Original Article

Investigating the Relationship between Structural Features of Built Environment and Physical Activity using Geographic Information Systems (GIS)

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Abstract

Background: Built environment determinants of engaging in physical activity are dependent on the properties of societies. This study investigates the relationship between structural variables of the environment using geographic information systems (GIS) and the level of physical activity in 22 districts of Tehran. **Methods:** This cross-sectional study was based on Urban Health Equity Assessment and Response Tool (Urban HEART-2). Physical activity level was assessed via the Global Physical Activity Questionnaire (GPAQ). The characteristics of the neighborhood environment, including land use, street pattern, population density, and traffic, were determined via ArcGIS software. Walkability index (population density, street pattern, land use) was calculated to assess the effect of the main variables of living environment on physical activity level. **Results:** Among the built environmental variables, land use was associated with the total physical activity and travel-related physical activity level (r: 0.155, *P* value: 0.001, and r: 0.122, *P* value: 0.007, respectively). The walkability index indicated an association with the total physical activity level and travel-related physical activity level (r: 0.126, *P* value: 0.006, and r: 0.135, *P* value: 0.001, respectively). Higher levels of the walkability index were associated with an improved level of physical activity (OR: 2.04). **Conclusions:** Walkability index and land use positively correlate with total physical activity level, and providing action plans that improve walkability index and land use might lead to increased physical activity level.

Keywords: *Built environmental, exercise, land use, physical activity, traffic, walkability index*

Introduction

Engaging in regular physical activity leads to a significant reduction in the prevalence of non-communicable diseases, including cerebrovascular disease, cardiovascular disease, diabetes, hypertension, depression, breast, and colon cancer.[1] Insufficient physical activity leads to 2.3% of global all-cause mortality, and 18,000 deaths were reported in Iran in 2017.[2,3] Lifelong-proven benefits of engaging in physical activity highlight the significant role of physical activity in public health.[4] Urban environmental facilities have a notable role in increasing the level of physical activity.[5]

The impact of the built environment on physical activity level has been investigated in previous studies.[6] The main purpose of the studies is to determine if investments in this domain will affect public health.[6,7] Land-use policies are important in facilitating individuals' engagement in physical activity.[8,9] However, detailed information regarding built environment determinants of engaging in physical activity is dependent on the properties of various societies.[10] Built environmental databases in geographic information systems (GIS) provide essential information about the determinants of participation in physical activity.

The physical environment could impact the level of physical activity in society.[8,9] This study investigates the relationship between the level of physical activity obtained through the Urban Health Equity Assessment and Response Tool (Urban HEART-2) project and structural variables of the environment via GIS. The main built environment variables affecting the level of physical activity will be determined, and the results could be applied as a roadmap for future policy-making in urban design.

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Methods

The study was a cross-sectional study based on Urban HEART-2. The purpose of the Urban HEART-2 study was to investigate health inequalities in Tehran. The Urban HEART project was originally proposed by the WHO Centre in Kobe. In this project, social determinants of health inequality are evaluated in the communities. In the Urban HEART project, health inequality in Tehran is assessed in six domains: health and nutrition, physical environment and infrastructure, human and social development, economic development, cultural development, and governance.[11]

Among all the individuals who participated in the Urban HEART-2 project in Tehran, ten regions from the west, east, north, south, and the central areas of Tehran from the 22 regions of Tehran were selected. In the next step, by simple random sampling method, 50 individuals were chosen from each region.

The location of residence of the participants is determined via the map of Tehran and entered into Arc geographic information systems (GIS) Version 10.1. A radius of 1000 meters for each individual is determined using ArcGIS software, to investigate the characteristics of the neighborhood environment of the participants. Four independent variables were applied in this study to express the characteristics of the neighborhood environment, consisting of land use, street pattern, population density, and traffic, which was estimated via ArcGIS software. Land use indicates the number of accessible types of human use of land among different land use types (including residential, agricultural, institutional, commercial, industrial, transportation, recreational, park, forestry, and other relatively natural land uses) at a distance of 1000 meters from the residence of the participants. Land use shows the diversity of accessible facilities in the neighborhood. The street pattern indicates the proportion of the total length of the available different types of the roads to the total area of the district at a distance of 1000 meters from the residence of the participants. Population density is defined as the number of people per unit land area at a distance of 1000 meters from the residence of the participants. Traffic is defined as the proportion of the length of the first and second type roads to the total roads. In the next step, independent variables (land use, street pattern, population density, and traffic) were calculated for each sample using ArcGIS. ArcGIS is a software that allows you to build a complete GIS. It includes tools for programming, creating, and managing maps. Also, ArcGIS is a powerful and easy-to-use software for GIS applications, allowing users to easily use spatial information and descriptive data to create maps, tables, and charts.

