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# Does the presence and mix of destinations influence walking and physical activity?

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## Abstract

**Background:** Local destinations have previously been shown to be associated with higher levels of both physical activity and walking, but little is known about how specific destinations are related to activity. This study examined associations between types and mix of destinations and both walking frequency and physical activity.

**Method:** The sample consisted of 2349 residents of 50 urban areas in metropolitan Melbourne, Australia. Using geographic information systems, seven types of destinations were examined within three network buffers (400 meters (m), 800 m and 1200 m) of respondents' homes. Multilevel logistic regression was used to estimate effects of each destination type separately, as well as destination mix (variety) on: 1) likelihood of walking for at least 10 min ≥ 4/week; 2) likelihood of being sufficiently physically active. All models were adjusted for potential confounders.

**Results:** All destination types were positively associated with walking frequency, and physical activity sufficiency at 1200 m. For the 800 m buffer: all destinations except transport stops and sports facilities were significantly associated with physical activity, while all except sports facilities were associated with walking frequency; at 400 m, café/takeaway food stores and transport stops were associated with walking frequency and physical activity sufficiency, and sports facilities were also associated with walking frequency. Strongest associations for both outcomes were observed for community resources and small food stores at both 800 m and 1200 m. For all buffer distances: greater mix was associated with greater walking frequency. Inclusion of walking in physical activity models led to attenuation of associations.

**Conclusions:** The results of this analysis indicate that there is an association between destinations and both walking frequency and physical activity sufficiency, and that this relationship varies by destination type. It is also clear that greater mix of destinations positively predicts walking frequency and physical activity sufficiency.

**Keywords:** Walking, Physical activity, Geographic information systems, Multilevel analysis, Built environment, Destinations

## Background

Physical inactivity is known to be associated with a range of serious health risks and diseases [1]; indeed it has been claimed that together with smoking, physical inactivity may be the most significant, modifiable determinant of all-cause mortality and chronic morbidity [1, 2]. Walking is the most common form of physical activity in both

Australia [3–5] and elsewhere such as the United States [1, 6, 7], and is known to offer many potential health benefits [8–10].

The local neighbourhood is an important setting for physical activity, and there is mounting evidence that elements of the built environment are associated with walking and physical activity [11–15]. Destinations are an increasing focus of investigation: if destinations can encourage more active travel, such as walking in neighbourhoods, it is possible that residents may be more likely to meet their physical activity needs. Increased

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accessibility to destinations is known to have positive associations with walking behaviours [16–20]. These associations between destinations, and walking, have been reported in many countries including Australia [18, 21, 22], Belgium [23], Japan [24], the US [25–28], New Zealand [29] and the United Kingdom [30] on a number of indicators including: the presence of destinations within walking distance of home [18, 27, 31], proximity to destinations [26, 32, 33], and density of destinations [27].

Other researchers have observed that walking is more likely to be influenced by the type and mix of destinations than simply the presence of destinations [21]. Most previous studies of destination mix (often referred to as *number of types of businesses/destinations*) indicate that increased destination mix is associated with increased walking [18, 32, 34, 35], however there are some contrary results, with destination mix having no effect on walking levels among older Australians (aged 65–84 years) [19].

There are some important limitations with the current evidence-base that this study seeks to address. First, it is unclear exactly what types of destinations produce the greatest effects on physical activity and walking, as few previous studies have looked at multiple, specific destinations. Other researchers have observed that most studies have focused on 'commercial destinations' such as shops and services [36], or destinations that are intuitively associated with walking [37]. Non-commercial destinations such as community resources (*e.g.,* libraries) may also influence neighbourhood physical activity and walking in adults. Second, it is difficult to judge the distance that residents might be prepared to walk to access destinations as most previous studies have used just one, sometimes two catchments/buffer distances. A recent review highlighted the need for research into potential threshold distances at which destinations might encourage walking [38]. Thirdly, there is a need for more sophisticated methods of measuring destination mix. While some authors have examined the mix of destinations, they have typically relied on relatively simple measures of the number of unique types of destinations within a specific distance of respondents' homes [18, 37]. However, some destinations such as transport stops may be more common than others (*e.g.,* supermarkets). Mix may be better captured by a measure that accounts for the relative frequency of the different types of destinations. We are aware of only one study that has considered how access to multiple destinations of a particular type might influence walking more than access to only one [29], however this incorporated mix into a broader index of destination accessibility.

To address some of the identified gaps in previous methods this study sought to:

1. Identify which destinations (of supermarkets, small food stores, transport stops and stations, community resources, cafes and takeaway food stores, sporting facilities, and educational facilities) within residential neighbourhoods are associated with walking for 10 min or more, at least four times a weeks.

2. Assess the extent to which the hypothesized associations between destinations and walking frequency translate into associations between destinations and physical activity sufficiency (given that walking is the most common form of physical activity).

3. Understand how the mix of destinations is associated with walking frequency and physical activity, where mix takes into account the relative frequency of different destination types across the sample.

## Methods
### Datasets
#### Individual-level data
Individual-level variables from the Victorian Lifestyle and Neighbourhood Environment Study (VicLANES) dataset were used. The methods used in the VicLANES study and details of the sample have been documented previously [39–42].

In brief, VicLANES was a large, multilevel study conducted in 2003–2004 across the 21 innermost local government areas (LGAs) in Melbourne, Australia. Fifty census collection districts (known as CCDs, at the time of the study these were the smallest geographic unit of measurement used by the Australian Bureau of Statistics (ABS)) were randomly selected from the sample of LGAs stratified by a household measure of low income (<$400/week). Surveys about physical activity were sent to 4005 residents 18 years and over, who were randomly selected from the electoral roll (voting is compulsory for all Australians over 18 years, and it is estimated that 97.7 % of those eligible to vote are enrolled) [43]. A 58.7 % valid completion rate was achieved, with 2349 residents returning a completed survey.

