Koohsari MJ, Owen N, Cole R, Mavoa S, Oka K, Hanibuchi T, Sugiyama T. Built environmental factors and adults' travel behaviors: Role of street layout and local destinations. Prev Med 2017;96:124-8.

Link to Elsevier publisher version: http://doi.org/10.1016/j.ypmed.2016.12.021

Built Environmental Factors and Adults' Travel Behaviors: Role of Street Layout and Local Destinations

MOHAMMAD JAVAD KOOHSARI, PhD (Corresponding author)
Faculty of Sport Sciences, Waseda University, Japan
Behavioural Epidemiology Laboratory, Baker IDI Heart and Diabetes Institute, Australia
Institute for Health and Ageing, Australian Catholic University, Australia
Melbourne School of Population and Global Health, The University of Melbourne, Australia
Javad.Koohsari@bakeridi.edu.au
Address: Level 4, 99 Commercial Rd, Melbourne, VIC 3004, Australia
Telephone: +61 3 8532 1874

NEVILLE OWEN, PhD
Behavioural Epidemiology Laboratory, Baker IDI Heart and Diabetes Institute, Australia
Swinburne University of Technology, Australia
Neville.Owen@bakeridi.edu.au

RACHEL COLE, PhD
Cluster for Health Improvement, University of the Sunshine Coast, Australia
rcole@usc.edu.au

SUZANNE MAVOA, PhD
Melbourne School of Population and Global Health, The University of Melbourne, Australia
suzanne.mavoa@unimelb.edu.au

KOICHIRO OKA, PhD
Faculty of Sport Sciences, Waseda University, Japan
koka@waseda.jp

TOMOYA HANIBUCHI, PhD
School of International Liberal Studies, Chukyo University, Japan
hanibuchi@gmail.com

TAKEMI SUGIYAMA, PhD
Institute for Health and Ageing, Australian Catholic University, Australia
Behavioural Epidemiology Laboratory, Baker IDI Heart and Diabetes Institute, Australia
Melbourne School of Population and Global Health, The University of Melbourne, Australia
Takemi.Sugiyama@acu.edu.au

Abstract

Street layout is consistently associated with adults' travel behaviors, however factors influencing this association are unclear.

We examined associations of street layout with travel behaviors: walking for transport (WT) and car use; and, the extent to which these relationships may be accounted for by availability of local destinations.

A 24-hr travel diary was completed in 2009 by 16,345 adult participants of the South-East Queensland Household Travel Survey, Australia. Three travel-behavior outcomes were derived: any home-based WT; over 30 min of home-based WT; and, over 60 min of car use. For street layout, a space syntax measure of integration was calculated for each Statistical Area 1 (SA1, the smallest geographic unit in Australia). An objective measure of availability of destinations – Walk Score – was also derived for each SA1. Logistic regression examined associations of street layout with travel behaviors. Mediation analyses examined to what extent availability of destinations explained the associations.

Street integration was significantly associated with travel behaviors. Each one-decile increment in street integration was associated with an 18% (95%CI: 1.15, 1.21) higher odds of any home-based WT; a 10% (95%CI: 1.06, 1.15) higher odds of over 30 min of home-based WT; and a 5% (95%CI: 0.94, 0.96) lower odds of using a car over 60 min. Local destinations partially mediated the effects of street layout on travel behaviors.

Well-connected street layout contributes to active travel partially through availability of more local destinations. Urban design strategies need to address street layout and destinations to promote active travel among residents.

Key words: Walking, Sitting time, Travel behaviour, Neighbourhood, Urban design,

Introduction

Regular physical activity has substantial health benefits including reduced risk of several of the most common chronic diseases, including type 2 diabetes, cardiovascular disease and some common cancers (U.S. Department of Health and Human Services, 2008). Sedentary behavior — too much sitting — has also been found as a distinct behavior associated with chronic disease risk (Owen et al., 2010; Rohm et al., 2016; Thorp et al., 2011). Physical inactivity and sedentary behavior can have synergistic impacts on health outcomes, including all-cause mortality (Ekelund et al., 2016). Given the limitations of individually-based approaches to increasing physical activity and reducing sitting time, ecological models are increasingly used to underpin the inclusion of broader determinants (Sallis et al., 2008). In particular, recent research findings building on the models emphasize the potential of the neighborhood built environment for facilitating physical activity and reducing sedentary behavior (Kerr et al., 2016; Owen et al., 2011; Sallis et al., 2008). For example, a recent international study on the associations of objectively-assessed environment attributes with accelerometer-measured physical activity identified a number of built environmental factors that are associated with adults' physical activity (Sallis et al., 2016).

