*Substituting passive for active travel—what is the potential among adolescents?*

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# Substituting Passive for Active Travel—What is the Potential among Adolescents?


## Abstract

The majority of Australian adolescents are insufficiently active and becoming car dependent. Replacing short passive travel (i.e. car, public transport) with active travel could be an important potential strategy to increase physical activity. This paper aims to characterise adolescents' travel patterns to various destinations, identify passive trips that could be feasibly replaced by active travel, and the characteristics associated with those trips. Analyses were based on 2,192 Victorian secondary school students aged 12-17 years with 24-h travel diary data in the Victorian Integrated Survey of Travel Activity 2012 – 2016. Feasible distance thresholds for walking and cycling were determined at the 80$^{th}$ percentile of distances of reported walking and cycling trips in the sample. Comparison tests were conducted to assess whether travel patterns differed by sociodemographic characteristics. Multilevel logistic regression analyses identified characteristics of individuals that could replace passive trips with active travel, and characteristics of passive trips that could be replaced by active travel. About 11% of adolescents could feasibly replace at least one of their short passive trips with walking and 48% could feasibly replace at least one of their short passive trips with cycling. Of all the passive trips recorded, about 7% could be replaced with walking and 40% could be replaced with cycling. Trips that commenced within daylight hours, and trips made for shopping and social reasons had higher odds of being replaceable by active travel. The sizable proportion of replaceable passive trips within the cyclable threshold calls for greater emphasis on encouraging cycling.



**Keywords:** active travel; motorised transport; modal shift; travel patterns; youth

## 1.0 Introduction

Physical activity promotes healthy growth and development in young people (Hallal, Victora, Azevedo, & Wells, 2006). Evidence suggests that physical activity established during adolescence is likely to endure into adulthood (Herman, Craig, Gauvin, & Katzmarzyk, 2009). In Australia, however, only 8% of adolescents aged 12 – 17 years meet current recommendations to participate in at least 60 minutes of moderate-to-vigorous intensity physical activity (MVPA) every day (Australian Institute of Health and Welfare, 2018). Therefore, this period of formative development is a critical window during which to intervene (Herman et al., 2009; Hills, King, & Armstrong, 2007).

Active travel is the use of non-motorised transport such as walking and cycling to get to and from places, including as part of a public transport journey, and is an important source of physical activity (Biggar, 2019). Research indicates that active travel accounts for a substantial proportion of adolescents' daily MVPA (Rainham et al., 2012; Stewart, Duncan, & Schipperijn, 2017). For example, Stewart et al. (2017) found that adolescents who engaged in active travel for at least one of their daily school journeys were more likely to participate in sufficient levels of physical activity. Among Canadian adolescents, more than half of their daily MVPA was accrued whilst commuting to school and other destinations (Rainham et al., 2012). As such, strategies that encourage participation in active travel may offer an equitable approach to offset the current low levels of physical activity among this age group.

The prevalence of active travel has been found to vary between and within countries. For example, in Denmark, 84% of 12-16 year-olds report walking or cycling as their usual mode of travel to and from school (Østergaard et al., 2012). In comparison, in Australia, on average only 43% of 12 – 17 year-olds report walking or cycling as their usual mode of travel to school (Schranz et al., 2018), and lower rates have been reported in different Australian cities. Data from a household travel survey in Melbourne show that only 17% of adolescents walked or cycled as their main mode of travel to school, 31% took public transport to school and 52% travelled to school by private vehicle (Victorian Integrated Survey of Travel & Activity, 2018). Further, it is of greater concern that in many countries such as Belgium (Marique, Dujardin, Teller, & Reiter, 2013), Brazil (Silva et al., 2014), China (Yang, Hong, Gurney, & Wang, 2017), Spain (Chillón et al., 2013) and Australia (Garrard, 2009), steep declines in the rates of active travel among young people have been reported over the last few decades, with walking and cycling trips being replaced by private motor vehicles.

Consistent with a socioecological view of health behaviour, the reasons young people engage in active travel are multifaceted, reflecting individual and parental preferences, existing social networks, the built environment around their home and school, as well as broader school and public policies (Ikeda et al., 2018; R Larouche, 2018). For example, one aspect of the built environment that may impact active travel is walkability, a composite measure of dwelling density, street connectivity, retail floor area ratio and land use mix (Frank et al., 2010). A US study found that neighbourhood walkability was associated with greater frequency of active transport among adolescents (Sallis et al., 2018). Travel distance, however, is the single strongest determinant of active travel across all age groups (Ikeda et al., 2018; Pont, Ziviani, Wadley, Bennett, & Abbott, 2009), reflecting the impracticality of travelling long distances on foot or by bike. Replacing passive trips, such as those made by car or public transport that are within a walkable and/or cyclable distance with active trips may be a promising strategy for increasing active travel, and therefore increasing habitual physical activity among adolescents. Reducing dependence on car travel and increasing active travel addresses several key national and international policy agendas (e.g., Sustainable Development Goals by the United Nations, Global Action Plan on Physical Activity by the World Health

Organization)(Foster, Shilton, Westerman, Varney, & Bull, 2018; United Nations, 2020), as well as climate change mitigation (Brand et al., 2021; World Health Organization, 2012). Importantly, systematic reviews (Mueller et al., 2015) and modelling studies (Maizlish et al., 2013; Rojas-Rueda et al., 2016) found that the health benefits attained through walking and cycling for transport far exceed the potential risks from road traffic and exposure to air pollution. However, the potential to shift from cars to active transport to school and other destinations among adolescents in Australia have not been quantified. National household travel surveys from the US (United States Department of Transportation, 2017) found that the average number of trips made by adolescents were 3.5 trips per day. Understanding adolescents' travel patterns to various destinations, not just to school, could have significant short- and long-term health and environmental impacts. Therefore, the aims of this study are to characterise adolescents' travel patterns to various destinations, identify passive (car, public transport) trips that could be feasibly replaced by active travel, and identify the characteristics associated with those trips.