#### Destination data
Destination information came from the VicLANES environmental audit, and publicly available spatial datasets such as Ausway™ and PSMA. The VicLANES environmental audit has been reported previously [41], and involved a team of trained auditors collecting detailed information on different food shops selling food for consumption within the home.

The destination variables included in the dataset were classified into seven categories: educational facilities, café/takeaway stores, transport stops, supermarkets, sports facilities, community resources, small food stores. Data for supermarkets, small food stores and café/takeaway stores came from VicLANES. Destinations included in the

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education, community resource and sport layers came from Ausway™, producers of Australian street directories. Transport data came from Metlink (the public transport operator for the Victorian State Government), and PSMA (Public Service Mapping Authority). A summary of these variables is contained in Additional file 1: Table S1.

The *community resources* category included the following: maternal and child health centres; community health centres; community centres; post offices; places of worship; cinemas, theatres and art galleries; public libraries. Based on advice from Ausway™ that 'core' community services such as schools, post offices, community services were complete, but non-core services such as restaurants were not, we chose '*community resource*' features that were deemed both 'core' and a potential destination for walking.

The *education* category was comprised of the following Ausway™ derived points of interest: schools (primary and secondary); childcare and kindergartens; other places of education such as universities and TAFE[1] campuses. *Public transport* contained tram and bus stops and railway stations. A *supermarket* was defined as a food store selling fresh produce with four or more checkouts. The *small food store* category included: fruit and vegetable shops; butchers and fishmongers; bakeries; small grocery stores (less than 4 checkouts); convenience store (corner store, fuel station with convenience food); specialty shops (such as delicatessens, health food stores, ethnic food stores). *Café and restaurant/takeaway* excluded restaurants that were only dine-in premises. The *sports category* contained information on all swimming pools and tennis courts in the study areas.

## Outcome measures
### Walking frequency
A closed response question asked respondents about their frequency of walking for at least 10 min in the previous month. Respondents were required to tick one of six response categories: never, about once or twice, about once a week, about 2–3 times a week, about 4–5 times a week, every day. Responses were dichotomized to 'less than four times a week' (≤4/week) and 'four times a week or more' (≥4/week). The cut-off response category (4–5 times a week) for this dichotomization closely approximates the number of sessions (at least five) recommended to meet physical activity sufficiency [1, 44].

### Physical activity sufficiency
Using items from the Active Australia Survey, respondents were asked to indicate the frequency and duration of their participation in walking, vigorous physical activity, moderate physical activity, vigorous garden or yard work. These items were then used to produce a measure of overall physical activity

sufficiency. The Active Australia Questionnaire has been used in national surveys, and demonstrates very good reliability and validity [44].

Australian and international guidelines recommend that a person participate in at least 30 min of moderate to vigorous intensity activity most days of the week, for a total of at least 150 min of activity [1, 44, 45]. According to the Active Australia Survey guidelines, physical activity sufficiency for health can be measured in two ways [44]: 1) measured as total time engaged in physical activity (at least 150 min for sufficiency); 2) measured as the total time across the total number of sessions (at least 150 min across at least five sessions). We have chosen to use the combined measure of time and number of sessions (at least 150 min of at least moderate intensity activity across at least five session week) [46, 47], because it matches guidelines for physical activity sufficiency.

In accordance with the Active Australia Survey administration and implementation guidelines, VicLANES responses were converted to total amount of time (minutes) engaged in each activity, and summed, with vigorous activity weighted by a factor of two [4, 44]. Respondents were then categorized in one of two categories: those reporting less than 150 min of at least moderate activity were classified as 'insufficiently active'; those with at least 150 min of at least moderate activity across at least five sessions were classified as 'sufficiently physically active'.

## Spatial analysis: buffer generation and network analysis
Geographic information systems (GIS) software was used to generate network buffers at 400 m, 800 m, 1200 m distances around each individual's residence. Network analysis was then conducted to identify the number of destinations within each distance of respondents' homes. Destination counts were then extracted from GIS, and formed the exposure variables, described henceforth.

## Exposure variables: destinations and destination mix
The destination counts arising from the spatial analysis were positively skewed and were therefore modelled as ordinal variables. In the first instance we sought to model the exposure variables as tertiles, as tertiles enable exploration of a dose response gradient. Due to the way that responses clustered around certain values, the use of tertiles was not always possible (*e.g.*, where responses were highly dominated by 0). In such instances variables were modelled as binary exposures (refer to Table 1 for list of exposure variable types and cut points).

## Exposure variables: derivation of mix measure
This study used a measure of destination mix that accounted for variation in the frequency of different destination types. The chief reason for measuring mix in

