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Research Articles

253 Lifetime Direct Medical Costs of Treating Type 2 Diabetes and Diabetic Complications
X Zhuo, P Zhang, TJ Hoerger

262 Physical Activity and the Incidence of Obesity in Young African-American Women
L Rosenberg, KL Kipping-Ruane, DA Boggs, JR Palmer

269 Walkability and Physical Activity: Findings from Curitiba, Brazil
RS Reis, AAF Hino, CR Rech, J Kerr, PC Hallal

276 Sitting-Time, Physical Activity, and Depressive Symptoms in Mid-Aged Women
JGZ van Uffelen, YR van Gellecum, NW Burton, G Peeters, KC Heesch, WJ Brown

282 Active Travel to Work and Cardiovascular Risk Factors in the United Kingdom
AA Laverty, JS Mindell, EA Webb, C Millett

289 Objective Food Environments and Health Outcomes
LM Minaker, KD Raine, TC Wild, CIJ Nykiforuk, ME Thompson, LD Frank

297 Evaluating a Standardized Measure of Healthcare Personnel Influenza Vaccination
MC Lindley, SA Lorick, A Geevarughese, S-J Lee, M Makvandi, BL Miller, DA Nace, C Smith, F Ahmed

304 Access to Preventive Health Care for Cancer Survivors
KR Yabroff, PF Short, S Machlin, E Dowling, H Rozjabek, C Li, T McNeel, DU Ekwueme, KS Virgo

Brief Reports

313 The Nutrition and Enjoyable Activity for Teen Girls Study: A Cluster Randomized Controlled Trial
DL Dewar, PJ Morgan, RC Plotnikoff, AD Okely, CE Collins, M Batterham, R Callister, DR Lubans

Review and Special Articles

318 Prostate-Specific Antigen and Prostate Cancer Mortality: A Systematic Review
LP Wallner, SJ Jacobsen

327 Agricultural Subsidies and the American Obesity Epidemic
C Franck, SM Grandi, MJ Eisenberg

334 Analysis of Legal and Scientific Issues in Court Challenges to Graphic Tobacco Warnings
JD Kraemer, SA Baig

343 Adverse Health Effects of Nighttime Lighting: Comments on American Medical Association Policy Statement
RG Stevens, GC Brainard, DE Blask, SW Lockley, ME Motta

347 Commercial Host (Dram Shop) Liability: Current Status and Trends
JF Mosher, EN Cohen, DH Jernigan

Research and Practice Methods

354 Children in the Public Benefit System at Risk of Maltreatment: Identification Via Predictive Modeling
R Vaithianathan, T Maloney, E Putnam-Hornstein, N Jiang

From APTR & ACPM

360 Policies to Restrict Secondhand Smoke Exposure: American College of Preventive Medicine Position Statement
M Jacobs, AM Alonso, KM Sherin, Y Koh, A Dhamija, AL Lowe, and the ACPM Prevention Practice Committee

Current Issues

368 Licensure Challenges in Preventive Medicine: A Public Policy Issue
SK Hull, ND Kohatsu, CB Schechter, HH Tilson

Editorials and Commentary

373 Integrated Health and Human Services Information Systems to Enhance Population-Based and Person-Centered Service
N Macchione, W Wooten, N Yphantides, JR Howell

Departments

375 Media Reviews and Reports

377 Corrections

Video podcast available online at www.ajpmonline.org
CME available online at www.ajpmonline.org

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Walkability and Physical Activity
Findings from Curitiba, Brazil

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Background: Evidence from developing countries is limited on how income level for a given neighborhood is related to physical activity among its residents.

Purpose: The goal of the study was to examine the association between walkability and physical activity outcomes, and the effect of income on the relationship between walkability and physical activity in adults.

Methods: The Spaces for Physical Activity in Adults Study (ESPACOS Project) took place in Curitiba, Brazil. Data were collected in 2010 in 32 census tracts selected to vary in income and walkability, as measured by GIS. Participants were 697 individuals aged 18–65 years (52.0% were women) randomly sampled from the selected neighborhoods. The International Physical Activity Questionnaire was used to measure physical activity. All analyses were conducted in 2012.

