Physical activity in relation to urban environments in 14 cities worldwide

a cross-sectional study

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Urban Environments in 14 Cities Worldwide Are Related to Physical Activity

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Abstract

Purpose: To document how objectively-measured urban environment attributes are related to objectively-measured physical activity, in an international sample of adults.

Methods: The International Physical activity and Environment Network (IPEN) Adult Study was a coordinated international study. The study design was to sample participants from neighbourhoods selected to be high or low on walkability and high or low on socioeconomic status. Present analyses were conducted with 6,822 adults aged 18–66 years from 14 cities in ten countries on five continents. Indicators of walkability, transit access, and park access were assessed in 1-km and 0·5-km street network buffers around each participant's residential address using Geographic Information Systems. Mean daily minutes of moderate-to-vigorous physical activity were measured by four to seven days of accelerometer monitoring. Associations of environmental attributes with physical activity were estimated using generalized additive mixed models with Gamma variance and logarithmic link functions.

Results: Four of six environmental attributes were significantly, positively, and linearly related to physical activity in single-variable models: net residential density, intersection density, public transit density, and number of parks. Mixed land use and distance to nearest public transit point were unrelated. The average difference in physical activity between residents living in low and high activity-friendly neighbourhoods ranged from 48 to 89 weekly minutes, which represent 33% to 60% of the 150 minutes per week health guideline.

Conclusion: Design of urban environments has the potential to contribute substantially to physical activity. Similarity of findings across cities suggests the promise of engaging urban planning, transportation, and parks sectors in efforts to reduce the health burden of the global physical inactivity pandemic.

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Physical inactivity is a global pandemic, responsible for over 5 million deaths per year[1] and is one of the United Nations' primary targets to reduce non-communicable diseases.[2,3] Improving urban environments to facilitate physical activity for transportation and recreation is a recommended strategy.[4,5]

People who live in walkable neighbourhoods that are densely populated, have interconnected streets, and are close to shops, services, restaurants, public transit, and parks tend to be more physically active than residents of less-walkable areas.[6,7] Studies of built environments and physical activity have been criticized for being conducted in a few countries, not capturing the full range of variability in urban form, and relying on self-report environmental measures.[6,8,9] International studies are needed to represent the full range of environmental variability. If findings are generally applicable across countries, then built environment interventions are likely to be viewed as relevant to non-communicable disease policies internationally.

The purpose of this 14-city/ten-country study was to document the strength, shape, and generalizability of associations of neighbourhood environment attributes with total moderate-to-vigorous physical activity. Objective measures of built environments and physical activity enhance precision and credibility of the findings.

Methods

Study design and neighbourhood selection

The International Physical Activity and Environment Network (IPEN) Adult Study is a multi-country cross-sectional epidemiologic study using a common design and comparable methods, described in detail elsewhere.[10] The study included participants from 17 cities in 12 countries: Australia (Adelaide, AUS), Belgium (Ghent, BEL), Brazil (Curitiba, BR), Colombia (Bogota, COL), Czech Republic (Olomouc and Hradec Kralove, CZ), Denmark (Aarhus, DEN), Hong Kong/China (HK), Mexico (Cuernavaca, MEX), New Zealand (North Shore, Waitakere, Wellington, and Christchurch, NZ), Spain (Pamplona, SP), the United Kingdom (Stoke-on-Trent, UK), and the United States of America (Seattle/King County, Washington and Baltimore, Maryland regions, US). The IPEN Adult study was designed to maximize variance in neighbourhood walkability and socioeconomic status (SES)[11] by identifying similar numbers of neighbourhoods stratified as follows: higher walkable/higher SES, higher walkable/lower SES, lower walkable/higher SES, and lower walkable/lower SES. Neighbourhood walkability index scores were created for small geographic areas in each city ("administrative units" equivalent to US Census block groups) using Geographic Information Systems (GIS),[11] with some differences by country.[10] Net residential density, intersection density, and land use mix variables were standardized, and the mean of the three z-scores was computed as the index. [11] The SES indicator was usually area-level income, but sometimes was education or a government-created composite.[10] Neighbourhoods that met criteria for the four types were selected, and participants were recruited from those neighbourhoods.

Participant recruitment

Households in selected neighbourhoods were identified using databases from commercial and government sources, with various methods used to obtain relatively representative samples in each neighbourhood, including recruitment by mail/telephone and personal visits.[10] In each selected household an adult was invited to complete a survey and wear an accelerometer to objectively measure physical activity. Study dates ranged from 2002 to 2011 across countries, with each country typically conducting recruitment over one full year. Each country obtained ethical approval from their local institutional review boards, and all participants provided informed consent.

Participants

The IPEN Adult study consisted of 14,222 adults aged 18–66 years. The current paper included 14 of the 17 cities (10,008 participants) from 10 countries where objective measures were available. Three cities were excluded because no accelerometer data were collected (Adelaide, Australia) or no GIS data were available (Pamplona, Spain; Hradec Kralove, Czech Republic). About half of Hong Kong participants had no GIS data. About one-quarter of participants did not wear an accelerometer, either because they did not consent or the investigators could not afford to collect accelerometer data on all participants (n=2,739). For cities able to collect accelerometer data on all participants, 87–100% provided complete data. Characteristics of the 6,822 participants with 4+ days of valid accelerometer data by study city are presented in Table 1. The percent of participants in each of the study quadrants was 26% in higher walkable/higher SES, 25% in higher walkable/lower SES, 27% in lower walkable/higher SES, and 22% in lower walkable/lower SES areas.