**Table 1** Summary of exposure variables

| Exposure variable | Buffer (m) | Mean (SD) | Range | Median (IQR) | Variable type (modelled as): | Category cut points | | |
|---|---|---|---|---|---|---|---|---|
| Education | 400 | 0.59 (0.97) | 0–7 | 0 (0, 1) | Binary | 0 | 1+ | |
| Education | 800 | 2.31 (2.31) | 0–14 | 2 (1, 3) | Tertile | 0–1 | 2–3 | 4+ |
| Education | 1200 | 5.05 (3.77) | 0–20 | 4 (2, 7) | Tertile | 0–3 | 4–6 | 7+ |
| Café/takeaway stores | 400 | 0.71 (1.59) | 0–16 | 0 (0, 1) | Binary | 0 | 1+ | |
| Café/takeaway stores | 800 | 4.69 (8.55) | 0–56 | 1 (0, 5) | Tertile | 0 | 1–3 | 4+ |
| Café/takeaway stores | 1200 | 12.14 (15.66) | 0–73 | 7 (1, 16) | Tertile | 0–3 | 4–11 | 12+ |
| Transport stops | 400 | 3.5 (3.13) | 0–18 | 3 (1, 6) | Tertile | 0 | 1–3 | 4+ |
| Transport stops | 800 | 13.42 (8.09) | 0–45 | 13 (8, 18) | Tertile | 0–10 | 11–16 | 17+ |
| Transport stops | 1200 | 29.75 (15.78) | 0–81 | 27 (19, 39) | Tertile | 0–23 | 24–35 | 36+ |
| Supermarkets | 400 | 0.05 (0.29) | 0–2 | 0 (0, 0) | Binary | 0 | 1+ | |
| Supermarkets | 800 | 0.31 (0.67) | 0–4 | 0 (0, 0) | Binary | 0 | 1+ | |
| Supermarkets | 1200 | 0.80 (1.02) | 0–4 | 0 (0, 1) | Binary | 0 | 1+ | |
| Sports facilities | 400 | 0.20 (0.52) | 0–4 | 0 (0, 0) | Binary | 0 | 1+ | |
| Sports facilities | 800 | 0.78 (1.05) | 0–5 | 0 (0, 1) | Binary | 0 | 1+ | |
| Sports facilities | 1200 | 1.72 (1.56) | 0–8 | 2 (0, 3) | Tertile | 0 | 1–2 | 3+ |
| Community resources | 400 | 0.51 (1.01) | 0–5 | 0 (0, 1) | Binary | 0 | 1+ | |
| Community resources | 800 | 2.54 (2.97) | 0–15 | 2 (0, 4) | Tertile | 0–1 | 2–3 | 4+ |
| Community resources | 1200 | 5.99 (5.56) | 0–31 | 5 (1, 9) | Tertile | 0–2 | 3–7 | 8+ |
| Small food stores | 400 | 0.71 (1.70) | 0–17 | 0 (0, 1) | Binary | 0 | 1+ | |
| Small food stores | 800 | 4.23 (6.13) | 0–55 | 2 (0, 5) | Tertile | 0 | 1–2 | 3+ |
| Small food stores | 1200 | 10.48 (11.28) | 0–58 | 7 (2, 15) | Tertile | 0–3 | 4–11 | 12+ |

this way was to equalize the effect of different destination types, particularly those more widespread than others. Some destinations (*i.e.*, transport destinations) were abundant, whereas others (*i.e.*, supermarkets) were sparse. The mix measure was constructed by:

1. Calculating the median number of destinations for each type at each buffer distance
2. For each person, assigning a value of 1 when the number of destinations were above the median and 0 if equal or below the median for each type
3. Summing each of the values derived in point (2), to create a mix variable with a range of 0–7

### Confounders

Based on the literature, several covariates were included in the models as potential confounders because they are likely to be related to walking frequency, physical activity and destination distribution. These were: age (18–24 years, 25–34 years, 35–44 years, 45–54 years, 55–64 years, 64 years and over); sex; country of birth (born in Australia, born in a country other than Australia); education (bachelor degree or higher, diploma, vocational training, and no post school qualification); household type (single adult-no children, single adult with children, two or more adults-no children, two or more adults with children); disability/injury that prevents exercise (yes, no); area disadvantage (least disadvantaged, mid disadvantaged and most disadvantaged); and dominant household occupation (professional, white-collar employee, blue-collar employee, not in labour force). The 'not in labour force' category included retirees, students, unemployed, those not looking for, or unable to work.

### Statistical analysis

All statistical analyses were conducted in Stata IC 10.0. Pregnant women (n = 22) were excluded because their walking and physical activity levels may have been altered by their pregnancy status. One CCD from just outside the central business district (CBD) of Melbourne was omitted from the final analysis (n = 14) as this CCD's catchment area encapsulated almost the entire CBD, and the number of features/destinations contained in its catchment was irregularly high. Missing data for the other variables ranged from 0.5–2.9 %, with the exception of the disability item, for which missing data amounted to 6.1 %. Eight respondents for whom there was no walking data were excluded, resulting in an analytical sample of 2305 respondents, and 49 CCDs for the walking analysis. For the physical activity analysis, data

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was missing from 373 respondents (15.9 %), resulting in an analytical sample of 1976.

Descriptive analyses included cross-tabulations between the outcomes and individual covariates and destination exposure variables. Using the xtmelogit commands in Stata, multilevel logistic regression was conducted to examine associations between the outcomes and exposure variables. All models adjusted for the above mentioned confounders and area level clustering. Odds ratios and 95 % confidence intervals are reported for the effect estimates. The referent category for the walking outcome was the lowest walking category (walking < 4/month); for the physical activity variable the referent was 'insufficient physical activity', while the referent categories for the exposure variables were the lowest category ('Tertile 1' for tertiles/'0' for binary categories). Destination mix was modelled as a continuous variable.

## Results

### Summary of destination variables

Cafes/takeaway stores, transport stops and small food stores were the most common destinations, while supermarkets and sports facilities were least common (see Table 1).

### Individual covariates and destinations

Refer to Additional file 2: Table S2 for a summary of covariates by destination types. Broadly, neighbourhoods with most destinations were characterized by: high area disadvantage; adults living alone, those aged 65 years or more; highly educated professionals.