Street layout — the way in which streets are laid out and connected in neighborhoods — is one of the built environment elements related to physical activity such as walking (Koohsari et al., 2014; Sugiyama et al., 2012b). For example, a study conducted in Australia found that residents of neighborhoods with highly-connected street layouts were more likely to walk, compared with those who living in less-connected areas (Kamruzzaman et al., 2014). In the USA, a longitudinal study found increases in street connectivity to be associated with greater increases in transportation walking over time (Hirsch et al., 2014).

Well-connected street layouts are hypothesised to support walking by providing short and direct routes between origins and destinations and permitting more route options to reach destinations (Dill, 2004; Handy et al., 2003; Handy et al., 2010; Saelens et al., 2003). Another potential factor involved in the relationship between street layout and walking is the presence of local destinations, which may exist in areas with well-connected street layouts (Tsou and Cheng, 2013). Koohsari et al. (2014; 2016) found availability of utilitarian destinations partially mediated the associations of street layout measures (intersection density and street integration) with transportation walking. However, these previous studies examining the role of destinations in associations of street layout with walking relied on self-reported availability of destinations within walking distance, which may not truly reflect the overall availability of local destinations. In addition, these studies used a non-location-specific measure of walking, which could cause spatial mismatch between the location where walking took place and the area where environmental attributes were measured. These methodological issues need to be addressed to accurately assess how destinations are involved in the relationships between street layout and walking. In addition, previous studies did not examine whether street layout is related to car use — a common sedentary behavior with known health impact (Sugiyama et al., 2012a; Sugiyama et al., 2016) — and the role of local destinations in the relationship between them.

We examined the associations of street layout with active and sedentary travel behaviors: home-based walking for transport (WT) and car use, and evaluated to what extent the relationship of street layout with these two types of travel behaviors may be explained by objectively-assessed availability of local destinations.

Methods

Data Source and Study Setting

Data from the 2009 South-East Queensland Household Travel Survey (SEQHTS) were used in this study. The SEQHTS is a large-scale repeated cross-sectional survey administered by the Queensland Government Department of Transport and Main Roads. Detailed methods of sampling, recruitment and data collection have been described elsewhere (Queensland Government 2010). Briefly, the SEQHTS has a multistage random sampling design in which Census Collection Districts (CCD, a geographical unit comprising of about 250 households) were first selected, followed by recruitment of households from each CCD. The median size of selected CCDs was 0.36 km^2 (interquartile range: 0.61 km^2). About 4.4% of households from selected CCDs (10,335 households) participated in this study (response rate of about 60%). The total number of participants in the 2009 SEQHTS was 27,213. Of these, this study examined adult participants aged between 18 and 64 years old who reported any trip on the day of the survey (N=16,345). The SEQHTS was administered in accordance with ethical guidelines under Queensland government statutes and regulations. Informed consent was obtained from participants.

Measures

Outcomes: Travel behaviors. All members of participating households were asked to report their travel behaviors using a 24-hr travel diary. For each travel, they reported the start time, end time, origin, destination (place the person went to for the particular trip), purpose, and mode of travel. This study focused on two types of travel behaviors: WT and car use that originated or ended at home (home-based WT and home-based car use). Based on the travel diary, we calculated the following three dichotomised outcomes for each participant: any home-based WT or not; accumulating over 30 min of home-based WT or not, and accumulating over 60 min of car use or not. The cut-off of 30 min was chosen for walking on the basis of current physical activity guidelines (Australian Government Department of Health And Ageing, 2005). For car use, we used 60 min as a cut-off based on a recent study showing adverse associations of spending more than 60 min per day in car with markers of cardio-metabolic risk (Sugiyama et al., 2016).