Results: The proportion of those who walked for transportation for ≥150 minutes/week was 21.1% in low-walkability areas, and ranged from 33.5% to 35.0% in high-walkability areas. A total of 12.6% of residents were found to walk for leisure for ≥150 minutes/week; this result did not vary across quadrants of walkability and income level. The prevalence of leisure-time moderate-to-vigorous physical activity (MVPA) was 7.1–10.5 percentage points higher in high-compared to low-walkability areas. After adjusting for all individual confounders, walkability showed an independent association with walking for transport (OR=2.10, 95% CI=1.31, 3.37, p=0.002) and leisure-time MVPA (OR=1.57, 95% CI=1.06, 2.32, p=0.024). Neighborhood income level was independently associated with leisure-time MVPA (OR=1.70, 95% CI=1.06, 2.74, p=0.029). No association was found between walkability and walking for leisure. No interaction was found between walkability and neighborhood income level.

Conclusions: This study, among adults living in Curitiba, Brazil, confirms findings from studies of high-income countries showing that walkability is positively associated with physical activity. People living in high-walkability areas were more likely to be physically active regardless of their neighborhood income level.
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Introduction

Various characteristics of urban form have been associated with physical activity, such as land-use mix, residential density, street connectivity,[1] and proximity to public transportation.[2] More recently, walkability (characterized by high residential density, land-use mix, and street connectivity) has been used to identify built environment characteristics that in combination may affect commuting and leisure-time physical activity.[3] Several studies have found a positive association between walkability and physical activity among adults in high-income countries.[4–8] Whether this association is also present in low- and middle-income countries, such as those in Latin America, has not been rigorously investigated.

In Latin America, the urban environment has historically differed from that found in North America and Australia. The overall population density is higher,[9] and in Latin American cities, the focus of activity is mainly in

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central business districts,[9] resulting in less urban sprawl. Additionally, public transportation is used more frequently in Latin America.[10] The social environment has marked inequalities and is less safe than that in high-income countries.[11]

These characteristics may work to either incentivize or inhibit physical activity in Latin American urban settings. For instance, in Bogota (Colombia), high-density areas and easy access to public transportation are positively associated with commuting physical activity.[12] In Curitiba (Brazil), the combination of access to physical activity infrastructure and public transportation has been found to be associated with higher levels of leisure-time physical activity.[13,14]

Finally, studies in U.S. and Europe have found that living in a low-income neighborhood has a negative effect on multiple health outcomes and on physical activity. Residents in such areas report a lower overall quality of life, less social cohesion, and less access to leisure facilities and public transportation.[2,13] In the U.S., suburban neighborhoods are often available for higher-income residents only, and resources are likely to be of higher quality. Even though residents may need to travel further to access amenities, the availability of cars mitigates this impact.

Evidence is limited on how neighborhood income level is related to physical activity in developing countries, as opposed to Europe and the U.S. For the current study, it was hypothesized that low-income neighborhoods in Brazil would have lower-quality physical activity resources, such as parks and playgrounds, and that measures indicating high walkability of low-income neighborhoods may predominantly reflect the high density found in urban centers rather than a higher quality of life.

Thus, the association between walkability and physical activity in Latin America may differ from that found in Europe and the U.S. The limited available evidence shows that built environment attributes such as slope, access to recreational facilities, and public transportation are associated with leisure-time and commuting physical activity in Latin America.[2,12,13] However, it is still unknown whether a cumulative walkability index, as defined from research in high-income countries,[4,6–8] is applicable to the Latin American context.

Previous studies[2,12,13] of neighborhood variability in walkability and income in Latin America have not focused on determining whether the environment supports physical activity only when the neighborhood also has income advantages. An understanding of the interaction of these factors is critical for a number of reasons. First, the rate of urbanization in Latin America is exceptionally high (~79%).[15] Additionally, by 2025, nearly two thirds of the region's population will be concentrated in large cities.[15] Second, physical inactivity is highly prevalent,[16,17] and changes in the built environment and daily transportation modes over the past decade may lead to even lower levels of physical activity.[18]

The current study was designed to help disentangle the complex of factors that relate to commuting and leisure-time physical activity in low- to middle-income countries. Therefore, the study examines the association between walkability and income, for walking for transportation and for leisure-time physical activity. The effect of income on the relationship between walkability and physical activity in adults in Curitiba, Brazil, is also explored.