### Individual covariates and destination mix

Table 2 presents a summary of covariates by destination mix. The associations were similar to those found for

**Table 2** Covariates by destination mix exposure variable

| Covariates | | Total N (%) | Mix 400 m mean (SD) | Mix 800 m mean (SD) | Mix 1200 m mean (SD) |
|---|---|---|---|---|---|
| Sex | Male | 1015 (44.0) | 1.9 (1.8) | 2.8 (2.3) | 3.1 (2.4) |
| | Female | 1290 (56.0) | 1.9 (1.8) | 2.7 (2.2) | 3.1 (2.4) |
| Age-group | 18–24 years | 182 (7.9) | 1.6 (1.6) | 2.3 (2.1) | 2.6 (2.3) |
| | 25–34 years | 395 (17.1) | 2.0 (1.7) | 2.9 (2.2) | 3.4 (2.3) |
| | 35–44 years | 492 (21.3) | 2.0 (1.7) | 3.0 (2.2) | 3.3 (2.3) |
| | 45–54 years | 495 (21.5) | 1.8 (1.7) | 2.5 (2.2) | 2.9 (2.4) |
| | 55–64 years | 391 (17.0) | 1.8 (1.7) | 2.5 (2.3) | 2.8 (2.5) |
| | 65+ years | 350 (15.2) | 2.2 (2.0) | 3.2 (2.3) | 3.5 (2.4) |
| Country of birth | Elsewhere | 663 (28.9) | 1.9 (1.7) | 2.6 (2.2) | 3.0 (2.4) |
| | Australia | 1631 (71.1) | 1.9 (1.8) | 2.8 (2.3) | 3.2 (2.4) |
| Education | Bachelor degree + | 719 (32.1) | 1.9 (1.8) | 3.1 (2.3) | 3.6 (2.4) |
| | Diploma | 257 (11.5) | 1.8 (1.8) | 2.8 (2.3) | 3.2 (2.4) |
| | Vocational | 431 (19.3) | 1.9 (1.8) | 2.5 (2.2) | 2.8 (2.3) |
| | No post school qualifications | 831 (37.1) | 1.9 (1.7) | 2.5 (2.2) | 2.9 (2.3) |
| Dominant household occupation | Professionals | 1060 (47.1) | 1.9 (1.7) | 2.9 (2.3) | 3.3 (2.4) |
| | White-collar | 352 (15.6) | 1.9 (1.7) | 2.5 (2.2) | 2.9 (2.4) |
| | Blue-collar | 243 (10.8) | 1.7 (1.5) | 2.3 (2.1) | 2.5 (2.2) |
| | Not in labour force | 597 (26.5) | 2.1 (1.9) | 2.9 (2.3) | 3.1 (2.3) |
| Household type | Single adult, no children | 397 (17.6) | 2.6 (1.9) | 3.8 (2.2) | 4.1 (2.3) |
| | Single adult, children | 133 (5.9) | 1.8 (1.7) | 2.3 (2.2) | 2.8 (2.2) |
| | 2+ adults, no children | 947 (42.0) | 1.8 (1.7) | 2.6 (2.2) | 3.0 (2.4) |
| | 2+ adults, children | 778 (34.5) | 1.7 (1.7) | 2.4 (2.2) | 2.8 (2.4) |
| Injury/disability | No | 1675 (77.4) | 1.8 (1.7) | 2.7 (2.3) | 3.0 (2.4) |
| | Yes | 489 (22.6) | 2.2 (1.9) | 2.9 (2.2) | 3.4 (2.3) |
| Area disadvantage | Low | 834 (36.2) | 1.5 (1.7) | 2.2 (2.1) | 2.3 (2.4) |
| | Mid | 772 (33.5) | 1.9 (1.7) | 2.6 (2.3) | 3.4 (2.5) |
| | High | 699 (30.3) | 2.4 (1.9) | 3.6 (2.1) | 3.8 (2.0) |
| Total sample | | 2305 (100.0) | 1.9 (1.8) | 2.7 (2.3) | 3.1 (2.4) |

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the individual destinations. Neighbourhoods with the greatest mix of destinations were more likely to be areas of high disadvantage, and contain a higher proportion of people: aged 65 years or more; living alone; with a bachelor degree or higher.

### Frequency of walking in areas characterized by destinations

For most destinations, a higher proportion of those walking ≥4/week and sufficiently active were in the higher exposure category (*e.g.,* tertile three). For example, for educational facilities within both the 800 m and 1200 m buffer, a higher proportion of those respondents both walking most frequently (≥4/week), and sufficiently physically active, were in the tertile or category with the most facilities (see Table 3).

### Multi-level logistic regression analysis: Specific types of destination

There was a clear gradient for each destination type: more destinations were associated with greater odds of walking ≥ 4/week, and greater odds of being sufficiently physically active (refer to Table 4).

More specifically, there were significant positive associations observed between each destination type and walking frequency for: all destination types at 1200 m; cafes/takeaway stores, transport stops, supermarkets, community resources, educational destinations and small food stores at 800 m; café/takeaway food stores, sport facilities and transport stops at 400 m.

Associations were similar for physical activity sufficiency, with significant positive associations noted for: all destinations at 1200 m; educational destinations, café/takeaway stores, supermarkets, community resources, small food stores at 800 m; cafes/takeaway stores and transport stops at 400 m.

For both outcomes, strongest effects were observed for community resources at 800 m and 1200 m, and small food stores at 800 m and 1200 m.

Associations between destinations and sufficient physical activity were largely attenuated when walking was included in the models.

### Multi-level logistic regression analysis: Destination mix

For each buffer distance, the effect of destination mix on walking was significant (see Table 5). The odds of walking ≥ 4/week significantly increased for each additional destination type above the median for that type, at each buffer distance. At 400 m the odds increased by almost 10 % (OR 1.09, 95 % CI 1.03–1.16). The odds increased by 12 % for both 800 m (OR 1.12, 95 % CI 1.06–1.17) and 1200 m, (OR 1.12, 95 % CI 1.07–1.17). Effects of physical activity sufficiency were similar to those of walking, with the odds of being sufficiently physically active increasing significantly for each destination type above the median for that type. These effects were significant at both 800 m (OR 1.10, 95 % CI, 1.04–1.15) and 1200 m (OR 1.10, 95 % CI, 1.05–1.16).

Inclusion of walking in physical activity models led to attenuation of the association between destination mix and physical activity.

## Discussion

This analysis provides evidence that the presence of several different types of destinations in local neighbourhoods is associated with a greater likelihood of walking at least four times a week, and being sufficiently active. Community resources and small food stores showed the strongest associations with walking and physical activity: significant effects being observed at both the 800 m and 1200 m buffer, for both tertile 2 and tertile 3 (relative to tertile 1). For both outcomes, more moderate associations were observed for cafes/takeaway stores, supermarkets and educational destinations at most buffers.

