What predicts children's active transport and independent mobility in disadvantaged neighborhoods?

Citation of final article:
Veitch, J., Carver, A., Salmon, J., Abbott, G., Ball, K., Crawford, D., Cleland, V. and Timperio, A. 2017, What predicts children's active transport and independent mobility in disadvantaged neighborhoods?, *Health & place*, vol. 44, pp. 103-109.

What predicts children's active transport and independent mobility in disadvantaged neighborhoods?

Veitch J[1], Carver A[2], Salmon J[1], Abbott G[1], Ball K[1], Crawford D[1], Cleland V[3], Timperio A[1]

[1] Deakin University, Geelong, Australia, Institute for Physical Activity and Nutrition (IPAN)

[2] Deakin University, Geelong, Australia, School of Exercise and Nutrition Sciences

[3] Menzies Institute for Medical Research, University of Tasmania, Australia

<u>Corresponding author</u>:
Dr Jenny Veitch
Deakin University, Geelong, Australia, Institute for Physical Activity and Nutrition (IPAN)
Phone: +61 3 92517723
Fax. +61 3 9244 6017
Email: jenny.veitch@deakin.edu.au

Abstract

This study examined two year changes in children's active transport and independent mobility and prospective associations between individual, social and physical environmental predictors of interest and these behaviors two years later. Overall, 43.5% of children (12.0±2.1 years) used active transport on the school journey at T1 and at T2 (p=0.77), and 35.3% engaged in independent mobility on the school journey at T1 and 29.6% at T2 (p=0.07). Enjoyment, parental safety concerns, and proximity to walking tracks were associated with independent mobility on the school journey. Road safety and social norms were associated with active transport and independent mobility to local destinations. These factors provide potential targets for interventions.

Keywords: child; adolescent; active transport; walking to school; independent mobility; neighborhood; disadvantage; longitudinal study

Introduction

The importance of regular physical activity for promoting both physical and mental health in childhood and adolescence is well-established (Janssen and Leblanc, 2010). Active transport, which involves walking or cycling to places such as school or local destinations, can make an important contribution to overall physical activity (Roth et al., 2012; van Sluijs et al., 2009). Active transport is an informal, low cost source of physical activity (Humbert et al., 2006) that also offers opportunities for independent mobility if children have the freedom to walk or cycle around their neighborhoods without adult accompaniment (Hillman et al., 1990). Independent mobility confers additional benefits to children by promoting their social, cognitive and emotional development (Kytta, 2004).

Despite these benefits, studies from various developed countries have shown rapid declines in the prevalence of active commuting and independent mobility (Fyhri et al., 2011; McDonald, 2007; Schoeppe et al., 2013). Since 2002 only about 40% of UK children 7 to 13 years have been allowed to commute to school unaccompanied (Mackett, 2013) and a recent study in Australia showed less than 46% of children walk or cycle to school, and less than 38% are independently mobile (Carver et al., 2012). Emerging evidence suggests that active transport to/from school increases with age during childhood, particularly from childhood to adolescence (Costa et al., 2012; Hume et al., 2009; Pabayo et al., 2011), though some studies have shown that active transport declines with age (Trang et al., 2012).

Individual, social and physical environmental level factors influence physical activity behavior (Sallis and Owen, 1997). Although mainly based on cross-sectional studies, evidence in relation to influences on active transport and independent mobility among children suggests that each of these levels of influence are important. A review study showed shorter distances to school, mixed land use, access to parks and other sport/recreation destinations, urban residence, population/residential density and ethnicity (non-white) are positively associated, while car ownership, family income, parental education, and concern about child and traffic safety are negatively associated with active travel to school (Pont et al., 2009). Longitudinal studies of active transport show that knowing many people in the neighborhood and satisfaction with the number of pedestrian crossings are associated with higher odds of active transport to school, and that insufficient traffic lights and crossings is associated with lower odds of active transport to school among children and adolescents (Hume et al., 2009).

Among 10 year-olds in the UK, Panter et al. (2010) found shorter distance to school, urban residence, lower socioeconomic status, parental perceptions of higher route safety and inconvenience of travelling to school by car were associated with higher odds of taking up active commuting to school and maintaining it after one year. Having direct routes to school was associated with lower odds of taking up active transport (Panter et al., 2010). Recent studies have found well-connected streets and cycling lanes to be positively associated with active travel among children (Helbich et al., 2016; Oliver et al., 2015).

