent physical activity and sedentary behaviour: a mixed-studies systematic review. *Obes Rev* 2016, 17(2):142-158.
11. de Vet E, de Ridder DT, de Wit JB: Environmental correlates of physical activity and dietary behaviours among young people: a systematic review of reviews. *Obes Rev* 2011, 12(5):e130-142.
12. Black IE, Menzel NN, Bungum TJ: The Relationship Among Playground Areas and Physical Activity Levels in Children. *J Pediatr Health Care* 2015, 29(2):156-168.
13. Button B, Trites S, Janssen I: Relations between the school physical environment and school social capital with student physical activity levels. *BMC Public Health* 2013, 13(1):1191.

14. Koorts H, Timperio A, Arundell L, Parker K, Abbott G, Salmon J: Is sport enough? Contribution of sport to overall moderate- to vigorous-intensity physical activity among adolescents. *J Sci Med Sport* 2019, 22(10):1119-1124.

15. Denstel KD, Broyles ST, Larouche R, Sarmiento OL, Barreira TV, Chaput JP, Church TS, Fogelholm M, Hu G, Kuriyan R *et al*: Active school transport and weekday physical activity in 9-11-year-old children from 12 countries. *Int J Obes Supp* 2015, 5(Suppl 2):S100-106.

16. Larouche R, Saunders TJ, Faulkner G, Colley R, Tremblay M: Associations between active school transport and physical activity, body composition, and cardiovascular fitness: a systematic review of 68 studies. *J Phys Act Health* 2014, 11(1):206-227.

17. Panter JR, Jones AP, van Sluijs EM: Environmental determinants of active travel in youth: A review and framework for future research. *Int J Behav Nut Phys Act* 2008, 5(1):34.

18. Abbott RA, Macdonald D, Nambiar S, Davies PS: The association between walking to school, daily step counts and meeting step targets in 5- to 17-year-old Australian children. *Pediatr Exer Sci* 2009, 21(4):520-532.

19. D'Haese S, Vanwolleghem G, Hinckson E, De Bourdeaudhuij I, Deforche B, Van Dyck D, Cardon G: Cross-continental comparison of the association between the physical environment and active transportation in children: a systematic review. *Int J Behav Nut Phys Act* 2015, 12:145.

20. Hardy LL, Mihrshahi, S., Drayton, B.A., Bauman, A., : NSW Schools Physical Activity and Nutrition Survey (SPANS) 2015, . In. Sydney: NSW Department of Health, ; 2016.

21. Bell L, Ullah S, Olds T, Magarey A, Leslie E, Jones M, Miller M, Cobiac L: Prevalence and socio-economic distribution of eating, physical activity and sedentary behaviour among South Australian children in urban and rural communities: baseline findings from the OPAL evaluation. *Public Health* 2016, 140:196-205.

22. Merom D, Tudor-Locke C, Bauman A, Rissel C: Active commuting to school among NSW primary school children: implications for public health. *Health Place* 2006, 12(4):678-687.

23. Pont K, Ziviani J, Wadley D, Bennett S, Abbott R: Environmental correlates of children's active transportation: a systematic literature review. *Health Place* 2009, 15(3):827-840.

24. Gutierrez-Zornoza M, Sanchez-Lopez M, Garcia-Hermoso A, Gonzalez-Garcia A, Chillon P, Martinez-Vizcaino V: Active commuting to school, weight status, and cardiometabolic risk in children from rural areas: the Cuenca study. *Health Edu Behav* 2015, 42(2):231-239.

25. Giles-Corti B, Wood G, Pikora T, Learnihan V, Bulsara M, Van Niel K, Timperio A, McCormack G, Villanueva K: School site and the potential to walk to school: the impact of street connectivity and traffic exposure in school neighborhoods. *Health Place* 2011, 17(2):545-550.

26. McCrorie PR, Fenton C, Ellaway A: Combining GPS, GIS, and accelerometry to explore the physical activity and environment relationship in children and young people - a review. *Int J Behav Nut Phys Act* 2014, 11:93.

27. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE: Neighborhood environment and physical activity among youth a review. *Am J Prev Med* 2011, 41(4):442-455.

28. Sarmiento OL, Lemoine P, Gonzalez SA, Broyles ST, Denstel KD, Larouche R, Onywera V, Barreira TV, Chaput JP, Fogelholm M *et al*: Relationships between active school transport and adiposity indicators in school-age children from low-, middle- and high-income countries. *Int J Obes Supp* 2015, 5(Suppl 2):S107-114.

29. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP: The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg* 2014, 12(12):1495-1499.

30. Australian Bureau of Statistics: Population - Local Government Area, Victoria, TableBuilder. Findings based on use of ABS TableBuilder data. 2016.

31. Allender S, Millar L, Hovmand P, Bell C, Moodie M, Carter R, Swinburn B, Strugnell C, Lowe J, de la Haye K *et al*: Whole of Systems Trial of Prevention Strategies for Childhood Obesity: WHO STOPS Childhood Obesity. *Int J Env Res Public Health* 2016, 13(11).