Exposure: Street layout. A space syntax measure of street integration was calculated for each street segment using Axwoman (Jiang, 2012) and University College London DepthMap (Turner, 2004) software. Street integration, which indicates how topologically ”close” a street segment is to the other segments within the street layout, is a key measure of space syntax (Hillier, 2009). We used this space syntax measure for street layout, building on our previous study in which integration was found associated with perceived availability of local destinations (Koohsari et al., 2016). Although space syntax is relatively new in research on active living, it has been used widely in urban planning practice (Lerman et al., 2014). There were two aggregation steps in the calculation of integration score. The first step was street-level identification: an integration score was assigned to each street segment considering all the other street segments within a 1 km distance from its centre. We chose 1 km as the buffer size in this step, as it is reported that walk to local destinations does not often exceed this distance (Millward et al., 2013). The second step was area-level calculation of integration. For each participating Statistical Area 1 (SA1), the mean integration score was calculated for all street segments within the area. SA1 is the smallest geographic unit for Census data in Australia from 2011 (Australian Bureau of Statistics, 2011). Although CCDs were used for recruitment, SA1s were used for analyses because they tend to be more consistent in population size and homogeneous in characteristics than CCD (Australian Bureau of

Statistics, 2011). The study area contained 1348 SA1s, which were classified into deciles according to the mean integration score. Since the exact address of each participant was unavailable, participants were assigned the integration score of the SA1 they lived in.

Potential mediator: Availability of local destinations. Walk Score – a web-based, publicly-available tool that scores places based on proximity to various local destinations – was used as a measure of objectively-assessed availability of local destinations (www.walkscore.com). Walk Score was determined for each SA1, using the score obtained for the centroid of SA1. SA1s were classified into deciles according to their Walk Score (Cole et al., 2015).

Covariates: Socio-demographic variables. The following socio-demographic characteristics were collected in household travel survey: age, gender, employment, living arrangements living arrangements, and household income.

Statistical Analysis

For the first question (associations of street layout with travel behaviors), we used logistic regression to estimate the odds of engaging in these travel behaviors according to the level of street integration.

The second question of this study was how much the associations of street layout with travel behaviors may be mediated by the availability of local destinations. We followed the procedure proposed by Baron and Kenny (1986), which consists of the following four steps (Figure 1). The first step is to establish a non-zero association between street layout (exposure) and travel behaviors (outcomes). This is the same as the first question discussed above, and corresponds to path C in Figure 1. The second step is to establish a non-zero association between street layout and availability of local destinations (potential mediator), corresponding to path A in Figure 1. The third step is to examine whether availability of local destinations was associated with travel behaviors, controlling for street layout (path B). The fourth step tests whether the effect of street layout on travel behaviors adjusting for availability of destinations was zero (path C'). Full mediation exists in a situation where all the four criteria are met, while mediation is partial in a situation where only the first three criteria are met (Kenny, 2016). Linear regression analyses were used to calculate path A, while logistic regression was used for path B and C'. All models accounted for clustering of participants at the SA1 level, and adjusted for socio-demographic variables (age, gender, employment, living arrangements, and household income). Analyses were conducted using Stata 14.0 (Stata Corp, College Station, Texas).

INSERT FIGURE 1 ABOUT HERE

The indirect effect of street layout on travel behaviors through the mediator (availability of local destinations) can be calculated as the product of the coefficients for path A and B (A × B). The Sobel test was applied to test whether the indirect effect was significant (Sobel, 1982). The proportion of the effect that is mediated was calculated as (A × B) / (A × B + C'), and presented as percentage. Because the binary outcome was used for path B, C, and C', we followed the methods of MacKinnon & Dwyer (1993), and calculated these mediation proportions using coefficients standardised to the same scale. Coefficients from the logistic regressions were used to assess the mediation, and odds ratios are shown for descriptive purposes. Only unstandardised coefficients are presented.

Results

Table 1 shows the characteristics of the study sample. Some 12% of the participants reported any home-based WT, 4% reported 30 min or more of home-based WT, and 35% reported 60 min or more of car use. Pearson's correlation coefficient between street integration and Walk Score was 0.57 ($p<0.01$) at the SA1 level.