Physical activity level was evaluated using the Global Physical Activity Questionnaire (GPAQ). The GPAQ is the most authoritative physical activity questionnaire designed under the supervision of the World Health Organization (WHO) in 2002.[12] The GPAQ measures physical activity in the work-related domain, leisure time, travel to and from places, and total physical activity level. GPAQ also measures sedentary behavior. Validity and reliability of the GPAQ among the Iranian population have been established. Active individuals are defined as individuals achieving 600 MET-min per week and more, and otherwise, individuals are defined as inactive.[13-15]

In previous studies, a variable called the walkability index had been used to summarize the effect of the main variables of living environment (population density, street pattern, land use) on the physical activity level.[6] First, the distribution of the three main variables (population density, street pattern, and land use) related to the living environment was normalized. Then they were converted into variables with a distribution between 0 and 1. Finally, by adding them together, we created a variable called the walkability index for each region.

The study was approved by the Tehran University of medical sciences ethical committee (Ethics code: IR.TUMS.IKHC.REC.1395.443). All individuals participating in the Urban HEART-2 were provided with comprehensive information about the purpose of the study. All participants signed informed consent.

Statistical analysis

Continuous variables are described as mean (standard deviation), and categorical variables are presented as frequency (percentage). Correlation was assessed via Spearman correlation test and logistic regression to identify the determents affecting the physical activity level (active/inactive). Logistic regression was adjusted for possible confounding variables such as age, sex, household economic level, and literacy level. All analyses were done using SPSS version 20, and the level of significance was set to $P < 0.05$.

Results

In the initial stage, 50 individuals from west, east, north, south, and the central regions of Tehran were selected (in total 500 individuals). After cleaning data, the study sample was comprised of 486 individuals. The mean (SD) age of the participants was 45.84 ± 16.23 years, and the mean (SD) body mass index (BMI) of the participants was 25.86 ± 4.29. Other of the study, participants are presented in Table 1.

Among the built environmental variables, land use was associated with the total physical activity and travel-related physical activity level (r = 0.155, P value = 0.001 and r = 0.122, P value = 0.007) [Table 2].

The distribution of the walkability index variable among the 10 regions shows that regions 10 and 14 have the highest and 19 and 21 have the lowest walkability index. The walkability index and the total physical activity level were

associated (r = 0.126, *P* value = 0.006). Also, the walkability index indicated an association with travel-related physical activity level (r: 0.135, *P* value: 0.001) [Table 2].

A binary logistic regression test with the consequence of two-state physical activity (active and inactive) was applied to investigate the relationship between different variables and physical activity. According to the logistic regression equation, the walkability index is directly related to physical activity. In other words, each unit increase in the walkability index promotes the likelihood of engaging in adequate physical activity (achieving 600 MET-min per week and more) significantly. Also, with increasing age and smoking, the possibility of doing enough physical activity decreases, and individuals are more likely to be in the low physical activity group [Table 3].

Discussion

In the current study among measures of built environment, land use was correlated with the total physical activity and travel-related physical activity level. The combined walkability index consisting of population density, street pattern, and land use was correlated with travel-related and total physical activity level.