Walking frequency largely attenuated the associations between the different destinations and sufficient physical activity, suggesting that increasing the number of destinations in areas has the potential to increase physical activity, largely through walking, such that more residents are sufficiently active for health.

There was also evidence that greater destination mix was associated with higher odds of walking at least four times a week: for each buffer distance, each additional destination type above the median was associated with a significant increase in the likelihood of walking at least once a week.

The strong associations between walking and community resources and small food stores within 1200 m of home suggest that people may walk up to 1200 m, (15 min) to access some services and destinations. The results for supermarkets and small food stores may suggest that having somewhere to buy basic food and household provisions within walking distance of home is important for walking.

Significant associations were observed for walking at all buffers for cafes/takeaway stores, and transport stops/stations – the most common destinations. The observed associations for public transport may be associated with the fact that people commonly access transport stops by walking. The comparative abundance of transport stops and café/takeaway stores may also mean that they are of sufficient quantity to enable the detection of an effect at 400 m.

Having a mixed set of destinations may offer the opportunity to achieve a range of shopping and other tasks in a single trip, thereby providing incentive to walk.

The importance of community resources in this study, is consistent with other research concluding that destinations

**Table 3** Summary statistics for outcome and exposures

| | Exposure variable | Exposure category | Walking frequency | | | Physical activity sufficiency | | |
|---|---|---|---|---|---|---|---|---|
| | | | Total | <4/week | ≥4/week | Total | Insufficient | Sufficient |
| | | | N | % | % | N | % | % |
| 400 | Education | 0 education facilities | 1469 | 65.5 | 61.5 | 1266 | 64.1 | 66.8 |
| | | 1 + education facilities | 836 | 34.5 | 38.5 | 710 | 35.9 | 33.2 |
| 800 | Education | Tertile 1 | 996 | 46.3 | 39.2 | 869 | 44.0 | 48.1 |
| | | Tertile 2 | 808 | 33.1 | 37.6 | 676 | 34.2 | 32.9 |
| | | Tertile 3 | 501 | 20.7 | 23.1 | 431 | 21.8 | 19.0 |
| 1200 | Education | Tertile 1 | 939 | 44.7 | 35.5 | 815 | 41.2 | 46.5 |
| | | Tertile 2 | 698 | 27.7 | 33.6 | 593 | 30.0 | 27.8 |
| | | Tertile 3 | 668 | 27.6 | 30.8 | 568 | 28.7 | 25.7 |
| 400 | Cafes/takeaway stores | 0 cafes/takeaway | 1659 | 75.5 | 67.4 | 1435 | 72.6 | 75.6 |
| | | 1 + cafes/takeaway | 646 | 24.5 | 32.6 | 541 | 27.4 | 24.5 |
| 800 | Cafes/takeaway stores | Tertile 1 | 798 | 38.7 | 29.3 | 707 | 35.8 | 39.2 |
| | | Tertile 2 | 761 | 32.6 | 33.5 | 632 | 32.0 | 32.2 |
| | | Tertile 3 | 746 | 28.7 | 37.1 | 637 | 32.2 | 28.7 |
| 1200 | Cafes/takeaway stores | Tertile 1 | 827 | 39.1 | 31.7 | 731 | 37.0 | 40.0 |
| | | Tertile 2 | 714 | 31.9 | 29.8 | 592 | 30.0 | 31.3 |
| | | Tertile 3 | 764 | 29.1 | 38.4 | 653 | 33.1 | 28.7 |
| 400 | Transport stops/stations | Tertile 1 | 561 | 27.6 | 20.0 | 496 | 25.1 | 28.4 |
| | | Tertile 2 | 684 | 29.1 | 30.4 | 584 | 29.6 | 28.3 |
| | | Tertile 3 | 1060 | 43.3 | 49.6 | 896 | 45.3 | 43.3 |
| 800 | Transport stops/stations | Tertile 1 | 893 | 41.0 | 35.7 | 784 | 39.7 | 41.4 |
| | | Tertile 2 | 730 | 32.5 | 30.6 | 630 | 31.9 | 31.9 |
| | | Tertile 3 | 682 | 26.5 | 33.6 | 562 | 28.4 | 26.8 |
| 1200 | Transport stops/stations | Tertile 1 | 825 | 39.3 | 31.2 | 724 | 36.6 | 40.0 |
| | | Tertile 2 | 760 | 31.4 | 35.0 | 651 | 33.0 | 31.2 |
| | | Tertile 3 | 720 | 29.3 | 33.7 | 601 | 30.4 | 28.9 |
| 400 | Supermarkets | 0 supermarkets | 2219 | 96.9 | 95.4 | 1905 | 96.4 | 96.4 |
| | | 1 + supermarkets | 86 | 3.1 | 4.6 | 71 | 3.6 | 3.6 |
| 800 | Supermarkets | 0 supermarkets | 1812 | 82.2 | 74.0 | 1557 | 78.8 | 81.5 |
| | | 1 + supermarkets | 493 | 17.8 | 26.0 | 419 | 21.2 | 18.5 |
| 1200 | Supermarkets | 0 supermarkets | 1218 | 56.3 | 48.4 | 1056 | 53.4 | 57.5 |
| | | 1 + supermarkets | 1087 | 43.7 | 51.7 | 920 | 46.6 | 42.5 |
| 400 | Sport facilities | 0 sport facilities | 1938 | 86.1 | 81.5 | 1678 | 84.9 | 84.9 |
| | | 1 + sport facilities | 367 | 13.9 | 18.5 | 298 | 15.1 | 15.1 |
| 800 | Sport facilities | 0 sport facilities | 1296 | 59.0 | 52.7 | 1136 | 57.5 | 59.2 |
| | | 1 + sport facilities | 1009 | 41.0 | 47.4 | 840 | 42.5 | 40.8 |
| 1200 | Sport facilities | Tertile 1 | 639 | 31.7 | 22.5 | 563 | 28.5 | 32.5 |
| | | Tertile 2 | 1045 | 43.2 | 48.2 | 900 | 45.6 | 42.2 |
| | | Tertile 3 | 621 | 25.1 | 29.3 | 513 | 26.0 | 25.3 |
| 400 | Community resources | 0 comm. resources | 1644 | 73.6 | 68.4 | 1427 | 72.2 | 74.7 |
| | | 1 + comm. resources | 661 | 26.4 | 31.6 | 549 | 27.8 | 25.3 |