## 2.0 Method

### *2.1 Household travel survey*

The characteristics of adolescents' travel patterns were explored using the publicly available Victorian Integrated Survey of Travel and Activity (VISTA) from 2012 to 2016. VISTA is a cross-sectional household survey of residents living in Greater Melbourne and Geelong, the largest and second-largest cities, respectively, in the state of Victoria, Australia (Transport for Victoria, 2018). Questionnaires were delivered to households within a random selection of Mesh Blocks, the smallest geographical area (with around 30-60 dwellings) defined by the Australian Bureau of Statistics, used for census data collection (Australian Bureau of Statistics, 2011). VISTA runs continuously throughout the year to allow daily travel behaviour to be described. A travel diary was provided for each household member aged 5 years and above (completed via self- or proxy-report) to collect information about all travel on a single nominated day on one occasion during the period of 2012-2016. The travel diary collected information such as trip origin and destination, trip purpose, trip length and duration, and travel mode (e.g., walking, cycling, and public transport), as well as household and socio-demographic information (i.e. age, gender, and household income). A total of 18,152 households and 46,562 people responded to the VISTA 2012-2016 surveys. For the purpose of this study, anyone attending secondary school was considered an adolescent and their data were extracted (n=3,060). Respondents who were aged 18 years and above (n=213), and those who did not undertake any travel activities on the nominated survey day (n=655) were excluded. The final sample comprised 2,192 adolescents from 1,690 households. Overall, 34% of participants self-reported their travel behaviour and 66% were proxy-reported by their caregivers.

As the data are publicly available in non-identifiable format, an ethics exemption was granted by the Deakin University Human Research Ethics Committee for use of these data (DUHREC 2019-328).

### *2.2 Travel behaviour*

Travel behaviours were analysed at the person- and trip-level. A trip is defined as a single-way movement from origin to destination and can involve multiple trip legs. A trip leg is defined as a component of a trip travelled for a single purpose and mode of travel without stops. For instance, if a person walked to the train station from their home, caught the train to another train station, and then walked from the train station to school, they have completed one trip (home-school) with three trip legs (leg 1: home – train station; leg 2: train station – train station (near school); leg 3: train station – school).

Trip purpose (education, social, recreation, shopping, and other); travel mode (walk, cycle, public transport [public bus, train, tram, school bus], car [vehicle passenger/vehicle driver/taxi]); distance (km; calculated using the shortest network distance between origin and destination provided in the travel diary), and start and end times for each trip and trip leg were collected as part of VISTA. For these analyses, travel mode was further classified as single or multimodal (more than one travel mode for a single trip). We classified single mode trips and trip legs in multimodal trips that were made by car or public transport as 'passive'. Although public transport is often viewed as an active mode, we treated any public transport trip or trip leg as a passive trip because any walking or cycling done to and from the public transport stop formed a separate active trip leg. Single mode trips and trip legs in multimodal trips that involved walking or cycling were classified as 'active'. Trips that commenced during daylight hours were considered to be 'daylight' trips. Daylight hours were determined using sunset and sunrise times obtained from the National Oceanic Atmospheric Administration's (NOAA) Solar Calculator algorithm (Cornwall, Horiuchi, & Lehman, 2017), based on the start time for each trip leg, the centroid of each participant's postcode, and date.

***2.3 Identifying passive trips that could be feasibly replaced by active trips***

Consistent with a previous study (Cole, Turrell, Koohsari, Owen, & Sugiyama, 2017), 'feasible' distance thresholds for active trips were determined at the 80$^{th}$ percentile of reported walking and cycling trip distances, which for this sample equated to 1.3 km and 4.2 km, respectively. We considered single mode and multimodal trips differently. Passive single mode trips that were made within these two thresholds were considered short trips that could be feasibly replaced by foot (walking threshold only) or bike. For multimodal trips, we considered the trip legs within the context of the whole trip. Where the entire trip was within these thresholds, the passive legs were considered replaceable. For longer multi-modal trips, individual passive trip legs within these thresholds were considered replaceable by active trip legs if the total of all active trip legs for the overall trip remained within the corresponding thresholds. For example, for a trip of 7km, where the first leg of 1 km to a train station was made by car, followed by 6 km train journey, this trip was considered to include a replaceable trip leg (leg 1). However, it would not be feasible to replace the second leg with active travel as the total distance of active travel would exceed the walking and cycling thresholds. If a trip consisted of 2 legs: walking for 1 km, then travelling by car for 1 km, replacement of the second leg by walking would not be considered feasible as the whole trip would exceed the feasible walking threshold. The second leg (or the entire trip) could, however, be replaced by bike as it is within 4.2 km. The proportion of participants with trips that could be replaced in their entirety, or that could be replaced in part by active travel, were calculated.