INSERT TABLE 1 ABOUT HERE

Outcome Measure: Physical Activity

Physical activity was measured objectively using accelerometers, a reliable, valid, and accepted method.[12–14] Participants were instructed to wear accelerometers for seven days around the waist, except during sleep, swimming, and showering. Except for New Zealand that used Actical devices (Philips Respironics), all countries used varying models of ActiGraph monitors (Pensacola, FL). Only vertical axis data were included in the scoring, expressed as counts per minute (cpm). For Actical data, new moderate (730–3399 cpm) and vigorous (≥3400 cpm) intensity cut points were developed to enable comparison with the ActiGraph estimates.[15] Sixty-second epochs were used in data collection, and non-wear time was defined as ≥60 consecutive minutes with zero cpm. Valid days had ≥10 hours of wear time. Participants with ≥4 valid days were included in analyses. These methods are consistent with recommendations and common practices.[12,16] Data were scored with MeterPlus 4·3 software (www.meterplussoftware.com), using Freedson's[17]cutpoint of 1952 cpm for moderate intensity to derive the outcome variable, mean minutes of moderate-to-vigorous intensity physical activity (MVPA) per valid day.

Independent Variables: Built Environment

Built environment variables were created using GIS software. "Buffers" or areas within 0·5-km and 1-km of participants' homes, reachable by the street network, were created to estimate accessible neighbourhood features. Templates were developed to guide international teams on constructing comparable GIS variables.[18] The templates were also used to document protocol adherence, which allowed for comparability evaluations. A description of GIS methods and variables, examples of data sources for each country, comparability evaluations, and descriptive results of variation in GIS-based environmental variables within and across cities has been published.[18] The following variables were adequately comparable across cities and were used in analyses: net residential density, street intersection density, retail and civic land use ratio (access to common destinations), public transit density, public park density, and distance to nearest transit. Table 2 provides definitions of variables and key terms. Table 3 presents descriptive findings for environmental variables overall and by city.

INSERT TABLES 2 AND 3 HERE

Covariates

Covariates included age, gender, education (<12 yrs/high school, high school graduation, university degree), marital status (married/living with partner vs. other), employment status (unemployed vs. employed), city, accelerometer wear time, and SES of administrative unit (low vs. high).

Data Analysis

Associations of environmental variables with physical activity (min/day) were estimated using generalized additive mixed models (GAMMs) with Gamma variance and logarithmic link functions, appropriate for the sampling strategy and distributional properties of the outcome variable.[19,20] These models also allow the simultaneous estimation of the amount of variability in participants' individual MVPA attributable to city-, administrative unit- and individual-level factors. Covariate-adjusted single-environmental-variable (SEV) and multiple-environmental-variable (MEV) GAMMs were estimated. The latter included only statistically significant ($p<0{\cdot}05$) buffer-specific environmental correlates for each buffer size. Environmental variables were entered simultaneously in the MEV GAMMs as collinearity was not problematic. Curvilinearity of relations was assessed using thin-plate spline smooth terms.[20] Separate GAMMs were run to estimate environmental features by study city interaction effects to assess heterogeneity in associations across cities. Significance of interactions was evaluated by comparing Akaike Information Criterion (AIC) values of models with and without an interaction term (≥10 difference indicated significance).[21] To quantify effect sizes of significant environmental correlates of MVPA, covariate-adjusted differences in weekly minutes of MVPA were estimated between participants living in areas (buffers) with the bottom 5% and top 5% of values of environmental correlates, and between participants living in areas with values of environmental correlates corresponding to the lowest and highest average city-level values. We also expressed these differences in activity in percentages of amount needed to meet the physical activity guidelines (i.e., percentages of 150 min/week of MVPA).[22]

To examine built environment contributions to city-, administrative-unit- (within-city), and person-level differences in physical activity, three-level GAMMs with random intercepts at the city and administrative unit levels adjusted and unadjusted for environmental features were estimated, and the percentage reduction in residual variances were computed. As only 2·2% of the cases had missing data, analyses were performed on complete cases. All analyses were conducted in R.

Results

On average, participants accumulated ~37 min/day of MVPA. Baltimore (USA) had the lowest (29·2 min) and Wellington (NZ) the highest average values of MVPA (50·1 min) (Table 1).The standard deviations of MVPA at the city, administrative-unit, and person levels were 6·3, 4·6, and 24·4 min/day, respectively. Higher variability at the person level was expected. Four of six environmental variables were significantly associated with MVPA in the single-environment-variable (SEV) models (Table 4). These four variables explained 0% to 11% and 7% to 11% of MVPA variability at the city and/or administrative-unit levels, respectively, but virtually no variance at the person (within-administrative-unit) level. Net residential density, intersection density, public transit density, and number of parks within participants' buffers were linearly and positively related with MVPA. Both buffer sizes were tested, and with the exception of number of parks, stronger relations were observed for variables calculated for 1-km rather than 0·5-km buffers. Table 4 reports relations for variables calculated for the most significant buffers (1-km or 0.5-km).

After adjusting for other environmental variables in the multiple-environmental variable (MEV) models, net residential density and public transit density remained significant, positive, and linear correlates of MVPA for both buffer sizes. In addition, number of parks significantly contributed to explaining MVPA in the model based on 0·5-km buffers (Table 4). The multiple-environmental variable models explained 11%-12% of the total MVPA variance.