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**Table 3** Summary statistics for outcome and exposures *(Continued)*

| 800 | Community resources | Tertile 1 | 733 | 37.3 | 24.6 | 654 | 33.1 | 38.6 |
|---|---|---|---|---|---|---|---|---|
| | | Tertile 2 | 692 | 28.0 | 32.7 | 593 | 30.0 | 27.7 |
| | | Tertile 3 | 880 | 34.8 | 42.6 | 729 | 36.9 | 33.7 |
| 1200 | Community resources | Tertile 1 | 796 | 39.4 | 28.1 | 707 | 35.8 | 40.8 |
| | | Tertile 2 | 744 | 32.2 | 32.3 | 628 | 31.8 | 32.4 |
| | | Tertile 3 | 765 | 28.3 | 39.5 | 641 | 32.4 | 26.8 |
| 400 | Small food stores | 0 small food stores | 1578 | 70.4 | 65.9 | 1370 | 69.3 | 69.9 |
| | | 1 + small food stores | 727 | 29.6 | 34.1 | 606 | 30.7 | 30.1 |
| 800 | Small food stores | Tertile 1 | 575 | 28.7 | 20.0 | 520 | 26.3 | 29.5 |
| | | Tertile 2 | 758 | 33.5 | 32.1 | 636 | 32.2 | 33.0 |
| | | Tertile 3 | 972 | 37.8 | 47.9 | 820 | 41.5 | 37.5 |
| 1200 | Small food stores | Tertile 1 | 814 | 39.8 | 29.4 | 726 | 36.7 | 40.5 |
| | | Tertile 2 | 761 | 32.2 | 34.0 | 625 | 31.6 | 32.8 |
| | | Tertile 3 | 730 | 28.0 | 36.5 | 625 | 31.6 | 26.7 |

offering and supporting social interaction were more predictive of walking than other destinations [19]. The findings in relation to the importance of food stores and schools/educational facilities are also consistent with the findings of other studies [16–18, 20, 21, 33].

In terms of distance effects, our results are similar to other studies. In Australia, local destinations within a 10 min walk from home have been found to be associated with walking for transport in adults [48]. Elsewhere, a Canadian study found that very few walks exceeded 1200 m [33].

### Strengths and limitations of this research

The use of three network buffers specific to individual respondents is a key strength of this analysis, as most previous studies have only examined one or two catchments/buffers. Information about distance is critical if we are to create new developments, or amend existing suburbs to make them more amenable to physical activity. Secondly, the destinations included in this analysis represent considerable breadth of possible destinations in local neighbourhoods. Thirdly, we have advanced the measurement of destination mix by accounting for variations in the distribution of different destinations.

There are some limitations of the data. The cross-sectional nature of this study means that causality cannot be inferred from associations. Secondly, the determinants of walking can vary according to walking purpose. While walking to a destination can be classified as walking for transport, the outcome measure used was total walking frequency in the past month (we did not distinguish between recreational and transport walking). This risks error in estimates of the effect of the exposure variables – most likely a bias toward null. Sensitivity analysis conducted by removing those who only reported walking for recreation

however, resulted in stronger effects for destinations. Importantly, it is often difficult for both respondents (and analysts) to distinguish between walking trips on the basis of purpose. For example, it is difficult to assign walking purpose to a person walking to a café or library.

The walking outcome measure was based on walking for 10 min or more (respondents were asked how often in the last month they had walked for 10 min or more). For most people, this equates to a distance of approximately 800 m. Consequently, walking trips to destinations within 400 m may not have been captured, and the effect of destinations within 400 m may be underestimated. However it is possible that some walking within 400 m was captured through trip chaining (walking to, and between multiple destinations), and making round trips (rather than one-way journeys), as the walking carried out by a person walking to several destinations within 400 m may amount to 10 min or more. Certainly this notion of trip-chaining is supported by the significance of results for destination mix within 400 m of home. Also in relation to the walking outcome, we have no measure of the intensity of respondents' walking and therefore do not know if people walked at sufficient intensity to benefit their health.

There is also a risk of confounding due to residential self-selection. Self-selection may occur when people who perceive that there are benefits to physical activity and walking choose to live in (self-select into) neighbourhoods that support such activities [32, 49]. However we controlled for many potential demographic and socio-economic confounders that predict attitudes, perceptions and behaviours in relation to both physical activity and walking.