Some studies have examined possible influences on children's independent mobility (Carver et al., 2012; Christian et al., 2015; Santos et al., 2013; Villanueva et al., 2013). These cross-sectional studies found positive associations with independent mobility and access to parks and outdoor play spaces, neighborhood walkability and safety, parental confidence that their child could travel independently and negative associations with social norms towards independent mobility. In one of the only studies to have examined longitudinal determinants of independent mobility, Carver et al (2014) reported that among English children (aged 9-10 years at baseline) those whose parents allowed them to play outside anywhere in the neighborhood (boys) and whose neighborhoods had high land use mix (girls) were more likely to engage in active travel to school independently one year later. Those with car access (boys), parental encouragement for walking/cycling to school, and a high proportion of the route being a main road (girls) had lower odds of being independently mobile on the school journey.

Overall, longitudinal studies examining patterns and predictors of active transport and independent mobility to school and other local destinations are rare, especially among school- aged children residing in socioeconomically disadvantaged areas. These children tend to be less physically active than those who reside in more advantaged areas and this may be detrimental to their future health (Humbert et al., 2006). This study aimed (1) to describe changes in levels of participation in active transport and independent mobility among children residing in low socioeconomic areas at two seasonally-matched time-points, two years apart; and (2) to examine prospective associations between individual, social and physical environmental predictors of interest and active transport and independent mobility two years later.

Methods

Individual, social and physical environmental predictors of interest were collected at T1 from a self-report survey completed by mothers and objective measures of the physical environment using GIS. Children's active travel and independent mobility were self-reported by children at T1 and T2.

Sample

Children were recruited through their mothers' participation in a longitudinal cohort study, 'Resilience for Eating and Activity Despite Inequality (READI)', for which baseline recruitment methods have been published previously (Ball et al., 2013; Cleland et al., 2010). Briefly, 18-46 year old women residing in 40 urban and 40 rural socioeconomically disadvantaged areas were invited to participate in a postal survey about diet and physical activity.

Of the 11,940 women randomly sampled from the electoral roll and sent a survey to complete, 861 surveys (7.2%) were returned as undeliverable. A total of 4938 surveys (45% response rate of those delivered) were completed between August 2007 and July 2008. Women who had moved house from the sampled neighborhood before completing the survey (n=571), completed the survey but were not an intended participant (n=3), withdrew their data after completing the survey (n=2), or were aged <18 or >46 years (n=13) were excluded, leaving 4349 (39% of those delivered a survey) eligible women with survey data at baseline. Those who were mothers of a child aged 5-12 years (n=1,457) were also invited to complete survey items on their child's diet and physical activity and 771 (53%) consented. Of these, 613 completed a survey about their child. Of the full cohort, those who consented to further follow-up and remained eligible (n=3019 women and 590 children) were re-contacted to complete a follow-up survey. Two follow-ups during which participating children also completed a guided questionnaire were conducted at three (2010) and five years (2012).

The current study is based on data collected at the two follow-up time-points only (2010 and 2012). Completed surveys were obtained for 311 children (53% response from those completing baseline and consenting to follow-up) in 2010 (T1) and for 207 of these children (67% retention of the T1 sample) in 2012 (T2). Ethical approval was obtained from the Deakin University Human Research Ethics Committee, the Victorian Catholic Education Office and the Department of Education and Training, Victoria.

Measures

Children completed a questionnaire under guidance by a trained research assistant at school (or at home if more convenient) about their active transport and independent mobility on journeys to/from school and to local destinations. Identical items were included at each time-point. One-week test–retest reliability of key items (described below) was established in a separate sample of 48 children aged 8-9 years in 2010. Mothers also completed a postal survey at T1 (2010).

Child survey

Active transport and independent mobility on the school journey

At both time-points, children reported the number of trips they made to and from school in a typical week via six modes of transport. Possible modes of transport in each direction were: (1) walk; (2) ride a bike; (3) skateboard/scooter/rollerblade; (4) public transport/school bus (excluding Walking School Bus); (5) car (child's family only); and (6) car pool (with other families). The habitual travel mode used to travel 1) to school and 2) from school was identified (operationalized as the travel mode used for three or more trips per week). Test-retest reliability of items assessing habitual modes of transport to and from school was high (κ=0.77 and 0.76, respectively). For each time-point, habitual travel modes to/from school were classified as (1) active vs (0) non-active travel. Active travel was defined as usually walking, riding a bike, or skateboard/scooter/rollerblading in at least one direction (test-retest reliability was moderate: κ=0.56).