INSERT TABLE 4 ABOUT HERE

Based on lack of significant environment by city interactions, we can conclude associations were generalizable across study cities, with the exception of number of parks in 0·5-km buffers. Specifically, positive associations between parks within 0·5-km buffers and physical activity in the single-variable model were found only in Ghent, Belgium (e^b = 1·772; 95% CI: 1·177, 2·669; p=·006) and Seattle, USA (e^b = 2·064; 95% CI: 1·399, 3·045; p<·001). After adjusting for other environmental variables, the park counts by city interaction was no longer significant, and a significant positive association of park counts with MVPA was observed across all cities (Table 4). Thus, there was evidence of similar relations of urban environment variables and physical activity across diverse cities. Analyses examining the shape of associations found no sufficient evidence for curvilinearity of effects. Therefore it can be concluded that environment associations with physical activity are linear.

Table 5 reports the estimated differences in min/week of MVPA between participants living in areas at the bottom 5% and top 5% of the sample values for specific significant environmental correlates, and in areas with values of environmental correlates equal to those of the cities with the lowest and highest average values. The differences in MVPA between residents living in areas at the bottom 5% and top 5% for specific single environmental features ranged from 21 to 32 min/week (5th column of Table 5). The differences in MVPA between participants living in areas with values of single environmental correlates equal to those of study cities with the lowest and highest average values ranged from 24 to 89 min/week. This corresponded to meeting between 16% and 59% of the recommended 150 min/week of physical activity (last column of Table 5). The estimated differences in min/week of MVPA between participants living in areas with all significant environmental correlates at the lowest and highest average city values ranged from 48 min/week (bottom 5% vs. top 5% sample values) to 89 min/week (lowest vs. highest average city values), equivalent to meeting 32% to 59% of the physical activity guidelines.

INSERT TABLE 5 ABOUT HERE

Discussion

This multi-country study identified urban environment attributes that accounted for large differences in adults' physical activity. Combinations of environmental features generally explained more variation in physical activity than single variables, suggesting a relatively comprehensive approach is needed to design activity-supportive neighbourhoods. When comparing participants living in the lowest 5% to the highest 5% of activity-supportive neighbourhoods, single environmental variables accounted for differences of 21–32 weekly minutes of moderate-to-vigorous physical activity, compared to ~49 weekly minutes in models including all significant environmental variables. When comparing participants living in areas similar to the cities with the most versus the least activity-supportive environments, single variables accounted for a difference of 24–89 weekly minutes of physical activity, compared to 68–89 minutes for combined variable models. Living in the most activity-friendly environments could help the average resident achieve 32% to 59% of the 150 minute/week physical activity guidelines. These observed effect sizes suggest that designing urban environments to be activity-supportive could have large effects on physical activity, and those effects can be expected to generally apply to adults living in the neighbourhoods as long as they live there. Such widespread and long-term effects are in contrast to programs that target individuals and tend to reach small numbers of people and produce short-term effects.[23]

Three environmental attributes had significant independent associations with total moderate-to-vigorous physical activity: net residential density, public transit density, and park density. Net residential density's strong associations were consistent with many other studies.[24] High residential density is generally considered necessary for other components of walkability, because it takes local patronage to support nearby shops and services and enough riders to support frequent transit service.[25] Density of public transit stops was independently related to total activity. It is notable that transit density was a significant correlate of MVPA, but distance to nearest transit stop was not significant. One interpretation is that having multiple options for transit lines makes it more likely that residents could walk to a transit facility that meets their needs. Transit access has been studied less often in relation to physical activity.[6,24] Good transit access is a requirement for living a less car-dependent lifestyle.[26] Particularly in the middle-income cities in the sample, car ownership was low, and in these settings active transport could represent necessity and not choice. Thus, it will be useful to examine the role of public transit access among car owners and non-owners. The third significant variable in the final model was number of parks in the 0·5-km buffer. Park density is a relatively consistent correlate of adult physical activity.[6,24] Though parks are usually seen as supporting recreational activities through facilities and aesthetics, nearby parks can also be a destination for active transportation. Thus, the most well-supported environmental variables were likely related to total physical activity through their effects on both recreational and transportation activities.

All observed associations were linear, so neither a threshold nor a point of diminishing returns was seen for environmental attributes. Present findings, with likely the widest range of environmental variables yet reported, support a recommendation that higher levels of residential density, transit access, and local parks should be recommended when designing physical activity-supportive environments.

The measure of mixed land use was not related to physical activity in the present study though it is one of the more consistent correlates of physical activity.[6,24] Proximal (e.g., within 1-km buffers) retail shops and services provide commonly-used destinations that stimulate frequent walking. Because of the large variation in the retail/civic land use ratio within and between countries, the non-significant results were surprising. One possible explanation is the limitations of the GIS-based measure. Because most countries only had data on the land area devoted to each use, as opposed to building floor area, it was impossible to tell whether each use was operating on part of the parcel or on several floors of a building covering the entire parcel. A related limitation was that the data were based on number of parcels, not number of shops or offices, which might be more strongly related to frequency of use and thus to physical activity. In middle-income cities with high prevalence of walking for transport, many shops were not registered, including those in permanent buildings as well as informal markets and street vendors. These data limitations could have reduced power to detect an association.