Methods

The Spaces for Physical Activity in Adults Study (ESPACOS) was a cross-sectional study conducted in Curitiba, Brazil.[19] Curitiba is a state capital in southern Brazil with a population of 1,746,896 inhabitants (52% women) and is the eighth-largest city in the country.[20] The current project was designed to investigate associations of neighborhood walkability and SES with physical activity in adults in the Brazilian context,[19] and it was part of the International Network Physical Activity Environment Study.[21] The IRB at Pontificia Universidade Catolica do Parana, Brazil, approved the research protocol (#3034/001/1). The data were collected between August and December 2010.

Walkability and Income Classification

The study was conducted in census tracts selected from a total of 2125 (~225 households/census tract) defined at the time of the project.[20] The average annual income within each census tract was obtained from the national census.[20] For each census tract, a walkability index was calculated using three indicators (residential density, intersection density, and land-use mix), obtained through data layers exported into a GIS. These built environment characteristics have been consistently related to physical activity.[3]

Residential density was obtained by calculating the ratio between residential units and the land area allocated to residential use within each census tract. Connectivity was computed as the density of intersections in the land area within each census tract. Land-use mix indicates the degree to which diverse land-use types are present within each census tract. Land-use mix was determined according to the distribution of five land-use categories (residential, commercial, recreational, educational/cultural, and other). Raw values for each indicator were normalized, and z-scores were calculated. Finally, the walkability index was obtained by using z-scores and by weighting the intersection z-scores, as suggested elsewhere.[22]

Finally, all census tracts were ranked according to their walkability and income by deciles. The second and third deciles were used to represent low-walkability/low-income quadrants; the eighth and ninth deciles were selected to represent high-walkability/high-income quadrants.[19] This approach, which has been consistently used in similar studies,[4,6–8] maximizes the contrast between areas with different walkability characteristics while taking income into account. In each quadrant, eight census tracts were selected, for a total of 32. Further details are available elsewhere.[19]

Sample

A minimum sample size of 500 participants was estimated according to the following criteria: power ≥0.80; assumed variance between 0.1 and 0.5 change-determinate coefficients (R^2); and probability 0.05 for Type I error. An addition of 20% was made to account for multivariate analyses; another 15% was considered for nonresponse and losses resulting in an estimated minimum sample of 675 adults. All census tracts were visited, and 10,063 eligible households were identified (~320 houses per census tract); within each area, 22 households were systematically sampled (total=704). Within each selected household, one adult was randomly sampled and interviewed (inclusion criteria: having lived in the neighborhood for ≥1 year at the date of the interview, having no serious impairment in ability to walk, and being aged 18–65 years). The sample selection was balanced to include equal gender participation (50% women). More details are available elsewhere.[19]

Study Variables

For this study, the questions relating to leisure-time physical activity (walking and moderate-to-vigorous physical activity [MVPA]), and walking for transportation, were derived from the long form of the International Physical Activity Questionnaire (IPAQ) and were used to measure the days and minutes of physical activity in the previous week.[23] These questions have demonstrated adequate reliability in Brazil[24] and have been used with adults from Curitiba.[14] Walking for transportation was dichotomized into ≥150 minutes/week vs <149 minutes/week. Leisure-time walking (≥150 minutes/week vs <149 minutes/week) and MVPA (≥150 minutes/week vs <149 minutes/week) were analyzed separately, and in combination were used as the leisure-time physical activity outcomes.

The following sociodemographic characteristics, assessed by survey, were included as covariates in the analyses: age (18–29 years [ref], 30–39 years, 40–49 years, and 50–65 years); gender; years of education (0–8 years [ref], 9–11 years, ≥12 years); marital status (single [ref] versus married/living with a partner); children in the household (yes versus no); number of cars in household (no car [ref], 1 car, ≥2 cars); and time living in the neighborhood (1–96 months [ref], 97–256 months, and ≥253 months).

Data Analysis

The main effects of walkability and income and their interaction were the main focus of these analyses. Logistic regressions with random intercept were performed. The crude model included walkability (low and high). The first step model included neighborhood income as an independent variable, and then all individual variables were included in the next model. Finally, interaction terms of walkability with income were determined, in order to test the effect of income on the association between walkability and physical activity. All analyses were conducted in 2012 using Stata, version 9.2, with the *xtmelogit* command. Analyses were adjusted for the clustering effect of census tract.