Physical environments have a significant impact on the level of physical activity.[8,16] Improving the built environment could be a facilitator for engaging in physical activity.[8,9] Improving land use diversity means that commercial, recreational, cultural, and administrative destinations are close to an individual's place of residence. The positive correlation between land use and increased physical activity level was reported in our study, which is consistent with the findings of the previous studies. In a study by Frank *et al*.,[6] land-use mix and net residential density indicated a positive relationship with the level of physical activity, and the walkability index could increase the moderate level of physical activity. Some previous studies have also demonstrated a strong positive relationship between land use mix and engaging in physical activity.[17-19] In a cross-sectional study by Sallis *et al*.[5] with a sample size of 6822 adults that was conducted in ten countries, net residential density, intersection density, number of parks, and public transport density based on GIS were related to physical activity level assessed via accelerometer. In a study by Troped *et al*.,[20] population density, intersection density, and land use mix indicated an association with moderate to vigorous physical activity within one kilometer home buffers. In a systematic review by Grasser *et al*.,[16] the correlation between population density and walkability indexes with travel-related physical activity was reported. In a study by Loh *et al*., walkability and residential density showed significant positive associations with moderate to vigorous physical activity outside school hours in the adolescent population.[21]

The increasing diversity of land use decreases using motor vehicles via providing the daily requirements of individuals, and people will be able to walk to these destinations and increase their physical activity level. Increased street connectivity means direct and easy access roads between required destinations and the individual's place of residence. In other words, more daily diverse destinations people have in their living environment, smoother, and more direct access to these destinations, and higher walkability index leads to the increased probability of engaging in physical activity.

According to these results, urban policy-makers can be suggested to always use expert consultants in the field of public health in planning urban development policies and reconstruction of cities and towns. It is possible to increase the physical activity level by building areas with improved walkability facilitation, including increased daily required destinations located with close distances to the place where people live. Identifying places with an improved walkability index and encouraging people to live in an environment with physical activity-facilitating features can effectively increase the physical activity level of people in the community. It should not be forgotten that many factors could be responsible for the level of physical activity. While some of them could be facilitated by the health system and education,[22] some others need to be provided by municipalities, such as pedestrian bridges

Table 1: Characteristics of participants at baseline

Variables	Percent (Number)
Sex	
Male	43.0% (209)
Female	57.0% (277)
Age range	
15-24 years	33% (33)
25-44 years	21% (210)
45-64 years	17% (170)
>65 years	73% (73)
Level of physical activity	
Low	61.5% (299)
Moderate	21.2% (103)
High	17.3% (84)

Table 2: Correlation of physical activity and built environment variables

	Correlation Coefficient (*P*)				
	Land use	Street pattern	Pop density	Traffic	Walkability index
PA travel (METs-minutes/week)	0.122** (0.007)	0.04 (0.35)	0.07 (0.11)	-0.08 (0.07)	0.135 (0.001)
Total PA (METs-minutes/week)	0.155** (0.001)	0.03 (0.55)	0.03 (0.46)	-0.03 (0.48)	0.126 (0.006)

MET=metabolic equivalents, [a]Spearman correlation test

Table 3: Correlation of different variables and physical activity*

	β	Standard Error	*P*	Odds Ratio	Estimated OR 95% CI
Age	-0.02	0.006	0.008	0.98	0.97-0.99
Smoking**	-0.45	0.22	0.04	0.64	0.41-0.99
Education***	-0.29	0.22	0.20	0.75	0.49-1.17
Walkability index	0.71	0.23	0.002	2.04	1.23- 3.24

*Binary Logistic Regression test. **(0=no smoke/1=Yes). ***(0=under diploma and diploma/1=higher)

and crosswalks. Therefore, increasing the level of physical activity in society requires coordinated cooperation between different organizations. With these available resources, physicians and health researchers can also design more effective interventions to increase physical activity levels by considering the neighboring environment as an influential factor in physical activity.[4,23]

To the best of our knowledge, as strength, this is the first study which investigates relationship between structural features of built environment and physical activity in the Tehran metropolitan and the results could help for future urban policy-making.

Limitations

However, there are some limitations in the current study. First, the physical activity information was obtained from subjectively measured tools. Overestimation has been reported in subjective self-reports of physical activity including GPAQ. Future research applying objective methods to assess physical activity level is recommended. In the present study, the correlations between land use, walkability index, and physical activity level were statistically significant, but the strength of the correlation was relatively weak, which should be considered when interpreting results. This study was a cross-sectional study and limited data with no follow-up was obtained. It is also suggested that the design of subsequent studies be longitudinal rather than cross-sectional to provide more accurate and standardized results.

Conclusions

Walkability index and land use have a positive relationship with total physical activity level. Thus, developing policies that promote walkability index and land use might lead to improving physical activity level and public health.

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Conflicts of interest

There are no conflicts of interest.

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