INSERT TABLE 1 ABOUT HERE

Associations of street layout with travel behaviors

There were significant associations of street layout with adults' WT and car use. Each one-decile increment in street integration was associated with an 18% (95%CI: 1.15, 1.21) higher odds of any home-based WT; a 10% (95%CI: 1.06, 1.15) higher odds of over 30 min of home-based WT; and a 5% (95%CI: 0.94, 0.96) lower odds of using a car over 60 min.

Mediation by availability of local destinations

Table 2 shows coefficients and odds ratios for the mediation analysis. The effect of street layout on all three travel behavior were reduced after adjusting for availability of destinations, but they were not zero (path C'). There was a significant positive association between street layout and availability of destinations (path A). One-decile increment of integration was associated with a 0.64 point greater decile score of Walk Score. Adjusting for street layout, each one-decile increment in Walk Score was associated with 21% higher odds of any home-based WT; a 15% higher odds of over 30 min of home-based WT; and a 5% lower odds of using a car over 60 min (path B).

The Sobel test showed that the indirect effect of the street layout on adults' WT and car use through the availability of destinations was significant (path A x B). The proportions of the total effect of street layout on any WT, 30 min or more of WT, and using a car over 60 min mediated by availability of destinations were 75%, 94%, and 73%, respectively.

INSERT TABLE 2 ABOUT HERE

Discussion

Using data from a large-scale cross-sectional travel survey, we found that well-connected street layout was associated with more walking and less car use, and that these relationships were mediated by availability of local destinations. Previous studies have shown street connectivity to be positively associated with physical activity, particularly walking (Badland et al., 2008; Christiansen et al.; Sarkar et al., 2015). Our study confirmed and extended these findings by showing that participants living in neighborhoods with more connected streets not only walked more but also used cars less, compared with those living in less connected areas. While there has been a well-established body of research examining environmental determinants of walking, there is less evidence on built environment attributes associated with sedentary behavior (Koohsari et al., 2015). Our findings highlight the relevance of street layout to active as well as sedentary travel behaviors.

Our findings indicated that local destinations partly accounted for the relationships of street layout with travel behaviors. The mediation role of local destinations may be explained by the concept of ‘natural movement’ in space syntax: more integrated (well-connected) streets are likely to attract more pedestrians, hence a higher chance of having more destinations (Hillier et al., 1993). Hillier further argued that street layout is the ‘primary generator of pedestrian movement patterns’ (Hillier et al., 1993). Several previous studies on space syntax indeed showed high correlations between street integration and pedestrian flow (Hillier and Iida, 2005; Hillier et al., 1993; Jiang, 2009). Although examining this hypothesis is not within the scope of this study, the results of our mediation analyses seem to support the inter-dependency of streets layout and local destinations in facilitating or deterring residents’ travel behaviors.

Strengths of our study include a large sample size and the use of detailed behavioral data collected from a 24-hr travel dairy. Although this is a self-report measure, the travel diary allowed us to identify home-based walking for transport that occurred in a local area where street layout and destinations were also determined. The use of an objective measure of availability of local destinations (Walk Score) is another strength. Limitations of the study include the use of SA1 in determining mean street integration. Due to the unavailability of participants’ residential address, SA1s where they lived were used as a spatial unit of analysis. However, SA1 is a relatively smaller spatial unit, which may not closely correspond with residents’ local neighborhood. Future studies need to examine the relationships within appropriate geographical areas where people’s daily activity behaviors occur. And this study did not consider the availability of public transit stops including train stations, ferry stops, and bus stops, which may affect travel behaviors. In addition, there are some studies showing the positive effect of street connectivity on walking remains weak even when it is statistically significant (Berrigan et al., 2010; Oakes et al., 2007). Future research is necessary to examine the effect size of association of street layout with active travel behaviors.