For the three active modes of travel (walk, ride a bike, skateboard/scooter/rollerblade) children were asked who they usually traveled with on these trips. Response options were: I don't usually [walk] to school; by myself; with parent/other adult; with friends/siblings (no adults). For each time-point, a dichotomous variable was derived to indicate whether the child habitually (i.e. 3+ trips/week) used independent active travel on the school journey (1=yes; 0=no). Independent active travel was defined as habitually walking, riding a bike or skateboard/scooter/rollerblading without adult accompaniment in at least one direction (test-retest reliability was substantial κ=0.86).

Active transport and independent mobility to local destinations

Children were asked which of the following four destination types were located within perceived walking distance of their home: friends' houses; sports or physical activity venues (e.g. walking tracks, tennis courts); parks/playgrounds; and shops. The total number of 'walkable' destination types was computed (possible range 0-4).

For each destination type, children who reported residing within walking distance were asked how often they usually walked to this venue: (a) alone; (b) with a parent/other adult (could include other children); and (c) with friends/siblings (no adults). Response options were: 'never'; 'rarely'; 'sometimes', 'often', and 'very often'. One point was scored for each destination type to which the child walked 'often' or 'very often', regardless of accompaniment. Scores for each destination type were summed to give a score for walking to local destinations. As the number of walkable destinations in each neighborhood varied, this score was weighted by dividing by the number of walkable destination types, and multiplying by 10 so that values ranged from 0 to 10. This score had high test-retest reliability (ICC=0.83). A similarly weighted score was computed for independent mobility when walking to local destinations, where the child scored one point for each destination type to which he/she walked 'often' or 'very often' without adult accompaniment. Similar survey items were administered for cycling to local destinations and scored as per items related to walking. Scores for walking and cycling to local destinations were summed to produce an overall score (with possible ranges 0-20) representing active transport to local destinations; scores for independently walking or cycling to local destinations were also summed to compute a score for independent mobility to local destinations.

Mothers' survey

Demographic information

Mothers reported their own age, education level (<Year 12; Year 12/trade/certificate; tertiary level), employment status (employed: including full-time work and part-time work; unemployed: including those unemployed/laid off, keeping house/raising children, full time study and retired), and their child's age and sex.

<u>Individual factors</u>

Mothers reported their child's enjoyment of walking and cycling to school, cycling for fun, walking for exercise, and playing outdoors (5 items). Response options (and scoring) were: dislikes a lot (1); dislikes (2); neither (3); enjoys (4); enjoys a lot (5). These items were summed to create an enjoyment of walking and cycling score.

<u>Social factors</u>

Mothers reported their confidence in their child's ability to a) walk and b) cycle to school and the closest shop without adult accompaniment (4 items): I am confident that my child has the ability to walk to school with other children, without an adult present; I am confident that my child has the ability to ride a bike to school with other children, without an adult present; I am confident that my child has the ability to walk to the closest shop with other children, without an adult present; I am confident that my child has the ability to ride a bike to the closest shop with other children, without an adult present. Response options were: disagree (1); neither (2); agree (3), and the four items were summed to create a confidence in their child's ability to walk/cycle score. To examine descriptive norms, parents were asked their level of agreement with one item, 'lots of kids we know walk or cycle to school'. A dichotomous variable was created (strongly agree/agree vs neither/disagree/strongly disagree).

<u>Perceived neighborhood attributes</u>

Mothers reported perceptions of their child's personal safety in their neighborhood (3 items): concerns about stranger danger prevent my child from going outside in my local area (reverse coded); my neighborhood is safe for children; and my neighborhood is safe for my child to walk/cycle around in the daytime. Response options were: strongly disagree (1); disagree (2); neither (3); agree (4); strongly agree (5), and the three items were summed to create a personal safety score. Four items assessed road safety barriers to create a road safety score: there are major barriers to walking/cycling that make it hard for my child to get from place to place; there are no lights/crossings/pedestrian overpasses for my child to use; my child would have to cross several roads to get to areas where he/she can play; and my child would have to cross a busy road to get to areas where he/she can play. Response options were as above. Each item was reverse-coded and summed to compute a road safety score. Four items assessed satisfaction with their local neighborhood: the neighborhood I live in has lots of good places for my child to play and be active; I am satisfied with the number of pedestrian crossings; I am satisfied with how easy it is for child to walk in my neighborhood; and I am satisfied with how easy it is for child to cycle in my neighborhood. Response options were the same as above and were summed to compute a neighborhood satisfaction score.