32. Whelan J, Strugnell C, Allender S, Korn AR, Brown AD, Orellana L, Hayward J, Brown V, Bell C, Moodie M *et al*: Protocol for the measurement of changes in knowledge and engagement in the stepped wedge cluster randomised trial for childhood obesity prevention in

Australia: (Reflexive Evidence and Systems interventions to Prevent Obesity and Non-communicable Disease (RESPOND)). *Trials* 2020, 21(1):763.

33. Crooks N, Strugnell C, Bell C, Allender S: Establishing a sustainable childhood obesity monitoring system in regional Victoria. *Health Prom Journal Austr* 2017, 28(2):96-102.

34. Strugnell C, Orellana L, Hayward J, Millar L, Swinburn B, Allender S: Active (Opt-In) Consent Underestimates Mean BMI-z and the Prevalence of Overweight and Obesity Compared to Passive (Opt-Out) Consent. Evidence from the Healthy Together Victoria and Childhood Obesity Study. *Int J Env Res Public Health* 2018, **15**(4).

35. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J: Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007, 85(9):660-667.

36. Card A, Manske, S., Mammen, G., King, M., Gleddie, D., Schwartz, M.,: Core Indicators and Measures of Youth Health Physical Activity & Sedentary Behaviour Module: Indicators and Questions to use with Youth Respondents and/or School Setting Assessments. St. John's, Newfoundland and Labrador: Memorial University of Newfoundland. 2012.

37. Wong SL, Leatherdale ST, Manske SR: Reliability and validity of a school-based physical activity questionnaire. *Med Sci Sports Exerc* 2006, 38(9):1593-1600.

38. Commonwealth Department of Health. Australia's physical activity and sedentary behaviour guidelines for children (5–12 years). 2014.

39. AURIN: Neighbourhood Generator [https://docs.aurin.org.au/portal-help/analysing-your-data/walkability-tools/walkability001-points-to-regions/]

40. Panter J, Corder K, Griffin SJ, Jones AP, van Sluijs EM: Individual, socio-cultural and environmental predictors of uptake and maintenance of active commuting in children: longitudinal results from the SPEEDY study. *The Int J Behav Nutr Phys Act* 2013, 10:83.

41. AURIN: Walkability Index with Gross Density (Regions) [https://docs.aurin.org.au/portal-help/analysing-your-data/walkability-tools/walkability003-gross-density/]

42. Victorian Government, data.vic.gov.au [http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803003642&publicId=guest&extractionProviderId=1#tab1]

43. ACARA My Schools [https://www.myschool.edu.au/]

44. Australian Bureau of Statistics ARIA (Accessibility/Remoteness Index of Australia) [https://www.adelaide.edu.au/apmrc/research/projects/category/about_aria.html]

45. Frank LD, Sallis JF, Saelens BE, Leary L, Cain K, Conway TL, Hess PM: The development of a walkability index: application to the Neighborhood Quality of Life Study. *British J Sports Med* 2010, 44(13):924-933.

46. Bader MDM, Mooney SJ, Bennett B, Rundle AG: The Promise, Practicalities, and Perils of Virtually Auditing Neighborhoods Using Google Street View. *Ann Am Acad Pol Soc Sci* 2016, 669(1):18-40.

47. Australian Statistical Geography Standard (ASGS). [http://www.abs.gov.au/websitedbs/D3310114.nsf/home/remoteness+structure]

48. ESRI: ArcGIS 10.2.2 for Desktop. In. Redlands, CA: Environmental Systems Research Institute, ; 2014.

49. StataCorp. 2017. Stata Statistical Software: Release 15. College Station TSL. In.

50. Jacobs J, Alston L, Needham C, Backholer K, Strugnell C, Allender S, Nichols M: Variation in the physical activity environment according to area-level socio-economic position-A systematic review. *Obes Rev* 2019, 20(5):686-700.

51. Morrissey B, Allender S, Strugnell C: Dietary and Activity Factors Influence Poor Sleep and the Sleep-Obesity Nexus among Children. *Int J Envir Res Public Health* 2019, 16(10):1778.

52. Boscoe FP, Henry KA, Zdeb MS: A Nationwide Comparison of Driving Distance Versus Straight-Line Distance to Hospitals. *The Prof Geogr* 2012, 64(2):10.1080/00330124.00332011.00583586.

53. Rodríguez-López C, Salas-Fariña ZM, Villa-González E, Borges-Cosic M, Herrador-Colmenero M, Medina-Casaubón J, Ortega FB, Chillón P: The Threshold Distance Associated With Walking From Home to School. *Health Educ Behav* 2017, 44(6):857-866.