Results

A total of 1052 households were visited, and the overall participation rate (i.e., eligible contacts that agreed to participate) was 66.4%. This rate was slightly higher among residents of high-income neighborhoods (70.9%–71.2%) compared with to those in low-income neighborhoods (62.3%–62.6%, p=0.034). The final sample included 697 participants from 32 census tracts. The sample was well distributed by gender and age; most participants had low or intermediate levels of education, were married, and had at least one car in the household (Table 1).

The proportion of those who walked for transportation for ≥150 minutes/week was 21.1% in low-walkability areas and ranged from 33.5% to 35.0% in high-walkability areas (Figure 1). Walking for leisure for ≥150 minutes/week was achieved by roughly 12% of participants and did not vary much across quadrants of walkability and income. Leisure-time MVPA of ≥150 minutes/week ranged from 12.2% to 19.3% in low-income areas, and from 25.3% to 35.8% in high-income areas. The prevalence of leisure-time MVPA was 7.1–10.5 percentage points higher in high- compared to low-walkability areas.

No interactions between walkability and income were found in any of the models (Table 2). After adjustments for all individual confounders, walkability showed an independent association with walking for transport (OR=2.10, 95% CI=1.31, 3.37, p=0.002) and leisure-time MVPA (OR=1.57, 95% CI=1.06, 2.32, p=0.024). Neighborhood income was independently associated with leisure-time MVPA (OR=1.70, 95% CI=1.06, 2.74, p=0.029). No association was found between walkability and walking for leisure.

Discussion

The main findings showed that adults living in high-walkability areas, in a Brazilian city, are more likely to achieve recommended levels of physical activity, both for transport walking and leisure-time MVPA. Additionally, no interaction between walkability and income was found, indicating that walkability is associated with physical activity regardless of neighborhood income level. Finally, walkability was not strongly associated with walking for leisure. This was one of the first studies that rigorously examined the association of neighborhood walkability, income, and physical activity in a developing country. These results extend the current evidence by demonstrating that the built environment is an important correlate of physical activity in developing countries.

Overall, the results on walkability and transport-related physical activity from the present study are supported by previous findings in developed countries[4,6–8] and showed that walkability plays an important role in the physical activity obtained from daily

Table 1. Sample sociodemographic characteristics according to walkability and income quadrants (Curitiba, Brazil, 2010; N=697), *n* (%) unless otherwise indicated

		Low-income		High-income			
	Total sample	Low-walkability	High-walkability	Low-walkability	High-walkability	χ^2	*p*-value
Gender							
Female	369 (52.94)	93 (54.07)	92 (51.98)	94 (53.71)	90 (52.02)	0.254	0.968
Male	328 (47.06)	79 (45.93)	85 (48.02)	81 (46.29)	83 (47.98)		
Age group, years							
18–29	169 (24.25)	38 (22.09)	31 (17.51)	43 (24.57)	57 (32.95)	16.313	0.061
30–39	161 (23.10)	36 (20.93)	45 (25.42)	40 (22.86)	40 (23.12)		
40–49	159 (22.81)	49 (28.49)	40 (22.60)	38 (21.71)	32 (18.50)		
50–65	208 (29.84)	49 (28.49)	61 (34.46)	54 (30.86)	44 (25.43)		
Education, years							
0–8	203 (29.12)	87 (50.58)	79 (44.63)	27 (15.43)	10 (5.78)	220.115	<0.001
9–11	229 (32.86)	68 (39.53)	69 (38.98)	55 (31.43)	37 (21.39)		
≥12	265 (38.02)	17 (9.88)	29 (16.38)	93 (53.14)	126 (72.83)		
Marital status							
Single	294 (42.18)	57 (33.14)	64 (36.16)	68 (38.86)	105 (60.69)	33.501	<0.001
Married	403 (57.82)	115 (66.86)	113 (63.84)	107 (61.14)	68 (39.31)		
Children at home							
Yes	361 (51.79)	63 (36.63)	83 (46.89)	97 (55.43)	118 (68.21)	37.142	<0.001
No	336 (48.21)	109 (63.37)	94 (53.11)	78 (44.57)	55 (31.79)		
Number of cars							
0	168 (24.10)	62 (36.05)	56 (31.64)	20 (11.43)	30 (17.34)	70.566	<0.001
1	319 (45.77)	84 (48.84)	84 (47.46)	70 (40.00)	81 (46.82)		
≥2	210 (30.13)	26 (15.12)	37 (20.90)	85 (48.57)	62 (35.84)		
Time in the neighborhood (months)							
1–96	242 (34.72)	40 (23.26)	50 (28.25)	60 (34.29)	92 (53.18)	45.160	<0.001
97–252	226 (32.42)	74 (43.02)	55 (31.07)	53 (30.29)	44 (25.43)		
≥253	229 (32.86)	58 (33.72)	72 (40.68)	62 (35.43)	37 (21.39)		