Intersection density is an indicator of street connectivity which provides direct pathways for pedestrians and vehicles. This variable was significant in single-variable models, but not the full models, suggesting a confounding effect with other variables, such as residential density or public transit density.[25]

An important finding was the strong support for the similarity or generalizability of built environment--physical activity associations across countries diverse in income, culture, and activity-supportiveness. The diversity of the study cities in climate, demographics [10] and built environments [18] was documented in prior publications. Present results suggest systematic principles of environments that support physical activity apply on a global scale. Generalizable associations with physical activity were also found in analyses of self-reported environment measures in the same study.[19]

Study strengths included the use of objective measures of both urban environments and physical activity, comparable variables across diverse countries, examination of two buffer sizes, and analyses that tested for curvilinear effects and generalizability of associations across cities. Limitations included small number of environmental variables that could be assessed through common environmental measures, likely variations in the quality of those measures across countries, lack of representation of low-income countries, modest sample size in some cities that reduced power to detect environment by city interactions, and cross-sectional design. Another limitation is covariates may have different meanings and functions across countries. Other patterns of association may be found with other age groups, and built environment correlates are expected to differ by physical activity outcome. Lack of adjustment for self-selection into neighbourhoods is a common criticism of built environment studies,[27] but not all countries in the present study included measures that assessed reasons for neighbourhood selection.

Conclusions and Recommendations

Recommendations for research are to expand the number of countries, especially low-income countries, in which urban environment--physical activity associations are examined; develop objective measures of environmental attributes for other physical activity-relevant environmental attributes, such as sidewalks, pedestrian zones, bicycle facilities, and intersection quality (e.g., crosswalks, pedestrian signals, traffic calming); conduct prospective studies; and conduct quasi-experimental evaluations of improvements in urban environments.

A recommendation for practice is to make the creation of activity-supportive environments a regular function of public health agencies globally by working with sectors outside of public health. Regular assessment and reporting (i.e., surveillance) of the quality of activity-supportive environments is a vital component of efforts to foster their creation. Health department staff should seek training, develop collaborations, and become advocates for improved policies in city planning, transportation, and parks agencies.

Design of urban environments has the potential to contribute nearly 90 minutes per week of physical activity, which is 60% of the 150 minutes per week physical activity guideline. These potentially large effects of built environments were found to apply similarly across ten diverse countries, indicating urban design should be a globally-relevant public health priority. Building, retrofitting, and maintaining physical activity-supportive features in cities around the world to increase residential density, provide good transit service, and ensure access to parks would be expected to substantially increase physical activity in the population on a permanent basis and contribute to meeting United Nations' goals for reducing non-communicable diseases.[2,3] Study findings provide an impetus for public health proponents to collaborate with other sectors, including environmental sustainability groups, to promote physical activity-supportive development as a means to reduce energy consumption, greenhouse gas emissions and air pollution,[11,28] while achieving health and economic benefits.[29]

Panel: Research in Context

Systematic Review

A paper in the 2012 Lancet Series on Physical Activity included a review of reviews of the literature on built environments and physical activity.[6] The review identified the most consistently-supported environmental correlates, two other papers critiqued reviews[24,8] and this information provided a context for interpreting present results. The Bauman et al.[6] Lancet Series review also commented that most of the studies to date had been conducted in high-income countries and encouraged more international studies that included low-and middle-income countries.

Interpretation

This high- and middle-income ten-country study provides novel evidence for the role of built environments in promoting physical activity globally. Credibility of the findings is enhanced by using objective measures for both exposure and outcome variables. The global relevance of urban environment attributes – particularly residential density, public transit access and park availability – for physical activity is supported by evidence of similar relationships across diverse countries.

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References

1 Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: and analysis of burden of disease and life expectancy. *Lancet* 2012; 380: 219–99.

2 Beaglehole R, Bonita R, Horton R, et al. Priority actions for the non-communicable disease crisis. *Lancet* 2011; **377**: 1438–47.

3 WHO. Draft comprehensive global monitoring framework and targets for the prevention and control of noncommunicable diseases, sixty-sixth World Health Assembly, 15 March 2013. Geneva: World Health Organization, 2013. http://apps.who.int/gb/ebwha/pdf_files/WHA66/A66_8-en.pdf?ua=1 (accessed June 26, 2015).

4 Kohl HW 3rd, Craig CL, Lambert EV, et al, for the Lancet Physical Activity Series Working Group. The pandemic of physical inactivity: global action for public health. *Lancet* 2012; 380: 294–305.

5 WHO. Global strategy on diet, physical activity and health. Geneva: World Health Organization May 2004. http://www.who.int/dietphysicalactivity/en/ (accessed June 25, 2015).

6 Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJF, Martin BW, on behalf of the Lancet Physical Activity Series Working Group. Correlates of physical activity: why are some people physically active and others not? *Lancet* 2012; 380, 258–71.

7 Heath G, Brownson R, Kruger J, et al. The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. *J Phys Act Health* 2006; 3: S55–71.

8 Ding D, Gebel K. Built environment, physical activity, and obesity: what have we learned from reviewing the literature? *Health Place* 2012; 18: 100–05.

9 van Holle V, Deforche B, van Cauwenberg J, et al. Relationship between the physical environment and different domains of physical activity in European adults: a systematic review. *BMC Public Health* 2012; 12: 807.

10 Kerr J, Sallis JF, Owen N, et al. Advancing science and policy through a coordinated international study of physical activity and built environments: IPEN methods. *J Phys Act Health* 2013; 10: 581–601.

11

Frank LD, Sallis JF, Saelens BE, et al. The development of a walkability index: Application to the Neighborhood Quality of Life Study. *British Journal of Sports Med* 2010; 44: 924-933.

12 Freedson PS, Miller K. Objective monitoring of physical activity using motion sensors and heart rate. *Res Q Exerc Sport* 2000; 71: S21–29.

13 Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* 2008; 40: 181–88.

14 Welk GJ. Use of accelerometry-based activity monitors to assess physical activity. In: Welk G.J., ed. Physical activity assessments for health-related research. Champaign, IL: Human Kinetics, 2002: 125–42.