Objective measures of neighborhood attributes

Using a Geographic Information System (GIS), ArcMap 10 (ESRI, California, 2010) with Vicmap Address, Property and Transport 2010 databases (State Government of Victoria, 2010), children's homes were mapped and availability of parks, walking tracks, and bike tracks within an 800m pedestrian network buffer (included bike paths and shared walking/cycling paths) around each child's home computed. Network buffers of 800m typically represent areas within a 10-15 minute walk (Mavoa et al., 2012). Distance between home and school along the most direct route via the pedestrian network was measured. The total area of parkland (hectares) accessible from within the 800m buffer (by at least partially overlapping) was derived using the StreetPro Australia database (Pitney Bowes Software, Australia, 2011).

Data analyses

Analyses were conducted using Stata SE v12. Twenty-three families moved house between T1 and T2 and were therefore excluded from all analyses and six children (including one who had also moved house) had left school at T2 and were excluded from the active transport to/from school analyses. The analytic sample therefore comprised 184 participants (completed surveys at T2 =207; 207-23=184) for analyses related to local destinations and 179 participants for analyses related to travel to school. No significant differences were found between baseline participants in the READI study and the analytic sample for: urban/rural location; maternal employment; and child's sex. The mothers within the participant sample were; however, more likely to be tertiary educated and the children were younger.

Descriptive analyses examined habitual travel modes to/from school, and independent mobility on journeys to school and local destinations at T1 and T2. Differences between T1 and T2 in (1) the proportion of children using active transport and (2) the proportion of children being independently mobile on the school journey were tested using mixed-effects logistic regression models, which included random intercepts for children and fixed effects of time. Similarly, differences between T1 and T2 in scores for (1) active transport to local destinations and (2) independent mobility on these journeys were tested using mixed-effects linear regression models, which included random intercepts for children and fixed effects of time.

Longitudinal associations between individual, social and physical environmental predictors of interest and each of the four outcomes (using active transport on the school journey, independent mobility on the school journey, walking/cycling to local destinations, walking/cycling independently to local destinations) were conducted first via a series of single-predictor models, and then repeated where necessary as multiple-predictor models which included all predictors significantly associated with that outcome in the single-predictor model. Logistic regression models examined associations between predictor variables and odds of using active transport on the school journey at T2, controlling for doing so at T1. These analyses were repeated with independent mobility on the school journey. Linear regression models examined how these predictors of interest were associated with walking/cycling to local destinations at T2, controlling for doing so at T1, and with walking/cycling independently to local destinations. All regression analyses were adjusted for potential confounders decided a priori including age and sex of the child, as well as for location (urban/rural), maternal education and employment, and clustering based on suburb of residence (the unit of recruitment). Analyses of the school journey additionally adjusted for distance between home and school, and whether the child had changed school between T1 and T2 (78 participants (42.3%) had changed school, mostly due to the transition from primary to secondary school). Statistical significance was set at $p<0.05$. All analyses were conducted in Stata/SE 13 (StataCorp, TX).

Results

Among the 184 children with data at both time-points, mean age at T1 was 12.0 years (SD 2.1), 45% were boys, 31% resided in rural areas and overall they traveled a median distance of 2.2 km to school (range 0.01 - 72.1 km). The mean age of mothers at T1 was 41.3 years (SD 8.4), 35% were tertiary-educated and 25% were employed full-time. Values for individual, social and neighborhood environmental variables are presented in Table 1.

Active transport and independent mobility on the school journey

Details of modal rates of active transport and independent mobility on the school journey by direction (i.e. to and from school) are described in Table 2.

Overall, 43.5% of children habitually used active transport (in at least one direction, i.e. to or from school) on the school journey at T1 and at T2. There were no significant changes over time in the proportion of children using active transport on the school journey (OR=0.93, 95% CI=0.56, 1.52, p=0.77). The proportion of children engaged in independent active travel on the school journey decreased over the two years from 35% at T1 to 30% at T2; however, there were no significant changes over time in the inferential analyses (OR=0.57, 95% CI=0.30, 1.05, p=0.07).

Overall, 27% of children who used active transport (in at least one direction) on the school journey at T1 also did so at T2 and the proportion who used active transport independently at both T1 and T2 was 21%. Overall, 18% used active transport at T1 but not at T2, 17% took up active transport at T2 and around half of the children used the same mode of transport at each time-point (to school 55%; from school 51%).