Conclusions

Our findings have implications for designing new neighborhoods and retrofitting existing neighborhoods to support active travel and hinder sedentary travel. Although well-connected street network is known to encourage active travel, street layout is a difficult element to modify in existing neighborhoods. As such, identifying pathways through which street layout influences travel behaviors provides alternative environmental interventions to promote active living in this context – both increasing physical activity and reducing sedentary behaviors. Policy initiatives to attract more local destinations, such as land use planning encouraging mixed-use and infill development, can be used to align integrated street segments with non-residential destinations to promote walking and reduce car use in existing neighborhoods (Nelessen, 1994; Tachieva, 2010). To inform the design of street network in new development, future research can examine the level of street integration that would be necessary to support local destinations and active travel among residents. Findings from such research can help identify urban form that can contribute to better community health.

Acknowledgments

Koohsari is supported by a Postdoctoral Fellowship (#100878) from the National Heart Foundation of Australia and a National Health and Medical Research Council (NHMRC) Program Grant [#569940]. Owen is supported by an NHMRC Program Grant [#569940] and a NHMRC Senior Principal Research Fellowship [#1003960]. Koohsari and Owen are supported by the Victorian Government's Operational Infrastructure Support Program.

Conflict of interest

The authors declare there is no conflict of interest.

References

Australian Bureau of Statistics, 2011. 1270.0.44.004 - Australian Statistical Geography Standard: Volume 4 - Significant Urban Areas, Urban Centres and Localities, Section of State. July 2011, in: Statistics, A.B.o. (Ed.). Australian Bureau of Statistics, Canberra, Australia.

Australian Government Department of Health And Ageing, 2005. National Physical Activity Guidelines for Adults., Australian Government Department of Health and Ageing, Canberra,Australia.

Badland, H.M., Schofield, G.M., Garrett, N., 2008. Travel behavior and objectively measured urban design variables: associations for adults traveling to work. Health Place 14:85-95.

Baron, R.M., Kenny, D.A., 1986. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. J. Pers. Soc. Psychol. 51:1173.

Berrigan, D., Pickle, L.W., Dill, J., 2010. Associations between street connectivity and active transportation. International journal of health geographics 9:1.

Christiansen, L.B., Cerin, E., Badland, H., Kerr, J., Davey, R., Troelsen, J., van Dyck, D., Mitáš, J., Schofield, G., et al., International comparisons of the associations between objective measures of the built environment and transport-related walking and cycling: IPEN adult study. Journal of Transport & Health.

Cole, R., Dunn, P., Hunter, I., Owen, N., Sugiyama, T., 2015. Walk Score and Australian adults' home-based walking for transport. Health Place 35:60-65.

Dill, J., 2004. Measuring network connectivity for bicycling and walking, Joint Congress of ACSP-AESOP, pp. 1-20.

Ekelund, U., Steene-Johannessen, J., Brown, W.J., Fagerland, M.W., Owen, N., Powell, K.E., Bauman, A., Lee, I.-M., Series, L.P.A., et al., 2016. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. The Lancet.

Handy, S., Paterson, R., Butler, K., 2003. Planning for street connectivity: getting from here to there. Chicago, IL: American Planning Association.

Handy, S.L., Tal, G., Boarnet, M., 2010. Draft policy brief on the impacts of network connectivity based on a review of the empirical literature, for Research on Impacts of Transportation and Land Use-Related Policies. California Air Resources Board., pp. 1-6.

Hillier, B., 2009. The city as a socio-technical system a spatial reformulation, Conference on Spatial Information Theory, Aber ‘wrach, Brittany.

Hillier, B., Iida, S., 2005. Network and psychological effects in urban movement, in: Cohn, A.J., Mark, D.M. (Eds.), Proceedings of Spatial Information Theory: International Conference, COSIT 2005. Springer, Berlin, pp. 475-90.

Hillier, B., Penn, A., Hanson, J., Grajewski, T., Xu, J., 1993. Natural movement: or, configuration and attraction in urban pedestrian movement. Environ. Plann. B Plann. Des. 20:29-66.

Hirsch, J.A., Moore, K.A., Clarke, P.J., Rodriguez, D.A., Evenson, K.R., Brines, S.J., Zagorski, M.A., Diez Roux, A.V., 2014. Changes in the Built Environment and Changes in the Amount of Walking Over Time: Longitudinal Results From the Multi-Ethnic Study of Atherosclerosis. Am. J. Epidemiol. 180:799-809.