### *2.4 Household-, individual- and area-level characteristics*

Household characteristics and individual sociodemographic factors included age, gender, weekly household income, household car ownership and region (inner-Melbourne [within 10 km from Central Business District, CBD], mid-Melbourne [10-20 km from CBD], outer-Melbourne [>20 km from CBD] and Geelong [a regional town, 75 km from CBD]). Age was categorised as 12 to < 16 years and ≥ 16 to <18 years, as 16 is the minimum age for a learner's driving permit in Victoria and this may impact older adolescents' travel behaviours. Those learning to drive must accrue sufficient driving experience (recorded as hours) before obtaining a probationary driver's licence at or after 18 years of age (State Government of Victoria, 2021). Area-level disadvantage was computed from the Socio-Economic Index for

Areas Index of Relative Socioeconomic Disadvantage at the Statistical Area 1 (SA1) level (Australian Bureau of Statistics, 2018b).

### *2.5 Data analysis*

Examination of descriptive statistics involved tabulation of sample characteristics. Median distances were calculated due to the skewed data distribution. Prior to statistical modelling, separate comparison tests were conducted to compare sociodemographic differences (age group, gender, area-level socioeconomic disadvantage and region) with respect to travel patterns at the person-level (number of trips and median distance) and trip-level (number of trips, median distance, travel purpose, transport mode, daylight vs non-daylight travel). One-way ANOVA tests were used to compare differences between sociodemographic characteristics and number of trips and trip legs. Chi-square tests were used to examine differences in sociodemographic characteristics and trip purpose, travel day of week, single vs multimode and transport mode. Testing for normality revealed non-normally distributed data for travel distance so non-parametric analyses were performed. Mann-Whitney U tests were used to assess whether travel distance differed by age group and gender. Kruskal-Wallis H tests were used to assess whether travel distance differed by area-level socioeconomic disadvantage and regions.

Multilevel logistic regression models were conducted to assess (i) characteristics of participants with passive trips that could be feasibly replaced (in their entirety or in part) with active travel and (ii) characteristics of passive trips that could be feasibly replaced by active travel. Models were adjusted for clustering at the SA1 level. We did not cluster by household-level in analyses because there was an average of only 1.2 adolescents per household. All models adjusted for age group, gender, household income, household car ownership, area-level disadvantage and regions. A specific threshold for denoting statistical significance was not used within the current study (Greenland et al., 2016; Ioannidis, 2019). However, the effect sizes (95% confidence interval) and exact p-values are presented to indicate the level of evidence they provide: $p < 0.005$ strong evidence, $p < 0.05$ some evidence, $0.05 < p < 0.1$ weak evidence and $p \geq 0.1$ no evidence (Thomas, Gastin, Abbott, & Main, 2020). All data were prepared and analysed in Stata SE 15.0.

## 3.0 Results

The study sample included 2,192 adolescents from 1,690 households who recorded a total of 6,428 trips comprising 8,986 trip legs. The majority of adolescents (66%) were aged 12 to 15 years, just over half (51%) were male and 78% completed their travel diary on a weekday. The average weekly household income was AUD$2,253 (SD= AUD $1478.80) and almost all households (99%) owned at least one car (Table 1).

[TABLE 1 NEAR HERE]

### *3.1 Travel patterns according to sociodemographic characteristics*

On average, adolescents recorded a total of 2.9 (SD = 1.4, range 1-12) trips and 4.1 (SD = 2.4, range 1-17) trip legs per day. The characteristics of travel patterns by sociodemographic factors are shown in Table 2. On average, the number of trip legs was higher among older adolescents, and those living in inner-Melbourne than among their counterparts who were younger, and living in other regions. Adolescents living in outer-Melbourne travelled a greater distance per day than those living in other regions.

At the trip-level, a higher proportion of recreation trips was reported among males compared to females. The most common trip purpose was education (41% of trips). Travel purpose for each trip differed according to area-level disadvantage and region. For example, for those living in the most disadvantaged area (Tertile 3), 48% of their total trips were for education while 13% were for social reasons. In contrast, for those living in the most advantaged area (Tertile 1), 37% of their total trips were for education and 19% were for social reasons. For those living in inner-Melbourne, 17% of trips were for social, 12% of trips for recreation and 9% of trips for shopping purposes. In contrast, those living in Geelong reported 12% of trips for social reasons, 15% for recreation reasons and 16% for shopping reasons.

The majority of trips were reported to be single mode (82%) and to commence during daylight hours (87%). Of single mode trips, the most common mode was car, followed by walking, biking and public transport. The transport mode choice for each trip differed by age, gender, area-level disadvantage and region. The proportion of trips made by car were higher among younger adolescents, females, those living in the most advantaged neighbourhoods and those living in outer-Melbourne than their counterparts. Conversely, the proportion of trips made by foot was higher among males, those living in the most disadvantaged area and those living in Geelong and inner-Melbourne than their counterparts. Males also reported a higher proportion of trips by bike compared to females. The most common multimode combination was walking and public transport, and the least common multimode combination was cycling and public transport.