Active transport and independent mobility to local (non-school) destinations

At each time-point, over 90% of children reported having at least one type of destination within walking or cycling distance of home. Rates of walking and cycling to local destinations are shown in Table 3.

Scores for active transport to local destinations were higher at T1 (mean=8.8, SD=6.8) than T2 (mean=6.3, SD=6.5), and this difference was statistically significant in inferential analyses (B=-2.46, 95% CI=-3.44, -1.49, p<.0005). Scores for independent mobility to local destinations were also higher at T1 (mean=6.8, SD=6.5) than T2 (mean=5.8, SD=6.1), but this difference was not statistically significant in inferential analyses (B=-0.88, 95% CI=-1.89, 0.13, p=.09).

Predictors of active transport and independent mobility on the school journey

None of the predictors examined were associated with habitual active transport on the school journey two years later (Table 4). Odds of independent mobility on the school journey at two years were higher among children who enjoyed walking/cycling activities (OR 1.24, 95% CI=1.07, 1.45, $p<0.01$), whose mothers had greater confidence in their child's abilities (OR 1.26, 95% CI=1.02, 1.55, $p<0.05$), greater agreement that their neighborhood was safe for their child (OR 1.37, 95% CI=1.11, 1.69, $p<0.01$), and greater satisfaction with the local neighborhood (OR 1.26, 95% CI=1.06, 1.49, $p<0.01$), and who lived within 800m of a walking track (OR 3.52, 95% CI=1.25, 9.95, $p<0.05$). Of these five predictors, all apart from maternal confidence and neighborhood satisfaction remained significantly associated with independent mobility on the school journey in the multivariable model.

Predictors of active transport and independent mobility to local (non-school) destinations

Mothers' confidence in their child's abilities (B=0.43, 95% CI=0.35, 0.57, $p<0.05$), and agreement that lots of children they and their child know walk/cycle to school (B=2.11, 95% CI=0.46, 3.76, $p<0.05$), at baseline were positively associated with children walking/cycling to local destinations two years later, while concern over road safety was inversely associated (B=-0.39, 95% CI= -0.65, -0.14, $p<0.01$) (Table 5). Only road safety concerns remained associated with children walking/cycling to local destinations in the multivariable model (B= -0.32, 95% CI= -0.59, -0.04, $p<0.05$).

Mothers' agreement that lots of children they and their child know walk/cycle to school (B=2.25, 95% CI=0.60, 3.90, $p<0.01$), and satisfaction with the neighborhood (B=0.45, 95% CI=0.04, 0.86, $p<0.05$), at baseline were positively associated with children walking/cycling independently to local destinations two years later, while concerns over road safety was inversely associated (B= -0.34, 95% CI= -0.59, -0.09, $p<0.01$) (Table 5). Only agreement that lots of children they and their child know walk/cycle to school remained a significant predictor in the multivariable model (B=1.65, 95% CI=0.04, 3.26, $p<0.05$).

Discussion

This study is among the first to prospectively examine selected predictors of active transport and independent mobility to school and other local destinations among school-aged children residing in socioeconomically disadvantaged areas. It is of particular importance because children in this demographic tend to have low levels of physical activity and are at risk of poor health outcomes (Humbert et al., 2006).

Overall, 43.5% of children habitually used active transport on the school journey with no significant changes observed over time. There was a small non-significant decline in the proportion of children using independent active travel on the school journey and to local destinations over the two years. Individual, social and environmental variables did not differentiate habitual active transport to/from school, but were associated with independent mobility on these trips. The findings from the current study suggest that children's enjoyment of walking/cycling activities has important associations with independent mobility on the school journey. Interventions that promote walking and cycling as enjoyable activities may be key to encouraging walking and cycling as alternative modal choices particularly on short trips, for which parental chauffeuring is pervasive (Carver et al., 2013). As well as contributing to physical activity levels, walking or cycling with friends provides an opportunity for socializing informally. Future studies need to explore predictors of children's enjoyment of walking and cycling; for example, opportunities to socialize when walking or cycling with friends, ease of walking or cycling in their neighborhood, or neighborhood aesthetics. Social norms within the local neighborhood may be predictive of active transport and independent mobility (Carver et al., 2008). This was supported in the current study, as knowing many other children who walked/cycled to school was positively associated with walking/cycling independently to local destinations.