Jiang, B., 2009. Ranking spaces for predicting human movement in an urban environment. Int. J. Geogr. Inf. Sci. 23:823-37.

Jiang, B., 2012. Axwoman 6.0: An ArcGIS extension for urban morphological analysis. University of Gävle, Sweden.

Kamruzzaman, M., Washington, S., Baker, D., Brown, W., Giles-Corti, B., Turrell, G., 2014. Built environment impacts on walking for transport in Brisbane, Australia. Transportation:1-25.

Kenny, D., 2016. Mediation, http://davidakenny.net/cm/mediate.htm.

Kerr, J., Emond, J.A., Badland, H., Reis, R., Sarmiento, O., Carlson, J., Sallis, J.F., Cerin, E., Cain, K., et al., 2016. Perceived neighborhood environmental attributes associated with walking and cycling for transport among adult residents of 17 cities in 12 countries: The IPEN study. Environ. Health Perspect. 124:290.

Koohsari, M.J., Sugiyama, T., Lamb, K.E., Villanueva, K., Owen, N., 2014. Street connectivity and walking for transport: Role of neighborhood destinations. Prev. Med. 66:118-22.

Koohsari, M.J., Sugiyama, T., Mavoa, S., Villanueva, K., Badland, H., Giles-Corti, B., Owen, N., 2016. Street network measures and adults' walking for transport: Application of space syntax. Health Place 38:89-95.

Koohsari, M.J., Sugiyama, T., Sahlqvist, S., Mavoa, S., Hadgraft, N., Owen, N., 2015. Neighborhood environmental attributes and adults' sedentary behaviors: review and research agenda. Prev. Med. 77:141-49.

Lerman, Y., Rofè, Y., Omer, I., 2014. Using space syntax to model pedestrian movement in urban transportation planning. Geographical Analysis 46:392-410.

Mackinnon, D.P., Dwyer, J.H., 1993. Estimating Mediated Effects in Prevention Studies. Evaluation Review 17:144-58.

Millward, H., Spinney, J., Scott, D., 2013. Active-transport walking behavior: destinations, durations, distances. Journal of Transport Geography 28:101-10.

Nelessen, A.C., 1994. Visions for a new American dream : process, principles, and an ordinance to plan and design small communities. Planners Press, American Planning Association, Chicago, Ill.

Oakes, J.M., Forsyth, A., Schmitz, K.H., 2007. The effects of neighborhood density and street connectivity on walking behavior: the Twin Cities walking study. Epidemiologic perspectives & innovations : EP+I 4:16-16.

Owen, N., Healy, G.N., Matthews, C.E., Dunstan, D.W., 2010. Too much sitting: the population-health science of sedentary behavior. Exerc. Sport Sci. Rev. 38:105.

Owen, N., Sugiyama, T., Eakin, E.E., Gardiner, P.A., Tremblay, M.S., Sallis, J.F., 2011. Adults' sedentary behavior: determinants and interventions. Am. J. Prev. Med. 41:189-96.

Queensland Government 2010. South-East Queensland travel survey 2009: survey procedures and documentation v1.0—- Gold Coast Survey 2009, Queensland Transport and Main Roads, Brisbane.

Rohm, Y.D., Hivert, M., Alhassan, S., Camhi, S., Ferguson, J., Katzmarzyk, P.T., Lewis, C.E., Owen, N., Perry, C., et al., 2016. American Heart Association position statement: Sedentary Behavior and Cardiovascular Morbidity and Mortality: The State of the Science. Circulation accepted for publication 8 January 2016.

Saelens, B.E., Sallis, J.F., Frank, L.D., 2003. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Ann. Behav. Med. 25:80-91.

Sallis, J.F., Cerin, E., Conway, T.L., Adams, M.A., Frank, L.D., Pratt, M., Salvo, D., Schipperijn, J., Smith, G., et al., 2016. Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. The Lancet.

Sallis, J.F., Owen, N., Fisher, E.B., 2008. Ecological Models of Health Behavior in: Glanz, K., Rimer, B., Viswanath, K. (Eds.), Health Behavior and Health Education: Theory, Research, and Practice, 4th ed. Jossey-Bass, San Francisco, CA, pp. 465-82.