15 Cain K. Accelerometer scoring protocol for the IPEN-adult study. University of California San Diego, CA. 2013. http://www.ipenproject.org/documents/methods_docs/IPEN_Protocol.pdf. Accessed 1 July, 2015.

16 Winkler EA, Paul A, Healy GN, Clark BK, Sugiyama T, Matthews CE, Owen NG. Distinguishing true sedentary from accelerometer non-wearing time: Accuracy of two automated wear-time estimations. *Med Sci Sports Exerc* 2009; 41(5): 171–172.

17 Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. *Med Sci Sports Exerc* 1998; 30: 777–81.

18 Adams MA, Frank LD, Schipperijn J, et al. International variation in neighborhood walkability, transit, and recreation environments using Geographic Information Systems: the IPEN Adult Study. *Int J Health Geogr* 2014; **13**: 43. DOI: 10.1186/1476-072X-13-43

19 Cerin E, Cain K, Conway TL, et al. Neighborhood environments and objectively measured physical activity in 11 countries. *Med Sci Sports Exerc* 2014; 46: 2253–64.

20 Wood SN. Generalized additive models: an introduction with R. Boca Raton, FL: Chapman and Hall, 2006.

21 Burnham KP, Anderson DR. Model selection and multimodel inference: a practical information-theoretic approach. 2nd edn. New York, NY: Springer, 2002.

22 US Department of Health and Human Services. Physical Activity Guidelines Advisory Committee Report. 2008. http://www.health.gov/paguidelines/guidelines/#committee (accessed June 26, 2015).

23 Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J. An ecological approach to creating more physically active communities. *Annu Rev Public Health*, 2006; **27**: 297–322.

24 Gebel K, Bauman AE, Petticrew M. The physical environment and physical activity: a critical appraisal of review articles. *Am J Prev Med*, 2007; 32: 361–69.

25 Frank LD. Land use and transportation interaction: implications on public health and quality of life. *J Planning Edu Res* 2000; **20**: 6–22.

26 Shoham DA, Dugas LR, Bovet P, Forrester TE, Lambert EV, Plange-Rhule J, Schoeller, DA, Brage S, Ekelund U, Durazo-Arvizu RA, Cooper RS, Luke A. Association of car ownership and physical activity across the spectrum of human development: Modeling the Epidemiologic Transition Study (METS). *BMC Public Health*, 2015; *15*:173. http://doi.org/10.1186/s12889-015-1435-9

27 Cao X, Mokhtarian P, Handy S. Examining the impacts of residential self-selection on travel behavior: a focus on empirical findings. *Transport Reviews* 2009; 29: 359–95.

28 Ewing R, Bartholomew K, Winkelman S, Walters J, Chen D. Growing cooler: the evidence on urban development and climate change. Washington, DC: Urban Land Institute, 2008.

29 Sallis JF, Spoon C, Cavill N, et al. Co-benefits of designing communities for active living: an exploration of literature. *Int J Behav Nutr Phys Act* 2015; 12**:** 30. DOI 10.1186/s12966-015-0188-2.

Table 1: Descriptive Statistics Of Sample Socio-Demographic Characteristics And Accelerometer-Based Moderate-To-Vigorous Physical Activity

Socio-demographics	ALL CITIES	BEL[1]	BRA[2]	COL[2]	CZE[1]	DEN[2]	HK[2]	MEX[1]	NZ				UK[2]	USA	
									City A[1]	City B[1]	City C[1]	City D[1]		City E[1]	City F[1]
N with ≥4 day valid PA data (*% sample*)	6,822 (68)	1,050 (90)	330 (47)	223 (23)	258 (78)	272 (42)	269 (56)	656 (97)	373 (73)	399 (78)	416 (84)	373 (75)	135 (16)	1198 (93)	870 (95)
Age, years *Mean (SD)*	43 (12)	43 (13)	42 (13)	46 (12)	39 (14)	40 (14)	42 (13)	42 (13)	43 (12)	42 (11)	40 (12)	43 (12)	44 (13)	44 (11)	47 (11)
Gender, *%men*	46·4	48·5	48·5	31·8	36·1	39·0	40·5	45·7	37·4	40·4	47·6	45·6	46·7	55·0	48·7
Education, *%*															
Less than HS	12·4	4·3	27·9	46·6	23·0	7·4	36·4	43·9	2·4	3·8	0·5	8·6	38·8	1·1	1·8
HS graduate	38·4	32·7	31·2	36·3	43·5	42·3	23·1	28·8	58·3	64·7	45·0	57·0	46·3	34·9	29·6
College or more	49·3	63·0	40·9	17·0	33·5	50·4	40·5	27·3	39·3	31·6	54·6	34·4	14·9	64·0	68·6
Work status, *%working*	78·9	80·3	79·4	60·5	77·9	75·4	62·7	71·5	76·4	86·2	87·5	85·5	64·4	81·4	83·0
Marital status, *%couple*	64·8	73·4	60·3	61·4	60·3	69·1	56·1	64·8	71·1	76·1	60·1	57·1	45·9	64·1	61·1
Accelerometer variables															
Valid days of accel wear time, *Mean (SD)*	6·5 (1·1)	6·7 (1·1)	6·7 (1·0)	6·6 (1·0)	6·2 (1·2)	7·0 (0·8)	5·9 (1·0)	5·7 (1·0)	6·4 (1·3)	6·4 (1·3)	6·7 (1·3)	6·5 (1·3)	6·6 (1·0)	6·7 (0·8)	6·7 (1·2)
Accel wear time (hrs/day) *Mean (SD)*	14·4 (1·3)	14·7 (1·3)	14·0 (1·3)	13·9 (1·2)	13·9 (1·4)	14·9 (1·1)	14·4 (1·4)	14·0 (1·4)	14·2 (1·2)	14·1 (1·3)	14·0 (1·2)	14·0 (1·2)	14·6 (1·2)	14·7 (1·3)	14·8 (1·4)
MVPA (min/day)* *Mean (SD)*	37·3 (26·5)	35·5 (23·5)	31·5 (24·6)	37·0 (26·4)	47·1 (27·7)	39·7 (23·2)	44·9 (25·3)	31·2 (25·2)	45·7 (28·4)	37·2 (29·2)	50·1 (31·0)	44·0 (32·5)	36·7 (27·3)	36·3 (24·9)	29·2 (22·0)
Median (IQR)	32·1 (32·2)	31·2 (25·3)	25·2 (27·9)	31·8 (28·9)	44·2 (34·5)	34·8 (29·4)	42·2 (33·3)	25·5 (28·9)	41·8 (35·2)	31·4 (33·0)	44·9 (33·9)	37·9 (38·9)	32·0 (32·9)	31·2 (31·0)	23·7 (29·1)