While the built environment has been proposed to be of key importance in promoting active transport among children and adolescents (Giles-Corti et al., 2009), the current study provides little empirical evidence of this. The objectively-measured presence of a walking track within 800m of the child's home was the only built environment variable associated with independent mobility on the school journey. Although the location of destinations within walking/cycling distance of home has been shown to encourage active transport among adults (Owen et al., 2004), the findings of the current study concur with those of other longitudinal studies conducted among children. For example, among school children in England few objectively-measured physical environmental variables other than distance to school were associated longitudinally with uptake or maintenance of active transport to school (Panter et al., 2013). Similarly, a more recent longitudinal study of children's independent mobility on the school journey in England reported that few objective measures (e.g., only land use mix [positive association] and the proportion of main roads in the neighborhood [negative association]) were associated with this behavior (Carver et al., 2014). However, more recent studies have found well-connected streets and cycling lanes to be positively associated with active travel among children (6-11 years) (Helbich et al., 2016) and street connectivity and distance to school to be consistently related to active travel trips among children (8-13 years) (Oliver et al., 2015). In the current study, particular environmental features that may be important for active transport such as presence of footpaths, street connectivity and road crossings were not objectively measured. An important consideration of future studies is to ensure a conceptual match between environmental attributes and the domain of physical activity being studied (Ding and Gebel, 2012).

Nevertheless, perceptions of the local neighborhood may be key predictors of children's active transport and independent mobility. For example, in the current study children whose mothers had greater concerns about their personal safety while out and about had reduced odds of independent mobility on the school journey. This concurs with findings from the aforementioned longitudinal study in England which reported that parental perception of the neighborhood being a safe place for walking or playing during the day was the strongest predictor of independent mobility on the school journey (Carver et al., 2014). Further, in the current study parent road safety concerns were inversely associated with walking/cycling to local destinations, as identified by a previous review (Carver et al., 2008).

Strengths and limitations

This prospective study included children aged from 8 to 15 years at baseline which spanned adolescence, a life-stage associated with increased autonomy (Valentine, 1997) but also with declines in physical activity (van Mechelen et al., 2000). The prospective study design enabled the examination of within person changes in behavior over time which allowed stronger conclusions than those possible from cross-sectional studies and provides insight into temporality. However, objective measures of the built environment were only taken at one time point therefore it is not possible to rule out self-selection whereby families with more or less inclination towards active travel for their children might be drawn to live in particular locations.

Conducting a guided questionnaire with these children improved children's understanding of survey questions and minimized the occurrence of missing survey items. A further strength was the inclusion of children from both urban and rural areas. Sampling from low socioeconomic areas presents both a strength, as health behaviors in socioeconomically disadvantaged populations are under-researched, and a limitation, as it potentially reduces the heterogeneity in the environments measured and the generalizability of findings. The small sample size may have resulted in insufficient power to detect small associations. It also precluded the data analysis from being stratified by age, sex or urban/rural location although they were adjusted for as confounders, and the broad age range of children may also have influenced the results. Our definition of active transport excluded public transport and it is possible that we excluded children who were being independently mobile apart from just walking and cycling. Future studies may consider the inclusion of public transport. In addition, the independent mobility score may reflect multiple influences and participants had to perceive the destination to be in walking distance for a journey to be considered independent mobility and this may have excluded some destinations. Further, objective measures of the built environment and other predictors of interest were only measured at T1 and it is possible that changes in these predictors occurred between the two time points. This could be a limitation of the study. It is also important to acknowledge that while we relied on the best available spatial data, we did not conduct validity testing or ground-truthing of the objective measures of neighbourhood attributes. It is possible, for example, that the area of parkland may be over or under-estimated. However, previous research in the UK has shown little variation in the quantity of green space detected and in associations between green space and health according to the indicator of green space coverage used (Mitchell et al., 2011).

Finally, the subjective predictors were only reported by the child's mother and children's own responses may also be important predictors of active transport and should be considered in future studies. In the future, experimental studies could also extend this work by testing or incorporating the predictors we identified as being associated prospectively.

Conclusion

This research provides novel information on patterns of children's active transport and independent mobility, and how individual, social and physical environmental factors are associated with these behaviors over time. This study makes an important contribution on this topic, for which there are a paucity of longitudinal studies. However, further longitudinal, observational and intervention studies are required with diverse populations of children and adolescents to build more conclusive evidence. Such research will inform the work of health promotion practitioners, urban planners, and local councils in the planning of potential programs that aim to promote active transport and independent mobility among youth.