Overall, 29.2% of adolescents made at least one single mode trip via active transport. Overall, 18% made a single mode trip by active travel for education purposes, 2.8% for social, 2.9% for recreation, 1% for shopping, and 4.5% for other purposes.

[TABLE 2 NEAR HERE]

### *3.2 Replaceable trips/trip legs*

Table 3 presents the number and proportion of trips made within walkable and cyclable thresholds, and trips able to be replaced in their entirety or in part by walking and by cycling.

At the person-level, 26% of adolescents had at least one trip within the walkable threshold and 61% had at least one trip within the cyclable threshold. Based on the walkable and cyclable thresholds, a total of 11% of adolescents could replace all or part of their passive trips by foot (i.e. entire trip or trip legs were within the walkable threshold), and 48% could replace all or part of their passive trips by bike.

At the trip-level, 16% of trips were within the walkable threshold and 48% were within the cyclable threshold. Overall, about 8% of passive trips could be replaced by foot, and 44% trips could be replaced by bike. Specifically, of the single mode trips travelled by car (n=4,001), 8% and 44% were within walkable and cyclable thresholds, respectively. Of the single mode trips made by public transport (n=77), none were within walkable distance and about 10% were within cyclable distance. Of multimode trips (n=1,149), less than one percent were within the walkable threshold and 14% were within the cyclable threshold.

[TABLE 3 NEAR HERE]

### *3.3 Characteristics of participants with passive trips that could be feasibly replaced by active travel*

The odds of having a trip that could feasibly be replaced in full or in part with active travel is shown in Table 4. Compared to younger adolescents, older adolescents had lower odds of having passive trips that could be fully or partly replaced by foot and by bike. Adolescents living in households with at least one car had higher odds of having passive trips that could be fully or partly replaced by bike than those living in households without a car. Compared to adolescents living in inner-Melbourne, adolescents living in outer-Melbourne had lower odds of having trips that could be fully or partly replaced by bike.

[TABLE 4 NEAR HERE]

### *3.4 Characteristics of passive trips that could be feasibly replaced by active travel*

The characteristics of passive trips that could be feasibly replaced by active travel are shown in Table 5. For both walking and cycling thresholds, single mode trips had higher odds of being replaceable than multimodal trips. Trips made for social, recreation, shopping and other (e.g., accompanying someone, buying something) purposes had higher odds of being fully/partly replaceable by foot and bike than trips made for education purposes. Trips commenced in non-daylight rather than daylight hours had lower odds of being fully or partly replaceable by bike.

[TABLE 5 NEAR HERE]

## 4.0 Discussion

This study highlighted the potential to shift passive travel to walking and cycling among adolescents based on data from the largest travel survey available in Victoria, Australia. Adolescents' travel patterns were found to differ by age, gender, area-level disadvantage and region. About one-tenth of adolescents could feasibly replace at least one of their short passive trips with walking and biking and almost half could feasibly replace at least one of their short passive trips by bike, based on the travel distances of those trips. Younger adolescents, and those with at least one car in their household had higher odds of making passive trips that could be feasibly replaced by active travel. Single mode trips that commenced within daylight hours and trips made for shopping and social reasons had higher odds of being replaceable with active travel. Replacing these trips with walking and biking could contribute to greater levels of physical activity among adolescents.

Although adolescents travel for a variety of reasons, most research on active travel among adolescents has focused on the school journey (Richard Larouche, Saunders, Faulkner, Colley, & Tremblay, 2014), which was the most common purpose of single mode active travel trips in this study. Increasingly, however, research suggests that non-school journeys may provide an important source of physical activity for adolescents. For example, a study from New Zealand using Global Positioning Systems (GPS) found that adolescents travelled actively to other destinations even when they did not travel actively to school (Stewart et al., 2017). Our study adds to the current literature by examining replaceable trips beyond school and found that trips that largely occur during discretionary time (e.g., for social, shopping and other reasons) were more likely to be replaceable by active travel than trips to school. This suggests that interventions to increase active travel should also focus on trips made for social and shopping purposes as they might be more amenable to change, in part because there may be less time pressure for these discretionary trips, compared with school trips.

Australia has a strong culture of car-centric travel (Australian Bureau of Statistics, 2018a). Our findings support this, as a sizable portion of trips made by adolescents were by car. This is concerning as adolescents who are regularly driven around are less likely to travel actively in adulthood (R Larouche, 2018). Travel patterns among Victorian adolescents differed by sociodemographic factors. In particular, adolescents living in outer-Melbourne travelled a greater distance and made more trips by car than those living in inner-Melbourne. Suburbs located in outer-Melbourne are typically characterised with low density and dispersed settlement patterns, contributing to increased journey distances and limited access to regular public transport (SNAMUTS, 2021). For example, public transport services in outer-Melbourne have been reported to be 75% less than inner-Melbourne and 50% less than mid-Melbourne (Currie, 2010). These factors may have contributed to the greater journey distances and therefore increased need to travel by car among adolescents living in outer-Melbourne. Consistent with another Australian study of adolescents (Leslie, Kremer, Toumbourou, & Williams, 2010), we also found that females made fewer trips by bike but more by car compared to males. This has also been observed in countries with poor cycling infrastructure (Heesch, Sahlqvist, & Garrard, 2012). There is evidence that across the life-span, females, compared with males, experience more barriers to cycling (Bell, Timperio, Veitch, & Carver, 2020), including lacking confidence in bike-related skills and risk aversion where cycle infrastructure is absent or limited (Garrard, Rose, & Lo, 2008; Mandic et al., 2018). Future studies should examine strategies to increase cycling among female adolescents.