transport in highly urbanized areas in Latin America. Moreover, the current findings showed that in Latin America, where physical activity levels are already higher than in Europe and the U.S.,[4,6,7] living in areas of greater walkability is still related to higher levels of physical activity. This result provides evidence that walkability can contribute to health benefits acquired from physical activity.[25]

These findings have important implications for Latin America and other developing countries. Given the current trends in these areas toward urbanization and high population concentrations in large cities,[15] walkability should be incorporated into the urban planning policies so that cities can provide residents with environments that are more conducive to physical activity. However, practitioners have not prioritized changes to the built environment,[26] even though research has demonstrated their importance in promoting physical activity. Lack of evidence from developing countries may have contributed to this gap between evidence and practice; thus, the current findings may help to advance policy planning and implementation in this area.

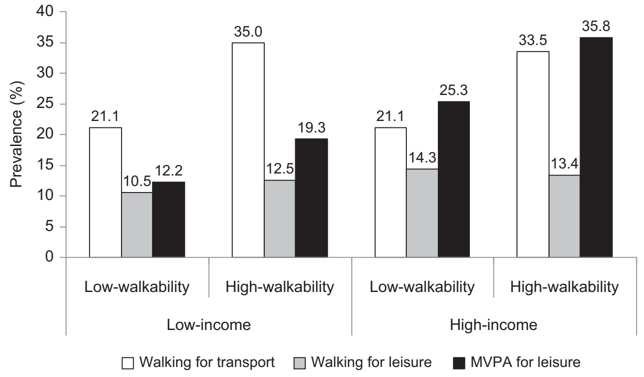

Figure 1. Transport and leisure physical activity according to quadrants of walkability and income (Curitiba, Brazil, 2010; N=697)
MVPA, moderate-to-vigorous physical activity

Finally, results showed that walking for transport at recommended levels was higher in high-walkability areas, regardless of income. Hence, changes in the built environment may have a broader population-level impact. This finding is particularly important, given the high social disparities that currently exist in Latin America.[11]

In Europe[6,7] and the U.S.,[4] both walking and MVPA for leisure were associated with walkability, whereas in the present study, only MVPA for leisure was associated with walkability. Some methodologic differences might explain this inconsistency. Although similar studies used the same self-reported physical activity measure, the outcomes were expressed as minutes per week of activity,[4,6] whereas the present study used the recommended level of physical activity.[25] Hence, increased walkability may contribute to some increase in leisure-time walking, but not at a level sufficient to achieve the recommended level of physical activity.

Nonetheless, the association between walkability and MVPA found in the current study was fairly consistent with previous findings.[4,6–8] Additionally, the available evidence shows that in Latin America, leisure-time physical activity is associated with access to recreational facilities.[2,12,13] Although this factor was not examined in the current study, the amount of recreational areas contributes to the variation in the land-use mix in the walkability index.

Additionally, MVPA was higher in high-income areas, confirming that more-affluent areas are more conducive to leisure-time physical activity because they provide more and safer recreational areas.[27,28] This finding also might suggest that the impact of walkability on leisure-time physical activity varies according to level of social equality of the region. For instance, whereas similar findings were observed in U.S. (i.e., less physical activity in low-income areas),[4] income was not related to physical activity in studies from Europe.[6,7] In fact, Europe is one of the areas of the world with the lowest levels of

Table 2. Multilevel analyses of association between walkability and physical activity (Curitiba, Brazil, 2010; N=697)