Acknowledgements

This research was supported by a Linkage Grant from the Australian Research Council (LP0990183), in partnership with the Victorian Health Promotion Foundation (VicHealth), Australia; and by a National Health and Medical Research Council Strategic Award, (NHMRC, ID 374241). We gratefully acknowledge Dr Clare Hume, Dr Michelle Jackson, Rebecca Roberts, Anne Griffiths, Winsfred Ngan and the team of research assistants who gathered the data, as well as all the school and families who participated in our study. JV is supported by an Early Career Research Fellowship from the NHMRC (ID 1053426). AT is supported by a National Heart Foundation Future Leader Fellowship (Award ID 100046); KB (APP1042442) and JS (APP1026216) are supported by NHMRC Principal Research Fellowships, VC is supported by a National Heart Foundation of Australia Future Leader Fellowship (ID100444) and was supported by a Public Health Training (Postdoctoral) Fellowship from the NHMRC (ID 533917). The contents of this manuscript are the responsibility of the authors and do not reflect the views of the funding bodies.

References

Ball, K., Cleland, V., Salmon, J., Timperio, A.F., McNaughton, S., Thornton, L., Campbell, K., Jackson, M., Baur, L.A., Mishra, G., Brug, J., Jeffery, R.W., King, A., Kawachi, I., Crawford, D.A., 2013. Cohort profile: the Resilience for Eating and Activity Despite Inequality (READI) study. International Journal of Epidemiology 42, 1629-1639.

Carver, A., Panter, J.R., Jones, A.P., van Sluijs, E.M., 2014. Independent mobility on the journey to school: A joint cross-sectional and prospective exploration of social and physical environmental influences. J Transp Health 1, 25-32.

Carver, A., Timperio, A., Crawford, D., 2008. Playing it safe: The influence of neighbourhood safety on children's physical activity - A review. Health and Place 14, 217-227.

Carver, A., Timperio, A., Crawford, D., 2013. Parental chauffeurs: what drives their transport choice? Journal of Transport Geography 26, 72-77.

Carver, A., Timperio, A.F., Crawford, D.A., 2012. Young and free? A study of independent mobility among urban and rural dwelling Australian children. Journal Of Science And Medicine In Sport / Sports Medicine Australia 15, 505-510.

Christian, H.E., Klinker, C.D., Villanueva, K., Knuiman, M.W., Foster, S.A., Zubrick, S., Divitini, M., Wood, L., Giles-Corti, B., 2015. The Effect of the Social and Physical Environment on Children's Independent Mobility to Neighborhood Destinations. J Phys Act Health.

Cleland, V., Hume, C., Crawford, D., Timperio, A., Hesketh, K., Baur, L., Welch, N., Salmon, J., Ball, K., 2010. Urban-rural comparison of weight status among women and children living in socioeconomically disadvantaged neighbourhoods. Medical Journal of Australia 192, 137-140.

Costa, F.F., Silva, K.S., Schmoelz, C.P., Campos, V.C., de Assis, M.A., 2012. Longitudinal and cross-sectional changes in active commuting to school among Brazilian schoolchildren. Preventive Medicine 55, 212-214.

Ding, D., Gebel, K., 2012. Built environment, physical activity, and obesity: what have we learned from reviewing the literature? Health & Place 18, 100-105.

Fyhri, A., Hjorthol, R., Mackett, R.L., Fotel, T.N., Kytta, M., 2011. Children's active travel and independent mobility in four countries: Development, social contributing trends and measures. Transport Policy 18, 703-710.

Giles-Corti, B., Kelty, S.F., Zubrick, S.R., Villanueva, K.P., 2009. Encouraging walking for transport and physical activity in children and adolescents: how important is the built environment? Sports Medicine 39, 995-1009.

Helbich, M., Emmichoven, M.J., Dijst, M.J., Kwan, M.P., Pierik, F.H., Vries, S.I., 2016. Natural and built environmental exposures on children's active school travel: A Dutch global positioning system-based cross-sectional study. Health & Place 39, 101-109.

Hillman, M., Adams, J., Whitelegg, J., 1990. One False Move: A study of children's independent mobility. PSI Publishing, London.

Humbert, M.L., Chad, K.E., Spink, K.S., Muhajarine, N., Anderson, K.D., Bruner, M.W., Girolami, T.M., Odnokon, P., Gryba, C.R., 2006. Factors that influence physical activity participation among high- and low-SES youth. Qualitative Health Research 16, 467-483.