Notes: City A: North Shore, B: Waitakere, C: Wellington, D: Christchurch, E: Seattle, F: Baltimore; HS=high school; MVPA = moderate-to-vigorous physical activity; SD = standard deviation; IQR = interquartile range; valid days of accelerometer wear are those with 10+ valid hours of wear; accel = accelerometer; * = average for valid days.

[1] Study City aimed to collect accelerometer data in the total sample

[2] Study City aimed to collect accelerometer data in a fixed proportion of the total sample

Table 2: Definitions and built environment variables measured using Geographic Information Systems (GIS) around participants' homes.

Variables	Definitions
Administrative units	Geographic areas with government-defined spatial boundaries in which population or socioeconomic (SES) data are available. IPEN investigators selected the administrative unit in each country that roughly represented a small neighborhood-level geographic scale (about 600 to 1,500 people) with available and best-quality SES and GIS data. Examples include New Zealand meshblocks, US census block groups, and Hong Kong tertiary planning units. Administrative units were used for a-priori identification of study neighborhoods representing high and low walkable and high and low SES, respectively, in each city.
Parcel	A parcel is a division of immovable land created for taxation purposes and defined by its ownership, size, shape (boundaries), and functional land use.
Participant buffers	An irregular shaped polygon around a participant's home address (geocoded). Buffer polygons were created for two distances (e.g. 0·5-km and 1-km) in ESRI's ArcGIS software (Redlands, CA) by tracing through their unique street network in all directions to approximate accessible areas. The "detailed no trim" setting was used. The total area of the buffer was used as the denominator for density variables (except for residential land density). These buffer sizes are used to define attributes within walking distances of participants' homes.
Net residential density (NRD)	Number of residential dwellings (i.e., houses, apartments) divided by the residential land area (derived from residential parcels only) within participants' buffers.
Intersection density	Number of pedestrian-accessible street intersections divided by the area within participants' buffers. Intersections on limited access roads (e.g., limited-access highways and onramps) were excluded.
Retail and civic land use ratio	Ratio of retail (including food and entertainment) and civic (public buildings) parcel land areas to participants' buffer areas. These land uses are common destinations participants could reach by walking. A value of zero indicates the absence of retail/civic destinations within participants' buffers, which is typical in predominantly residential neighbourhoods, and a value of 1·0 indicates retail and civic land uses dominate participants' buffers.
Public transit density	Number of bus, rail, or ferry stops and stations divided by the land area within participants' buffers. The complexity was reflected by a variety of modes (i.e., bus, rail and ferry) and mode types (e.g., regular bus vs. bus rapid transit, light vs. heavy rail) present within and across cities.
Distance to nearest transit	Distance in meters via the street-network from participant homes to the nearest stop or station.
Public park density	Number of public parks of any size contained in or intersected by the buffer, divided by the land area within participants' buffers. A public park was defined as a government-designated park of any size that was free and

	open to the public and maintained by a government agency. Parks included improved and unimproved areas.