54. Sharman SJ, Skouteris H, Powell MB, Watson B: Factors Related to the Accuracy of Self-Reported Dietary Intake of Children Aged 6 to 12 Years Elicited with Interviews: A Systematic Review. *J Acad Nutr Diet* 2016, 116(1):76-114.
55. Boone-Heinonen J, Gordon-Larsen P, Guilkey DK, Jacobs DR, Jr., Popkin BM: Environment and Physical Activity Dynamics: The Role of Residential Self-selection. *Psychol Sport Exerc* 2011, 12(1):54-60.
56. Jones A, Hillsdon M, Coombes E: Greenspace access, use, and physical activity: Understanding the effects of area deprivation. *Prev Med* 2009, 49(6):500-505.
57. Kessel A, Green J, Pinder R, Wilkinson P, Grundy C, Lachowycz K: Multidisciplinary research in public health: A case study of research on access to green space. *Public Health* 2009, 123(1):32-38.
58. Svastisalee C, Schipperijn J, Hostein BE, Powell LM, Due P: Exposure to physical activity resources by neighborhood sociodemographic characteristics in Copenhagen. *J Phys Act Health* 2012, 9(8):1065-1073.
59. Ellaway A, Kirk A, Macintyre S, Mutrie N: Nowhere to play? The relationship between the location of outdoor play areas and deprivation in Glasgow. *Health Place* 2007, 13(2):557-561 555p.
60. Engelberg JK, Conway TL, Geremia C, Cain KL, Saelens BE, Glanz K, Frank LD, Sallis JF: Socioeconomic and race/ethnic disparities in observed park quality. *BMC Public Health* 2016, 16:1-11 11p.
61. Ogilvie D, Lamb KE, Ferguson NS, Ellaway A: Recreational physical activity facilities within walking and cycling distance: Sociospatial patterning of access in Scotland. *Health Place* 2011, 17(5):1015-1022.
62. Schneider S, D'Agostino A, Weyers S, Diehl K, Gruber J: Neighborhood Deprivation and Physical Activity Facilities - No Support for the Deprivation Amplification Hypothesis. *J Phys Act Health* 2015, 12(7):990-997.
63. Macdonald L, McCrorie P, Nicholls N, Ellaway A: Walkability around primary schools and area deprivation across Scotland. *BMC Public Health* 2016, 16:328.
64. Lee BY, Bartsch SM, Mui Y, Haidari LA, Spiker ML, Gittelsohn J: A systems approach to obesity. *Nutr Rev* 2017, 75(suppl 1):94-106.
65. Meron D, Rissel C, Reinten-Reynolds T, Hardy LL: Changes in active travel of school children from 2004 to 2010 in New South Wales, Australia. *Prev Med* 2011, 53(6):408-410.
66. Leslie E, Coffee N, Frank L, Owen N, Bauman A, Hugo G: Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes. *Health Place,* 2007, 13(1):111-122.
67. Carver A, Panter JR, Jones AP, van Sluijs EMF: Independent mobility on the journey to school: A joint cross-sectional and prospective exploration of social and physical environmental influences. *J Trans Health* 2014, 1(1):25-32.
68. Giles-Corti B, Kelty SF, Zubrick SR, Villanueva KP: Encouraging walking for transport and physical activity in children and adolescents: how important is the built environment? *Sports Med,* 2009, 39(12):995-1009.
69. Trapp GS, Giles-Corti B, Christian HE, Bulsara M, Timperio AF, McCormack GR, Villaneuva KP: Increasing children's physical activity: individual, social, and environmental factors associated with walking to and from school. *Health Educat Behav* 2012, 39(2):172-182.
70. Gustat J, Richards K, Rice J, Andersen L, Parker-Karst K, Cole S: Youth Walking and Biking Rates Vary by Environments Around 5 Louisiana Schools. *J School Health* 2015, 85(1):36-42.
71. Harten N, Olds T: Patterns of active transport in 11-12 year old Australian children. *Aust N Z J Public Health* 2004, 28(2):167-172.
72. Su JG, Jerrett M, McConnell R, Berhane K, Dunton G, Shankardass K, Reynolds K, Chang R, Wolch J: Factors influencing whether children walk to school. *Health Place* 2013, 22:153-161.

73. Rothman L, To T, Buliung R, Macarthur C, Howard A: Influence of social and built environment features on children walking to school: an observational study. *Prev Med* 2014, 60:10-15.

74. van Loon J, Frank LD, Nettlefold L, Naylor P-J: Youth physical activity and the neighbourhood environment: Examining correlates and the role of neighbourhood definition. *Soc Sci Med* 2014, 104:107-115.

75. Kerr J, Frank L, Sallis JF, Saelens B, Glanz K, Chapman J: Predictors of trips to food destinations. *The Int J Behav Nutr Phys Act* 2012, 9:58.

76. Thornton LE, Crawford DA, Lamb KE, Ball K: Where do people purchase food? A novel approach to investigating food purchasing locations. *Int J Health Geograph* 2017, 16(1):9.

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)
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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
Discussion			
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
Other information			
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.