	Crude[a]		Adjusted[b]		Adjusted[c]	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Walking for transport						
Low-walkability (ref) vs high-walkability	2.00 (1.27, 3.18)	0.003	2.00 (1.27, 3.18)	0.003	2.10 (1.31, 3.37)	0.002
Low-income (ref) vs high-income			0.97 (0.62, 1.54)	0.907	1.25 (0.73, 2.15)	0.418
Walkability x income (interaction)					0.91 (0.36, 2.32)	0.840
Walking for leisure						
Low-walkabilty (ref) vs high-walkability	1.04 (0.65, 1.66)	0.872	1.04 (0.66, 1.66)	0.856	1.01 (0.63, 1.62)	0.971
Low-income (ref) vs high-income			1.25 (0.78, 1.98)	0.354	1.02 (0.58, 1.80)	0.938
Walkability x income (interaction)					0.86 (0.34, 2.19)	0.753
Leisure MVPA						
Low-walkability (ref) vs high-walkability	1.64 (1.04, 2.60)	0.034	1.69 (1.16, 2.40)	0.006	1.57 (1.06, 2.32)	0.024
Low-income (ref) vs high-income			2.39 (1.65, 3.47)	<0.001	1.70 (1.06, 2.74)	0.029
Walkability x income (interaction)					0.90 (0.41, 1.95)	0.77

[a]Unadjusted OR
[b]OR adjusted for area income
[c]OR adjusted for area income, gender, age, education, marital status, number of children at living at home, car ownership, and time living in the neighborhood
MVPA, moderate-to-vigorous physical activity

socioeconomic disparity among its residents.[29] On the other hand, the U.S. and Latin America, particularly Brazil,[29] clearly have greater socioeconomic inequality across society.

This was the first study, to our knowledge, to examine walkability and income and its association with physical activity outcomes in a developing country. Additionally, walkability was assessed through objective GIS-based measures rather than with subjective measurements,[30] thus avoiding self-report bias. The walkability also followed a standardized approach[21] which allowed comparisons across studies from high-income and low-income countries.[31]

Physical activity outcomes were examined through various domains that have important implications for developing countries. For instance, although active transportation might be the norm for poor people in developing countries, leisure-time physical activity is more frequent in high-income countries.[31] Additionally, the most-recent international recommendations were used to define the physical activity outcomes,[25] which is important when examining the potential public health impact of the findings. Finally, the recruitment and participation rates did not vary significantly across the census tracts, regardless of area income level,[19] which increases the generalizability of the findings.

Limitations

Nonetheless, some limitations are present. The cross-sectional design prevents determination of causality. Walkability was examined in census tracts, which are "artificial" representations of a neighborhood; as a result, areas closer to participants' homes, where they may be more likely to be physically active, were not represented in the study. Additionally, the walkability index included only a few combined aspects of the built environment; other features of leisure-time physical activity environments may provide different results.

Although the results are fairly consistent with findings from Europe, the U.S., and Australia, the study was conducted in only a single city in Brazil, which is an upper middle–income country. Thus, the extent to which these results apply to other cities in developing countries is not clear. For instance, Curitiba has a long history of urban planning and built environment changes (e.g., availability of and access to recreational areas and public transportation),[14] making its urban development pattern closer to that in European cities. In other cities where urban planning has not played a substantial role in urbanization, walkability and physical activity outcomes might show different associations.

Conclusion

The findings of this study show that walkability was associated with leisure-time and transport physical activity in Brazil and suggest that in Latin America and other developing regions where urbanization is high, walkability could affect the level of physical activity among adults. This study has important political implications. The rapid urbanization taking place in developing countries and accompanying changes in motorized transportation[30] has negative consequences for physical activity levels.[31]

These changes are still underway, which provides an opportunity to use urban planning to positively affect the direction of growth; adding the concept of walkability into the process could help reverse or attenuate the increase in sedentary behavior. Although the importance of changes in the built environment to promote active behavior has been recognized in academia for more than a decade,[31] there is a clear gap between research and practice.[26] Because policy decisions are made outside of academia and very often not by the health sector,[31] it is crucial to provide relevant, region-specific evidence. However, the forces that drive urban planning, such as the real estate and mortgage industries, motor vehicle corporations, and social mobilization,[32,33] also need to be considered when incorporating the current findings into the planning and implementation process.

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