To date, few studies have examined the extent to which shifts from passive to active trips are feasible among adolescents. Our study found that about 8% of passive trips (car or public transport) could be replaced by foot, which is consistent with previous studies among different age groups. Studies among both Australian adults (aged 18-84 years) and Canadian children and adults (aged 5-65+ years) reported that 8% of car trips were walkable based on a 1.6 km threshold (Cole et al., 2017; Morency, Demers, & Poliquin, 2014). Our study also found that about 40% of passive trips could be replaced by bike. This is similar to a study among Spanish adults (Delso, Martín, & Ortega, 2018), whereby 30 – 40% of car trips were replaceable with walking and cycling, albeit with lower distance thresholds (1.6 and 2 km). In contrast, a Belgian study among adults reported that 64% of car trips could be walked or cycled using a threshold of 8 km (Beckx, Broekx, Degraeuwe, Beusen, & Panis, 2013). Nevertheless, the relatively high proportion of replaceable passive trips within the cyclable threshold that we identified, calls for attention to improve cycling infrastructure that is safe and connected as these factors are commonly reported as major barriers to cycling (Egli, Ikeda, Stewart, & Smith, 2018). In this study, about one-fifth of trips were made by public transport, and these trips were typically coupled with walking. This highlights the important role public transport systems play in providing opportunities for incidental physical activity (Carver & Veitch, 2020; Le & Dannenberg, 2020). While the focus of this study was on replaceable short passive trips, some longer car trips could potentially be replaced by integrating active travel with public transport. Planners and policymakers should focus on improving infrastructure that is safe and connected to key destinations to encourage more cycling to public transport. Bike lockers, bike parking and allowing bikes to be taken onto public transport may also be important to facilitate multimodal journeys that include cycling.

Adolescents that could shift at least one passive trip to active travel tended to be younger, living in a household with more than one car and living in inner-Melbourne areas. Previous studies have found that parents are the gatekeepers for children's and adolescents' travel behaviours (Schoeppe, Duncan, Badland, Rebar, & Vandelanotte, 2016), and it may be that many younger adolescents, compared with older adolescents, are not afforded as much freedom to travel independently. Even though distance has been reported to be one of the main factors associated with active travel, 30% of car trips were within the cyclable threshold. Other factors such as perceived road safety, 'stranger danger', social norms, weather, convenience for parents, and built environment barriers may contribute to adolescents' decision to travel passively for short trips (Francis, Martin, Wood, & Foster, 2017; Mitra, Faulkner, Buliung, & Stone, 2014; Timperio et al., 2006).

*Strengths and limitations*

Strengths of this study include the use of a large, representative dataset of adolescents from randomly selected households across Victoria. The VISTA data provided rich and detailed travel information, such as trip length and purpose by single or multimodal trips, which enabled better understanding of adolescents' travel patterns. It is important to acknowledge that, typical of travel surveys, the VISTA survey collected travel-related data for a single day (mostly completed on a weekday), and the reported travel patterns may not be representative of adolescents' habitual behaviour. Trip activities were self- or proxy-reported and may therefore be subject to recall or social desirability biases. However, these biases are likely to have been mitigated, in part, because participants were required to record the origin, destination and purpose of trips over a single day which may promote more accurate recall, and diaries were completed within a week from the assigned travel day. Crude thresholds for determining 'feasible' walkable and cyclable distances were based on distance only and considered a journey to be walkable or cyclable based on the $80^{th}$ percentile of walking and cycling trips in the sample. These thresholds did not account for other factors such as the built environment (e.g., lack of foot and bike paths, hilliness) (Carver et al., 2019; Ikeda et al., 2018), perceived road or personal safety concerns (Francis et al., 2017), mode-specific attitudes (van de Coevering, Maat, & van Wee, 2021), trip chaining (Carver et al., 2019), weather (Gropp, Pickett, & Janssen, 2012) or other factors that may make walking and cycling less feasible as a mode of transport (e.g., carrying heavy bags) (Beckx et al., 2013). Further, as these walkable and cyclable thresholds are data-dependent, they may vary by country. For example, for adolescents living in countries with high prevalence of cycling, the cyclable thresholds are higher (8 km in Belgium and 7.5 km in the Netherlands) (De Hartog, Boogaard, Nijland, & Hoek, 2010; Panis et al., 2009), than in countries with low cycling prevalence such as Australia (4.2 km in our sample). Nonetheless, the walkable threshold in our study (1.3 km) was relatively similar to the thresholds reported in studies with adolescents in Canada (1.3 km) (Morency et al., 2014), the US (1.6 km for commute trips, 1.5 km for shopping trips and 1.4 km for school trips) and Germany (0.9 km for commute trips, 0.6 km for shopping trips, and 1.3 km for school trips) (Merlin, Teoman, Viola, Vaughn, & Buehler, 2021). There was some ambiguity in the data about recreational trips—it is possible that some recreation trips were actually trips done for the purpose of recreation (i.e. to go for a run) rather than to get to or from a recreation setting It is also important to note that trip distance was calculated based on street network distance and that the exact route taken may have varied. In addition, the two categories of walkable and cyclable thresholds were not mutually exclusive, as walkable distances could be cycled. Further, a sizeable number had no reported trips and were excluded. The findings of our study may be not be generalizable to other countries with different population distributions, geographical areas and public transport networks. Further, the COVID-19 pandemic may have impacted the frequency of and the way in which Victorians travel to and from places. Therefore, examining how travel patterns changed during- and post-COVID-19 pandemic should be a priority for future research. Future studies should also utilise objective measures (e.g., accelerometer coupled with Global Positioning Systems [GPS]) or geographic ecological momentary assessment (e.g., smartphone-based survey, wearable camera with built-in GPS receiver) as a complementary approach that allows space- and time-specific interactions to further unpack adolescents' travel behaviours (Chaix, 2020) and to identify practical strategies to support adolescents to make the shift to active travel.