Hume, C., Timperio, A., Salmon, J., Carver, A., Giles-Corti, B., Crawford, D., 2009. Walking and cycling to school: Predictors of increases among childlren and adolescents. American Journal of Preventive Medicine 36, 195-200.

Janssen, I., Leblanc, A.G., 2010. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act 7, 40.

Kytta, M., 2004. The extent of children's independent mobility and the number of actualised affordances as criteria for child-friendly environments. Journal of Environmental Psychology 24, 179-198.

Mackett, R.L., 2013. Children's travel behaviour and its health implications. Transport Policy 26, 66-72.

Mavoa, S., Witten, K., McCreanor, T., O'Sullivan, D., 2012. GIS based destination accessibility via public transit and walking in Auckland, New Zealand. Journal of Transport Geography 20, 15-22.

McDonald, N.C., 2007. Active transportation to school - Trends among US schoolchildren, 1969-2001. American Journal of Preventive Medicine 32, 509-516.

Mitchell, R., Astell-Burt, T., Richardson, E.A., 2011. A comparison of green space indicators for epidemiological research. Journal of Epidemiology and Community Health 65, 853-858.

Oliver, M., Mavoa, S., Badland, H., Parker, K., Donovan, P., Kearns, R.A., Lin, E.Y., Witten, K., 2015. Associations between the neighbourhood built environment and out of school physical activity and active travel: An examination from the Kids in the City study. Health & Place 36, 57-64.

Owen, N., Humpel, N., Leslie, E., Bauman, A., Sallis, J.F., 2004. Understanding environmental influences on walking: review and research agenda. American Journal of Preventive Medicine 27, 67-76.

Pabayo, R., Gauvin, L., Barnett, T.A., 2011. Longitudinal changes in active transportation to school in Canadian youth aged 6 through 16 years. Pediatrics 128, e404-413.

Panter, J., Corder, K., Griffin, S.J., Jones, A.P., van Sluijs, E.M., 2013. Individual, socio-cultural and environmental predictors of uptake and maintenance of active commuting in children: longitudinal results from the SPEEDY study. Int J Behav Nutr Phys Act 10, 83.

Panter, J.R., Jones, A.P., van Sluijs, E.M., Griffin, S.J., 2010. Attitudes, social support and environmental perceptions as predictors of active commuting behaviour in school children. Journal of Epidemiology and Community Health 64, 41-48.

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

Roth, M.A., Millett, C.J., Mindell, J.S., 2012. The contribution of active travel (walking and cycling) in children to overall physical activity levels: a national cross sectional study. Preventive Medicine 54, 134-139.

Sallis, J.F., Owen, N., 1997. Ecological Models, in: Glanz K (Ed.), Health Behavior and Health Education: theory, research and practice (second edition). Jossey-Bass, San Francisco, pp. 403-424.

Santos, M.P., Pizarro, A.N., Mota, J., Marques, E.A., 2013. Parental physical activity, safety perceptions and children's independent mobility. BMC Public Health 13, 584.

Schoeppe, S., Duncan, M.J., Badland, H., Oliver, M., Curtis, C., 2013. Associations of children's independent mobility and active travel with physical activity, sedentary behaviour and weight status: A systematic review. Journal of Science and Medicine in Sport 16, 312-319.

Trang, N.H., Hong, T.K., Dibley, M.J., 2012. Active commuting to school among adolescents in Ho Chi Minh City, Vietnam: change and predictors in a longitudinal study, 2004 to 2009. American Journal of Preventive Medicine 42, 120-128.

Valentine, G., 1997. 'My son's a bit dizzy. My wife's a bit soft: gender, children, and cultures of parenting. Gend Place Cult 4, 37-62.

van Mechelen, W., Twisk, J., Post, G., Snel, J., Kemper, H., 2000. Physical activity of young people: the Amsterdam Longitudinal Growth and Health Study. Medicine and Science in Sports and Exercise 32, 1610-1616.

van Sluijs, E.M., Fearne, V.A., Mattocks, C., Riddoch, C., Griffin, S.J., Ness, A., 2009. The contribution of active travel to children's physical activity levels: cross-sectional results from the ALSPAC study. Preventive Medicine 48, 519-524.

Villanueva, K., Giles-Corti, B., Bulsarac, M., Trapp, G., Timperio, A., McCormack, G., Van Nielf, K., 2013. Does the walkability of neighbourhoods affect children’s independent mobility, independent of parental, socio-cultural and individual factors? . Children's Geographies 11, 1–19.