Table 3: Descriptive statistics of objectively-assessed environmental attributes

Environmental attribute	ALL CITIES	BEL	BRA	COL	CZE	DEN	HK	MEX	NZ				UK	USA	
									City A	City B	City C	City D		City E	City F
Net residential density (per km^2) – 1 km buffer															
Mean (SD)	6682 (12522)	7853 (6795)	5993 (3950)	9273 (3248)	18086 (9808)	7115 (5649)	57322 (25592)	2237 (933)	1764 (739)	2029 (738)	4203 (4973)	1658 (360)	4579 (1447)	3015 (3574)	2498 (2330)
Median (IQR)	2493 (4298)	5214 (11425)	4652 (2982)	8995 (5049)	18810 (15088)	4635 (9545)	65456 (43080)	2202 (1133)	1735 (302)	2126 (965)	1909 (4137)	1544 (487)	4161 (1150)	2183 (1888)	1585 (3143)
Net residential density (per km^2) – 0·5 km buffer															
Mean (SD)	7025 (13355)	7246 (6894)	6338 (5262)	12997 (5147)	19219 (15579)	8398 (7633)	57276 (30728)	2619 (1964)	1748 (382)	2665 (1476)	3559 (3014)	1669 (447)	4471 (1674)	3328 (4471)	3424 (4505)
Median (IQR)	2729 (4684)	5190 (8333)	4776 (3394)	12475 (6034)	14880 (17387)	4661 (14876)	60912 (56476)	2309 (1800)	1790 (445)	2462 (1068)	1767 (3459)	1552 (643)	3979 (1422)	2244 (2001)	1774 (3509)
Intersection density (per km^2) – 1 km buffer															
Mean (SD)	76 (57)	84 (62)	76 (16)	227 (91)	67 (20)	83 (22)	128 (58)	146 (47)	27 (7)	28 (10)	42 (15)	35 (6)	93 (29)	71 (22)	55 (28)
Median (IQR)	65 (57)	73 (57)	72 (19)	234 (148)	67 (26)	86 (26)	129 (88)	135 (57)	27 (9)	28 (7)	43 (17)	36 (8)	87 (39)	71 (29)	53 (28)
Intersection density (per km^2) – 0·5 km buffer															
Mean (SD)	87 (69)	86 (61)	84 (23)	249 (111)	75 (25)	105 (31)	174 (79)	174 (72)	31 (12)	35 (18)	42 (21)	37 (9)	113 (37)	76 (28)	64 (40)
Median (IQR)	71 (69)	74 (73)	80 (26)	222 (178)	75 (28)	105 (40)	162 (94)	166 (115)	31 (19)	33 (16)	40 (28)	36 (13)	116 (52)	77 (38)	59 (39)
Ratio retail and civic land area to total buffer area – 1 km buffer*															
Mean (SD)	0·17 (0·24)	0·14 (0·13)	0·16 (0·10)	0·12 (0·09)	0·06 (0·06)	0·52 (0·42)	0·54 (0·24)	0·17 (0·12)	0·12 (0·27)	0·10 (0·13)	0·31 (0·52)	0·18 (0·31)	0·04 (0·04)	0·08 (0·06)	0·12 (0·13)
Median (IQR)	0·09 (0·16)	0·09 (0·22)	0·13 (0·10)	0·08 (0·13)	0·04 (0·05)	0·44 (0·64)	0·58 (0·21)	0·15 (0·20)	0·08 (0·10)	0·07 (0·08)	0·11 (0·25)	0·06 (0·10)	0·02 (0·04)	0·06 (0·10)	0·08 (0·13)

Ratio retail and civic land area to total buffer area – 0·5 km buffer*															
Mean (SD)	0·17 (0·33)	0·16 (0·21)	0·14 (0·11)	0·10 (0·08)	0·07 (0·09)	0·74 (0·76)	0·73 (0·44)	0·17 (0·16)	0·14 (0·31)	0·08 (0·15)	0·28 (0·60)	0·08 (0·30)	0·05 (0·07)	0·07 (0·09)	0·11 (0·21)
Median (IQR)	0·07 (0·17)	0·09 (0·22)	0·13 (0·13)	0·07 (0·10)	0·04 (0·04)	0·49 (0·91)	0·65 (0·45)	0·14 (0·26)	0·06 (0·16)	0·01 (0·09)	0·07 (0·21)	0·02 (0·07)	0·01 (0·06)	0·04 (0·10)	0·05 (0·13)
Transit density – 1 km buffer															
Mean (SD)	15·8 (12·9)	9·4 (6·3)	25·8 (7·3)	2·2 (2·6)	13·6 (5·4)	9·4 (4·6)	12·0 (8·2)	29·1 (24·4)	19·0 (7·3)	9·0 (7·1)	16·6 (8·6)	16·0 (9·0)	25·3 (7·9)	15·9 (9·7)	16·9 (13·6)
Median (IQR)	14·3 (15·3)	7·7 (11·3)	25·0 (9·3)	1·2 (3·3)	14·5 (8·7)	9·1 (6·8)	13·0 (12·9)	26·0 (28·0)	20·1 (10·5)	6·9 (8·1)	14·9 (10·2)	16·2 (10·5)	24·0 (12·0)	15·7 (13·8)	15·7 (17·0)
Transit density – 0·5 km buffer															
Mean (SD)	17·0 (17·0)	10·4 (9·8)	24·0 (11·5)	2·4 (4·5)	15·0 (9·1)	10·9 (7·1)	13·0 (13·2)	33·3 (35·6)	20·1 (12·2)	8·4 (7·5)	19·4 (12·2)	16·8 (14·7)	28·2 (13·7)	16·8 (13·1)	18·0 (17·7)
Median (IQR)	14·1 (20·0)	8·6 (11·0)	23·5 (15·1)	0·0 (2·7)	14·4 (12·0)	10·8 (10·5)	11·2 (20·0)	25·2 (49·0)	20·0 (14·9)	7·6 (10·0)	20·7 (13·4)	15·8 (17·4)	26·4 (16·9)	16·8 (21·9)	15·5 (26·7)
Street network distance to nearest transit stop or station (m)															
Mean (SD)	421 (638)	317 (284)	178 (111)	1863 (1525)	265 (173)	303 (230)	426 (350)	501 (659)	245 (216)	343 (266)	222 (284)	300 (240)	212 (136)	382 (439)	639 (1017)
Median (IQR)	242 (305)	258 (211)	161 (165)	1193 (2828)	232 (119)	235 (234)	353 (301)	239 (489)	186 (245)	297 (314)	147 (241)	242 (297)	189 (199)	227 (321)	238 (433)
Number of parks contained or intersected by buffer – 1 km buffer															
Mean (SD)	5·5 (6·5)	3·8 (3·6)	6·0 (4·6)	25·4 13·3	3·7 (4·4)	4·4 (3·4)	13·5 (10·0)	1·5 (2·1)	12·3 (6·5)	8·7 (3·9)	4·6 (2·5)	5·6 (2·5)	2·8 (1·5)	3·8 (2·9)	2·4 (2·1)
Median (IQR)	4·0 (6·0)	3·0 (5·0)	5·0 (6·0)	24·0 (20·0)	2·0 (4·0)	4·0 (4·0)	11·0 (14·0)	1·0 (1·0)	11·0 (8·0)	8·0 (5·0)	4·0 (4·0)	6·0 (4·0)	2·0 (2·0)	3·0 (5·0)	2·0 (2·0)
Number of parks contained or intersected by buffer – 0·5 km buffer															
Mean (SD)	1·8 (2·3)	1·2 (1·3)	2·0 (2·3)	7·4 (4·6)	1·1 (1·6)	1·3 (1·4)	4·0 (3·5)	0·6 (0·9)	4·1 (2·7)	3·5 (2·6)	1·4 (1·0)	1·6 (1·2)	1·3 (0·9)	1·2 (1·2)	0·9 (1·0)
Median (IQR)	1·0 (2·0)	1·0 (2·0)	1·0 (3·0)	7·0 (6·0)	1·0 (2·0)	1·0 (2·0)	3·0 (4·0)	0·0 (1·0)	4·0 (4·0)	3·0 (3·0)	1·0 (2·0)	1·0 (1·0)	1·0 (1·0)	1·0 (2·0)	1·0 (1·0)