## 5.0 Conclusion

Active travel is an important source of physical activity for adolescents. Our study found that adolescent's travel behaviour differs by age, gender, area-level disadvantage and geographical area. There is potential to shift passive travel to active travel, particularly for trips that are single mode, those that are made during discretionary time for social, shopping and other reasons rather than trips to school, and those that commenced during daylight hours. The relatively high proportion of replaceable passive trips within a cyclable threshold calls for attention to improve safe and connected cycling infrastructure to encourage more cycling. While shifting towards active travel is a complex and long-term process, promoting active travel among adolescents may reap benefits for health and the environment.

## Disclosure statement

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## References


Australian Bureau of Statistics. (2011). Census of Population and Housing: Mesh Block Counts. from http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/2074.0main+features12011

Australian Bureau of Statistics. (2018a). *Census of Population and Housing: Commuting to Work*. (2071.0.55.001). Canberra: Retrieved from https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/2071.0.55.001~2016~Main%20Features~Feature%20Article:%20Journey%20to%20Work%20in%20Australia~40.

Australian Bureau of Statistics. (2018b). *Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2016*. (2033.0.55.001). Canberra.

Australian Institute of Health and Welfare. (2018). Physical activity across the life stages. Canberra: AIHW.

Beckx, C., Broekx, S., Degraeuwe, B., Beusen, B., & Panis, L. I. (2013). Limits to active transport substitution of short car trips. *Transportation Research Part D: Transport and Environment, 22*, 10-13.

Bell, L., Timperio, A., Veitch, J., & Carver, A. (2020). Individual, social and neighbourhood correlates of cycling among children living in disadvantaged neighbourhoods. *Journal of Science and Medicine in Sport, 23*(2), 157-163.

Biggar, M. (2019). Non-motorized Transport: Walking and Cycling. In W. Leal Filho, A. M. Azul, L. Brandli, P. G. Özuyar & T. Wall (Eds.), *Sustainable Cities and Communities* (pp. 1-10). Cham: Springer International Publishing.

Brand, C., Götschi, T., Dons, E., Gerike, R., Anaya-Boig, E., Avila-Palencia, I., . . . Iacorossi, F. (2021). The climate change mitigation impacts of active travel: Evidence from a longitudinal panel study in seven European cities. *Global Environmental Change, 67*, 102224.

Carver, A., Barr, A., Singh, A., Badland, H., Mavoa, S., & Bentley, R. (2019). How are the built environment and household travel characteristics associated with children's active transport in Melbourne, Australia? *Journal of Transport & Health, 12*, 115-129.

Carver, A., & Veitch, J. (2020). Perceptions and patronage of public transport–are women different from men? *Journal of Transport & Health, 19*, 100955.

Chaix, B. (2020). How daily environments and situations shape behaviors and health: momentary studies of mobile sensing and smartphone survey data. *Health & Place, 61*, 102241.

Chillón, P., Martínez-Gómez, D., Ortega, F. B., Pérez-López, I. J., Díaz, L. E., Veses, A. M., . . . Delgado-Fernández, M. (2013). Six-year trend in active commuting to school in Spanish adolescents. *International Journal of Behavioral Medicine, 20*(4), 529-537.

Cole, R., Turrell, G., Koohsari, M. J., Owen, N., & Sugiyama, T. (2017). Prevalence and correlates of walkable short car trips: A cross-sectional multilevel analysis. *Journal of Transport & Health, 4*, 73-80.

Cornwall, C., Horiuchi, A., & Lehman, C. (2017). NOAA Solar Calculator. *USA: Department of Commerce, 27*.

Currie, G. (2010). Quantifying spatial gaps in public transport supply based on social needs. *Journal of Transport Geography, 18*(1), 31-41.

De Hartog, J. J., Boogaard, H., Nijland, H., & Hoek, G. (2010). Do the health benefits of cycling outweigh the risks? *Environmental Health Perspectives, 118*(8), 1109-1116.