Sarkar, C., Webster, C., Pryor, M., Tang, D., Melbourne, S., Zhang, X., Jianzheng, L., 2015. Exploring associations between urban green, street design and walking: Results from the Greater London boroughs. Landsc Urban Plan 143:112-25.

Sobel, M.E., 1982. Asymptotic confidence intervals for indirect effects in structural equation models. Sociol. Methodol. 13:290-312.

Sugiyama, T., Merom, D., van der Ploeg, H.P., Corpuz, G., Bauman, A., Owen, N., 2012a. Prolonged sitting in cars: prevalence, socio-demographic variations, and trends. Prev. Med. 55:315-18.

Sugiyama, T., Neuhaus, M., Cole, R., Giles-Corti, B., Owen, N., 2012b. Destination and route attributes associated with adults' walking: a review. Med. Sci. Sports Exerc. 44:1275-86.

Sugiyama, T., Wijndaele, K., Koohsari, M.J., Tanamas, S.K., Dunstan, D.W., Owen, N., 2016. Adverse associations of car time with markers of cardio-metabolic risk. Prev. Med. 83:26-30.

Tachieva, G., 2010. Sprawl repair manual. Island Press, Washington.

Thorp, A.A., Owen, N., Neuhaus, M., Dunstan, D.W., 2011. Sedentary behaviors and subsequent health outcomes in adults: a systematic review of longitudinal studies, 1996–2011. Am. J. Prev. Med. 41:207-15.

Tsou, K.-W., Cheng, H.-T., 2013. The effect of multiple urban network structures on retail patterns – a case study in Taipei, Taiwan. Cities 32:13-23.

Turner, A., 2004. Depthmap 4, a researcher's handbook'.

U.S. Department of Health and Human Services, 2008. 2008 physical activity guidelines for Americans.

Table 1. Characteristics of study participants (n=16,345) (South-East Queensland, Australia, 2009)

Variable	**Mean (SD) or N (%)**
Age (years)	46.6 (16.0)
Gender	
Women	8564 (52.4%)
Employed	
Yes	11656 (71.3%)
living arrangements	
Single	2015 (12.3%)
Couple	12114 (74.1%)
Other	2216 (13.6%)
Household income (AUD$ per week)	
<$799	3008 (18.4%)
$800-1399	3251 (19.9%)
$1400-2499	5679 (34.7%)
≥$2500	4407 (27.0%)
Reported any home-based WT	1897 (11.6%)
Reported 30 min or more min of home-based WT	690 (4.2%)
Reported 60 min or more of car use	5684 (34.8%)

AUD: Australian dollar

WT: walking for transport

Table 2. Mediation analyses between street layout, availability of destinations, and travel behaviors (South-East Queensland, Australia, 2009)

Travel behaviors	c'-path OR (95% CI)	a-path *B* (95% CI)	b-path OR (95% CI)	Indirect effect (ab) *B* (95% CI)	Proportion mediation (%)
Any home-based WT	**1.05 (1.01, 1.08)**	**0.64 (0.60, 0.68)**	**1.21 (1.17, 1.25)**	**0.21 (0.17, 0.24)**	75.2
Over 30 min of home-based WT	1.00 (0.96, 1.05)	**0.64 (0.60, 0.68)**	**1.15 (1.10, 1.21)**	**0.16 (0.10, 0.21)**	93.7
Using a car over 60 min	0.99 (0.97, 1.00)	**0.64 (0.60, 0.68)**	**0.95 (0.93, 0.96)**	**-0.06 (-0.08, -0.04)**	73.0

Note: c'-path= association of street layout with travel behaviors adjusted for availability of local destinations, a-path = associations of street layout with availability of local destinations, b-path = associations of availability of destinations with travel behaviors, *B*= regression coefficients, OR = odds ratio, CI= confidence interval, WT= walking for transport, All models corrected for clustering at the SA1 level and adjusted for age, gender, employment, living arrangements, and household income.

Figure 1. Diagram showing mediation pathway between street layout, availability of destinations, and travel behaviors