Finally, we did not have information about where people walked or were physically active. Given that the

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**Table 4** Multilevel logistic regression odds ratios for each destination, across three buffer distances[1]

| Exposure variable | Buffer distance | Response category | Odds ratios (CI) | | |
| --- | --- | --- | --- | --- | --- |
| | | | Walking four times a week or more[2] | Physical activity sufficiency[3] | Physical activity sufficiency adjusted for walking |
| Education | 400 | 0 education facilities | 1.00 | 1.00 | 1.00 |
| | | 1+ education facilities | 1.11 (0.90, 1.38), p = 0.326 | 1.16 (0.92, 1.46), p = 0.217 | 1.10 (0.85, 1.43), p = 0.470 |
| Education | 800 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.40 (1.11, 1.77), p = 0.005 | 1.45 (1.14, 1.83), p = 0.002 | 1.28 (0.97, 1.70), p = 0.081 |
| | | Tertile 3 | 1.27 (0.96, 1.69), p = 0.099 | 1.50 (1.13, 1.99), p = 0.005 | 1.42 (1.03, 1.96), p = 0.035 |
| Education | 1200 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.77 (1.39, 2.24), p = 0.000 | 1.60 (1.24, 2.06), p = 0.000 | 1.28 (0.95, 1.73), p = 0.111 |
| | | Tertile 3 | 1.54 (1.19, 1.98), p = 0.001 | 1.44 (1.10, 1.89), p = 0.009 | 1.25 (0.90, 1.72), 0.179 |
| Cafes/takeaway stores | 400 | 0 cafes/takeaway | 1.00 | 1.00 | 1.00 |
| | | 1+ cafes/takeaway | 1.47 (1.18, 1.83), p = 0.001 | 1.36 (1.08, 1.73), p = 0.009 | 1.23 (0.94, 1.62), p = 0.130 |
| Cafes/takeaway stores | 800 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.34 (1.04, 1.73), p = 0.022 | 1.35 (1.04, 1.75), p = 0.023 | 1.18 (0.88, 1.60), p = 0.274 |
| | | Tertile 3 | 1.80 (1.38, 2.34), p = 0.000 | 1.60 (1.22, 2.09), p = 0.001 | 1.28 (0.94, 1.75), p = 0.120 |
| Cafes/takeaway stores | 1200 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.18 (0.92, 1.53), p = 0.198 | 1.07 (0.82, 1.39), p = 0.622 | 1.00 (0.74, 1.37), p = 0.985 |
| | | Tertile 3 | 1.66 (1.27, 2.17), p = 0.000 | 1.61 (1.23, 2.12), p = 0.001 | 1.37 (0.99, 1.88), p = 0.057 |
| Transport stops/stations | 400 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.59 (1.22, 2.08), p = 0.001 | 1.56 (1.18, 2.06), p = 0.002 | 1.30 (0.94, 1.79), p = 0.111 |
| | | Tertile 3 | 1.58 (1.22, 2.06), p = 0.001 | 1.54 (1.17, 2.01), p = 0.002 | 1.32 (0.97, 1.81), p = 0.077 |
| Transport stops/stations | 800 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.06 (0.83, 1.37), p = 0.628 | 1.09 (0.84, 1.40), p = 0.531 | 1.05 (0.78, 1.40), p = 0.748 |
| | | Tertile 3 | 1.35 (1.02, 1.79), p = 0.035 | 1.13 (0.84, 1.52), p = 0.409 | 1.02 (0.73, 1.42), p = 0.923 |
| Transport stops/stations | 1200 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.47 (1.14, 1.89), p = 0.003 | 1.49 (1.15, 1.93), p = 0.003 | 1.29 (0.95, 1.75), p = 0.104 |
| | | Tertile 3 | 1.46 (1.11, 1.93), p = 0.007 | 1.33 (0.99, 1.79), p = 0.058 | 1.19 (0.85, 1.68), p = 0.309 |
| Supermarkets | 400 | 0 supermarkets | 1.00 | 1.00 | 1.00 |
| | | 1 + supermarkets | 1.23 (0.73, 2.08), p = 0.441 | 0.82 (0.47, 1.44), p = 0.495 | 0.72 (0.38, 1.37), p = 0.317 |
| Supermarkets | 800 | 0 supermarkets | 1.00 | 1.00 | 1.00 |
| | | 1 + supermarkets | 1.69 (1.30, 2.20), p = 0.000 | 1.43 (1.08, 1.88), p = 0.012 | 1.15 (0.83, 1.58), p = 0.406 |
| Supermarkets | 1200 | 0 supermarkets | 1.00 | 1.00 | 1.00 |
| | | 1 + supermarkets | 1.40 (1.12, 1.77), p = 0.004 | 1.53 (1.22, 1.91), p = 0.000 | 1.41 (1.09, 1.83), p = 0.009 |
| Sport facilities | 400 | 0 sport facilities | 1.00 | 1.00 | 1.00 |
| | | 1 + sport facilities | 1.33 (1.00, 1.76), p = 0.049 | 0.93 (0.68, 1.27), p = 0.647 | 0.76 (0.53, 1.09), p = 0.137 |
| Sport facilities | 800 | 0 sport facilities | 1.00 | 1.00 | 1.00 |
| | | 1 + sport facilities | 1.21 (0.97, 1.52), p = 0.089 | 1.17 (0.93, 1.47), p = 0.178 | 1.05 (0.81, 1.36), p = 0.707 |
| Sport facilities | 1200 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.53 (1.19, 1.98), p = 0.001 | 1.58 (1.22, 2.03), p = 0.000 | 1.39 (1.03, 1.87), p = 0.030 |
| | | Tertile 3 | 1.66 (1.22, 2.25), p = 0.001 | 1.53 (1.14, 2.06), p = 0.005 | 1.22 (0.86, 1.73), p = 0.270 |
| Community resources | 400 | 0 comm. resources | 1.00 | 1.00 | 1.00 |
| | | 1 + comm. resources | 1.12 (0.89, 1.40), p = 0.334 | 1.06 (0.82, 1.36), p = 0.661 | 1.04 (0.78, 1.37), p = 0.800 |