Delso, J., Martín, B., & Ortega, E. (2018). Potentially Replaceable Car Trips: Assessment of Potential Modal Change towards Active Transport Modes in Vitoria-Gasteiz. *Sustainability, 10*(10), 3510.

Egli, V., Ikeda, E., Stewart, T., & Smith, M. (2018). Interpersonal Correlates of Active Transportation *Children's Active Transportation* (pp. 115-125): Elsevier.
Foster, C., Shilton, T., Westerman, L., Varney, J., & Bull, F. (2018). World Health Organisation to develop global action plan to promote physical activity: time for action: BMJ Publishing Group Ltd and British Association of Sport and Exercise Medicine.
Francis, J., Martin, K., Wood, L., & Foster, S. (2017). 'I'll be driving you to school for the rest of your life': A qualitative study of parents' fear of stranger danger. *Journal of Environmental Psychology, 53*, 112-120.
Frank, L. D., Sallis, J. F., Saelens, B. E., Leary, L., Cain, K., Conway, T. L., & Hess, P. M. (2010). The development of a walkability index: application to the Neighborhood Quality of Life Study. *British Journal of Sports Medicine, 44*(13), 924-933.
Garrard, J. (2009). Active transport: Children and young people. *VicHealth (www. vichealth. vic. gov. au)*.
Garrard, J., Rose, G., & Lo, S. K. (2008). Promoting transportation cycling for women: the role of bicycle infrastructure. *Preventive Medicine, 46*(1), 55-59.
Greenland, S., Senn, S. J., Rothman, K. J., Carlin, J. B., Poole, C., Goodman, S. N., & Altman, D. G. (2016). Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations. *European Journal of Epidemiology, 31*(4), 337-350.
Gropp, K. M., Pickett, W., & Janssen, I. (2012). Multi-level examination of correlates of active transportation to school among youth living within 1 mile of their school. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 1-14.
Hallal, P. C., Victora, C. G., Azevedo, M. R., & Wells, J. C. (2006). Adolescent physical activity and health. *Sports Medicine, 36*(12), 1019-1030.
Heesch, K. C., Sahlqvist, S., & Garrard, J. (2012). Gender differences in recreational and transport cycling: a cross-sectional mixed-methods comparison of cycling patterns, motivators, and constraints. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 1-12.
Herman, K. M., Craig, C. L., Gauvin, L., & Katzmarzyk, P. T. (2009). Tracking of obesity and physical activity from childhood to adulthood: the Physical Activity Longitudinal Study. *International Journal of Pediatric Obesity, 4*(4), 281-288.
Hills, A. P., King, N. A., & Armstrong, T. P. (2007). The contribution of physical activity and sedentary behaviours to the growth and development of children and adolescents. *Sports Medicine, 37*(6), 533-545.
Ikeda, E., Stewart, T., Garrett, N., Egli, V., Mandic, S., Hosking, J., . . . Rodda, J. (2018). Built environment associates of active school travel in New Zealand children and youth: A systematic meta-analysis using individual participant data. *J. Transp. & Health, 9*, 117-131.
Ioannidis, J. P. (2019). What have we (not) learnt from millions of scientific papers with P values? *The American Statistician, 73*(sup1), 20-25.
Larouche, R. (2018). *Children's Active Transportation* (R. Larouche Ed.): Elsevier.
Larouche, R., Saunders, T. J., Faulkner, G. E. J., Colley, R., & Tremblay, M. (2014). Associations between active school transport and physical activity, body composition, and cardiovascular fitness: a systematic review of 68 studies. *Journal of Physical Activity and Health, 11*(1), 206-227.
Le, V. T., & Dannenberg, A. L. (2020). Moving Toward Physical Activity Targets by Walking to Transit: National Household Transportation Survey, 2001–2017. *American Journal of Preventive Medicine, 59*(3), e115-e123.
Leslie, E., Kremer, P., Toumbourou, J. W., & Williams, J. W. (2010). Gender differences in personal, social and environmental influences on active travel to and from school for Australian adolescents. *Journal of Science and Medicine in Sport, 13*(6), 597-601.

Maizlish, N., Woodcock, J., Co, S., Ostro, B., Fanai, A., & Fairley, D. (2013). Health cobenefits and transportation-related reductions in greenhouse gas emissions in the San Francisco Bay area. *American Journal of Public Health, 103*(4), 703-709.

Mandic, S., Flaherty, C., Ergler, C., Kek, C. C., Pocock, T., Lawrie, D., . . . Bengoechea, E. G. (2018). Effects of cycle skills training on cycling-related knowledge, confidence and behaviour in adolescent girls. *Journal of Transport & Health, 9*, 253-263.

Marique, A.-F., Dujardin, S., Teller, J., & Reiter, S. (2013). School commuting: the relationship between energy consumption and urban form. *Journal of Transport Geography, 26*, 1-11.

Merlin, L. A., Teoman, D., Viola, M., Vaughn, H., & Buehler, R. (2021). Redrawing the Planners' Circle: Analyzing Trip-Level Walk Distances Across Two National Surveys. *Journal of the American Planning Association*, 1-14.

Mitra, R., Faulkner, G. E., Buliung, R. N., & Stone, M. R. (2014). Do parental perceptions of the neighbourhood environment influence children's independent mobility? Evidence from Toronto, Canada. *Urban Studies, 51*(16), 3401-3419.