Notes: City A: North Shore, B: Waitakere, C: Wellington, D: Christchurch, E: Seattle, F: Baltimore; SD = standard deviation; IQR = interquartile range; * values truncated to 3·1 (1 value truncated for 1km buffer measure and 22 for 0·5km buffer measure).

Table 4 Pooled associations of environmental attributes with daily minutes of moderate-to-vigorous physical activity (N= 6,679)

Environmental variable (unit of measurement)	Model	Buffer size (km)	exp(b)	exp(95% CI)	p
Net residential density (1000 dwellings / km^2)	SEV	1	1·006	(1.003, 1.009)	<.001
	MEV	1	1·004	(1.001, 1.007)	.006
Intersection density (100 intersections / km^2)	SEV	1	1.069	(1.011, 1.130)	.019
	MEV	1	-	-	-
Ratio of retail combined and civic land area to total buffer	SEV	1	1.056	(0.964, 1.157)	.238
	MEV	1	-	-	-
Transit density (10 transit points / km^2)	SEV	1	1.037	(1.018, 1.056)	<.001
	MEV	1	1.030	(1.011, 1.049)	.006
# parks contained or intersected by buffer (10 parks / km^2)*	SEV	0·5	1.146	(1.033, 1.272)	.010
	MEV	0·5	1.111	(1.000, 1.233)	.046
Street network distance to nearest transit stop (1000m)	SEV	1	1.033	(0.996, 1.071)	.078
	MEV	1	-	-	-

Notes. *Estimates adjusted for net residential density, intersection density and transit density. SEV = single-environmental-variable; MEV = multiple-environmental-variable (only significant environmental correlates included); exp(b) = antilogarithm of regression coefficient; exp(95% CI) = antilogarithm of confidence intervals; - = not applicable. All regression coefficients are adjusted for respondents' age, sex, marital status, educational attainment, employment status, administrative-unit socio-economic status, accelerometer wear time, and study city. exp(b) is to be interpreted as the proportional increase in physical activity associated with a 1 unit of measurement increase in the predictor (e.g., 1000 dwellings / km^2 is a 1 unit of measurement for net residential density, and 10 transit points / km^2 is for 1 unit of measurement for transit density). Only the most significant buffer size is reported.

Table 5: Differences in estimated moderate-to-vigorous physical activity (MVPA) between participants with low and high values on significant environmental correlates

		5% bottom and 5% top values of environmental correlate		Differences in weekly minutes of MVPA between bottom 5% and top 5% values of correlate (95% CI)	Lowest and highest average study-city values on environmental correlate		Differences in weekly minutes of MVPA between lowest and highest average study-city values of correlate (95% CI)
		5% bottom	**5% top**		**Lowest**	**Highest**	
Model	Environmental correlate						
SEV	Net residential density – 1km bf	710	21078	29 (12, 46) 19% of PAG	1658	57322	89 (38, 147) 59% of PAG
	Intersection density – 1km bf	16	198	31 (5, 60) 21% of PAG	27	227	34 (5, 68) 23% of PAG
	Public transit density – 1km bf	0	35	32 (17, 52) 21% of PAG	2·2	29·1	24 (12, 36) 16% of PAG
	No. of parks contained or intersected by 0·5km bf	0	6	21 (5, 37) 14% of PAG	0·6	7·4	24 (5, 43) 16% of PAG
MEV	Net residential density – 1km bf	710	21078	49 (15, 86)	1658	57322	89 (29, 161)
	Public transit density – 1km bf	0	35	33% of PAG	2·2	29·1	59% of PAG
	Net residential density – 0·5km bf	652	28917	48 (6, 78)	1669	57276	68 (11, 144)
	Public transit density – 0·5km bf	0	46	32% of PAG	2·4	33·3	45% of PAG
	# Parks contained or intersected by 0·5km bf	0	6		0·6	7·4	

Notes. * The residual variability in MVPA at a specific level is expressed in standard deviations (after adjusting for socio-demographics and accelerometer-wear time). 95% CI = 95% confidence intervals; bf = buffer; SEV = single-environmental-variable; MEV = multiple-environmental-variable (only significant environmental correlates included); PAG = physical activity guidelines (total recommended amount of 150 min/week of MVPA). Only the most significant buffer size is reported