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**Table 4** Multilevel logistic regression odds ratios for each destination, across three buffer distances[1] *(Continued)*

| | | | | | |
|---|---|---|---|---|---|
| Community resources | 800 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.85 (1.44, 2.37), p = 0.000 | 1.82 (1.40, 2.37), p = 0.000 | 1.55 (1.13, 2.12), p = 0.006 |
| | | Tertile 3 | 1.92 (1.49, 2.48), p = 0.000 | 1.58 (1.2, 2.07), p = 0.001 | 1.23 (0.88, 1.70), p = 0.222 |
| Community resources | 1200 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.41 (1.11, 1.79), p = 0.006 | 1.45 (1.12, 1.89), p = 0.005 | 1.32 (0.96, 1.81), p = 0.084 |
| | | Tertile 3 | 2.20 (1.71, 2.83), p = 0.000 | 1.97 (1.49, 2.58), p = 0.000 | 1.47 (1.06, 2.04), p = 0.023 |
| Small food stores | 400 | 0 small food stores | 1.00 | 1.00 | 1.00 |
| | | 1 + small food stores | 1.12 (0.9, 1.4), p = 0.296 | 1.07 (0.85, 1.35), p = 0.573 | 1.04 (0.8, 1.37), p = 0.747 |
| Small food stores | 800 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.42 (1.08, 1.85), p = 0.011 | 1.39 (1.05, 1.85), p = 0.020 | 1.28 (0.92, 1.78), p = 0.146 |
| | | Tertile 3 | 1.85 (1.41, 2.44), p = 0.000 | 1.70 (1.29, 2.26), p = 0.000 | 1.34 (0.96, 1.87), p = 0.081 |
| Small food stores | 1200 | Tertile 1 | 1.00 | 1.00 | 1.00 |
| | | Tertile 2 | 1.40 (1.09, 1.8), p = 0.009 | 1.18 (0.91, 1.54), p = 0.206 | 0.98 (0.72, 1.34), p = 0.922 |
| | | Tertile 3 | 1.96 (1.49, 2.58), p = 0.000 | 1.96 (1.48, 2.58), p = 0.000 | 1.51 (1.09, 2.11), p = 0.015 |

[1]Models adjusted for age, sex, country of birth, dominant household occupation, education, disability, area SEP
[2]Reference group for walking outcome: walking less than four times a week
[3]Reference group for physical activity outcome: insufficient level of activity

majority of the sample was in the labour force, many people may have walked close to work. We did not have information about destinations close to the workplace and therefore we do not know the extent to which they exert an influence over walking.

### Implications for policy and practice

These results have important implications for policy and practice. The results provide guidance for urban planners, suggesting that several different types of destinations may encourage walking. The associations between physical activity and destinations suggest that destinations may encourage physical activity to a level sufficient to confer health and lifestyle benefits to residents. Given that cycling, another mode of active transport that might be used to reach destinations, is very infrequent among Australian adults [50], it is likely that much of the physical activity measured here is derived through walking.

The different associations between destination types and physical activity and walking provide a guide for priorities in the planning of shops and services. In terms of a hierarchy of importance, the results suggest that small food stores and destinations offering opportunity for social interaction such as community resources may induce greatest influence on walking and physical activity. Evidence from this same study found the presence of healthy food stores close to home is associated with healthy eating [41]. This suggests a two-pronged benefit of having supermarkets or small shops within walking distance of home: with benefits in terms of physical activity, and healthy eating.

The strength and significance of the associations between the outcomes and shop and service destinations at 800 m and 1200 m is important in guiding decisions about proximity. The results suggest that destinations up 1200 m may still exert an influence on walking and physical activity (which from both an economic and public health point of view is advantageous). Additionally, when planning new suburbs, and working within existing suburbs it is important to include a mix of destination types, as a mix of destinations is associated with an increase in the odds of walking and physical activity.

While these results have implications for planning practices, it is also important to acknowledge that the location of destinations is driven by many factors including (but not limited to) population density, street

**Table 5** Multilevel logistic regression odds ratios for destination mix, at three distances[1]

| Exposure variable | Buffer distance | Odds ratios (CI) | | |
|---|---|---|---|---|
| | | Walking[2] | Physical activity[3] | Physical activity adjusted for walking |
| Mix | 400 | 1.09 (1.03, 1.16), p = 0.004 | 1.06 (0.99, 1.13), p = 0.090 | 1.02 (0.95, 1.10), p = 0.521 |
| Mix | 800 | 1.12 (1.06, 1.17), p = 0.000 | 1.10 (1.04, 1.15), p = 0.000 | 1.05 (0.99, 1.11), p = 0.141 |
| Mix | 1200 | 1.12 (1.07, 1.17), p = 0.000 | 1.10 (1.05, 1.16), p = 0.000 | 1.06 (1.00, 1.12), p = 0.044 |

[1]Models adjusted for age, sex, country of birth, dominant household occupation, education, disability, area SEP
[2]Reference group for walking outcome: walking less than four times a week
[3]Reference group for physical activity outcome: insufficient level of activity

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connectivity, and pedestrian safety. Increasing walkable destinations alone is unlikely to promote walking and physical activity if these other aspects of pedestrian infrastructure are unsupportive.

## Conclusion

These results build on previous studies and add to the weight of evidence regarding the importance of destinations for walking and physical activity. In particular, key destinations such as small food stores, community resources and schools within 800 m-1200 m of home may offer the greatest scope to promote local physical activity and walking. The results also suggest that greatest walking and physical activity potential is realized if destinations are mixed.

## Ethics approval

The VicLANES project design was approved by the La Trobe University Human Ethics Committee (#02-130). Participants received an information pack, along with their survey in the mail. This advised them: of the risks and benefits of participating; that their participation was voluntary; of the ways that the data would be used; of the strict procedures to protect confidentiality and ensure anonymity. Return of completed surveys was considered indicative of consent - a procedure approved by the Latrobe University Human Ethics Committee.

## Endnotes

[1]TAFE stands for 'technical and further education'. In Australia, TAFE institutions provide vocational training and courses in fields such as engineering, business, finance, hospitality, and tourism.

## Additional files

**Additional file 1: Table S1.** Types and sources of destination data. (DOC 46 kb)

**Additional file 2: Table S2.** Summary of destination exposures and covariates. (DOC 39 kb)

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