Morency, C., Demers, M., & Poliquin, E. (2014). Shifting short motorized trips to walking: The potential of active transportation for physical activity in Montreal. *Journal of Transport & Health, 1*(2), 100-107.

Mueller, N., Rojas-Rueda, D., Cole-Hunter, T., De Nazelle, A., Dons, E., Gerike, R., . . . Nieuwenhuijsen, M. (2015). Health impact assessment of active transportation: a systematic review. *Preventive Medicine, 76*, 103-114.

Østergaard, L., Grøntved, A., Børrestad, L. A. B., Froberg, K., Gravesen, M., & Andersen, L. B. (2012). Cycling to school is associated with lower BMI and lower odds of being overweight or obese in a large population-based study of Danish adolescents. *Journal of Physical Activity and Health, 9*(5), 617-625.

Panis, L., Meeusen, R., Thomas, I., BLEUX, N., DEGRAEUWE, B., DE VLIEGER, I., . . . VANDENBULCKE-PASSCHAERT, G. (2009). Systematic analysis of health risks and physical activity associated with cycling policies.

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*(3), 849-862.

Rainham, D. G., Bates, C. J., Blanchard, C. M., Dummer, T. J., Kirk, S. F., & Shearer, C. L. (2012). Spatial classification of youth physical activity patterns. *American Journal of Preventive Medicine, 42*(5), e87-e96.

Rojas-Rueda, D., De Nazelle, A., Andersen, Z. J., Braun-Fahrländer, C., Bruha, J., Bruhova-Foltynova, H., . . . Tainio, M. (2016). Health impacts of active transportation in Europe. *PLoS One, 11*(3), e0149990.

Sallis, J. F., Conway, T. L., Cain, K. L., Carlson, J. A., Frank, L. D., Kerr, J., . . . Saelens, B. E. (2018). Neighborhood built environment and socioeconomic status in relation to physical activity, sedentary behavior, and weight status of adolescents. *Preventive Medicine, 110*, 47-54.

Schoeppe, S., Duncan, M. J., Badland, H. M., Rebar, A. L., & Vandelanotte, C. (2016). Too far from home? Adult attitudes on children's independent mobility range. *Children's Geographies, 14*(4), 482-489.

Schranz, N., Glennon, V., Evans, J., Gomersall, S., Hardy, L., Hesketh, K. D., . . . Stylianou, M. (2018). Results from Australia's 2018 report card on physical activity for children and youth. *Journal of Physical Activity and Health, 15*(s2), S315-S317.

Silva, K. S., Lopes, A. d. S., Silva, R. C. R. d., Costa, F. F., Assis, M. A. A. d., & Nahas, M. V. (2014). Time spent by Brazilian students in different modes of transport going to school: changes over a decade (2001-2011). *Cadernos de Saúde Pública, 30*, 2471-2476.

SNAMUTS. (2021). Melbourne 2016 SNAMUTS Composite Accessibility Index. Retrieved 20 April, 2021, from http://www.snamuts.com/uploads/2/1/8/1/21813274/melbourne_2016__23r__benchmark_composite.pdf

State Government of Victoria. 120 hours driving experience (2021).

Stewart, T., Duncan, S., & Schipperijn, J. (2017). Adolescents who engage in active school transport are also more active in other contexts: A space-time investigation. *Health & Place, 43*, 25-32.

Thomas, C. E., Gastin, P. B., Abbott, G., & Main, L. C. (2020). Impact of the talent development environment on the wellbeing and burnout of Caribbean youth track and field athletes. *European Journal of Sport Science*, 1-29. doi: https://doi.org/10.1080/17461391.2020.1775894

Timperio, A., Ball, K., Salmon, J., Roberts, R., Giles-Corti, B., Simmons, D., . . . Crawford, D. (2006). Personal, family, social, and environmental correlates of active commuting to school. *American Journal of Preventive Medicine, 30*(1), 45-51.

Transport for Victoria. (2018). *Victorian Integrated Survey of Travel and Activity (VISTA)*. Melbourne, Australia.

United Nations. (2020). The Sustainable Development Agenda. Retrieved 19 February 2021, from https://www.un.org/sustainabledevelopment/development-agenda/

United States Department of Transportation. (2017). Mean number of trips by all persons by sex, age, driver status, worker status and medical condition. from https://www.bts.gov/archive/publications/highlights_of_the_2001_national_household_travel_survey/table_a09

van de Coevering, P., Maat, K., & van Wee, B. (2021). Causes and effects between attitudes, the built environment and car kilometres: A longitudinal analysis. *Journal of Transport Geography, 91*, 102982.

Victorian Integrated Survey of Travel & Activity. (2018). Total journeys to education by region and mode. from https://public.tableau.com/profile/vista#!/vizhome/VISTA-JourneytoeducationAccess/JTE-methodoftravel

World Health Organization. (2012). *Health in the green economy: health co-benefits of climate change mitigation-transport sector*: World Health Organization.

Yang, Y., Hong, X., Gurney, J. G., & Wang, Y. (2017). Active travel to and from school among school-age children during 1997–2011 and associated factors in China. *Journal of Physical Activity and Health, 14*(9), 684-691.