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Built Environment and Health among Urban Residents

: Spatial Analysis of Community Health Surveillance Data

건조환경과 도시거주자의 건강

: 지역사회 공중보건 감시자료를 이용한 공간분석의 적용

2018 년 2 월

서울대학교 대학원
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Abstract

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Background

A neighborhood environment is comprised of a physical environment and a socioeconomic environment and influences human health in a range of ways. Within a physical environment, all the human-made surroundings are referred to as built environment (BE), and it substantially influences the health of people living in an urban setting, more so in cities with higher population density. Interests and intervention from the public health perspective on health and wellness in the BE as a remedy against communicable diseases diminished after the 19th century but began to resurface in recent years to get to the

bottom of noninfectious disorders relating to physical activities. Unfortunately, most studies conducted in this area focused on increasing quantity of physical activities of the general population and the scope of dialogue needs to be much expanded to deal with various health issues and effect on a vulnerable population. In South Korea, the demographic convergence in the Seoul Metropolitan Area is on the extremely high side, making it one of the most densely populated regions in the world. Accordingly, a multilateral evaluation in public health on its BE is very important. Especially, to overcome the numerous problems materialized due to the rapid expansion of cities in the past few decades, it is imperative to deliberate urban renewal programs regarding public health. However, the previous studies verified individual environmental factors, that was evaluated in Western cities, in connection with physical activities, and most of them were in the field of urban planning. A continuous health surveillance system is indispensable to determine and evaluate health effects of BE, and it is important to first determine whether the regional data from public health surveillance system are compatible with this study. Furthermore, applying spatial analysis and geographic information system will facilitate determining the relationship between urban planning components and its public health impact in a more extensive geographical region.

Objectives

The purpose of this study is to explore the urban built environmental factors that affect public health through spatial analysis using regional public health surveillance data, determine correlation among those factors and present basis stemming from the public health perspective for healthy urban renewal. This study aimed to evaluate the effect of urban BE on healthy activities and health results. Applying three aspects, density, distance, and accessibility, for measuring BE out of the available 5, the following analyses were performed:

Analysis 1: Correlation between accessibility to public transport and walking practices in adults

Analysis 2: Correlation between fast food outlet density and prevalence of obesity in adults

Analysis 3: Correlation between distance to a major roads and allergic diseases in children

Methods

Information on individual health behaviors and diseases prevalence was collected from public health surveillance data, more specifically, the Community Health Survey data (2011-2014, 92,357 subjects) for adults of 19 years of age or higher and the Seoul Atopy-Friendly School Survey data (2010, 24,040 subjects) for children. The built environmental factors influencing them were analyzed using a geographic information system, which required very precise location information. To achieve this, the participants of the Seoul Atopy-Friendly School Survey were geocoded on their home addresses. Those of the Community Health Survey were geocoded on regional representative location based on their type of residence (detached house, apartment) and geographically censored information of their home address at the community level (424 dongs in 2014). Of the many elements to the BE, accessibility to public transport by a community, density of top 5 fast food outlets (McDonald's, Lotteria, Burger King, KFC, Popeyes) by county, distance to major roads from residential address were used in analyses 1, 2 and 3. As for the impact of BE, walking duration (minutes) per week, obesity as defined by BMI of 25kg/m^2, and prevalence of allergic and atopic diseases (atopic eczema, asthma, allergic rhinitis) were determined in each analysis.

Results

Accessibility to public transport and weekly walking duration had a nonlinear relationship, where the walking duration for those who lived between 1.0 to 1.5km from a subway station increased by 28.5 minutes (95% CI=16.7 - 40.2) but for those who lived 1.5km or farther away from a subway station decreased by 1.9 minutes (-19.9 - 16.1). The density of fast food outlets, when adjusted with personal and regional factors, had an insignificant correlation with obesity in a county-level (male: Odds ratio=1.01, 95% CI=0.97 - 1.05; female: 1.04, 0.99 - 1.09). Because the density of fast food restaurants closely correlated with regional socioeconomic level, when the effect was determined after adjusting the financial independence of the region, there was some discrepancy between the regional socioeconomic level and gender, but overall it had an insignificant correlation with obesity. The odds of atopic eczema were higher for children living on less than 4 floors and 150m, 150−300m, and 300−500m away from a major street than those living over 500m away, respectively by 1.15 (1.01 − 1.32), 1.17 (1.03 − 1.34) and 1.16 (1.01 − 1.34) times; and the odds of atopic dermatitis increased by 1.08 (1.01 − 1.15) times if the road density increased by 13,120m2 within 300m of place of residence. For the children living on the tenth floor and higher, the prevalence of asthma and allergic rhinitis was higher for those living closer to major roads, but its effect was not consistent.

Discussions

In this study, the effect of urban BE measure regarding accessibility, density, and distance on walking practice and health results such as obesity and atopic eczema were analyzed by applying spatial analysis on public health monitoring data. Based on the results of analyses, the following implications were drawn: (1) the recently diminishing amount of physical activities exercised by urban residents could be significantly improved through increased neighborhood walkability, and one of the methods for improvement may increase adjusting accessibility to public transport from the place of residence; (2) because obesity of urban residents is affected by neighborhood

diet environment, additional intervention from the public health discipline must be considered simultaneously; and (3) higher proximity to roads indicate higher air pollution in the neighborhood and it may trigger other health issues such as allergic reaction and atopic eczema especially for those with restricted activity perimeter, e.g., children. To sum up, adjusting access in BE will increase physical activity level, and thereby, effectively reduce noninfectious disorders such as obesity, but it may also increase the prevalence of noninfectious disorders in a certain population with vulnerability. Therefore, to improve the health issues in our cities, we must first adequately test various urban planning concepts formulated in Western urban environments and need better awareness and proactive intervention from the public health perspective.

Keywords : Built environment, Physical Activity, Obesity, Allergic diseases, Public health surveillance, spatial analysis

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Contents

List of Tables

List of Figures

Chapter 1. Introduction

Built Environment and Health

As a phrase of 'where one lives affects to how one lives' emphasizes, the touchpoint embraces the overall modifiable environment including both material and social neighborhood characteristics potentially related to health (Figure 1-1). Built environment (BE) comprises the physical environment layer with the natural environment and locates outer ring of social and individual determinants of health (1, 2).

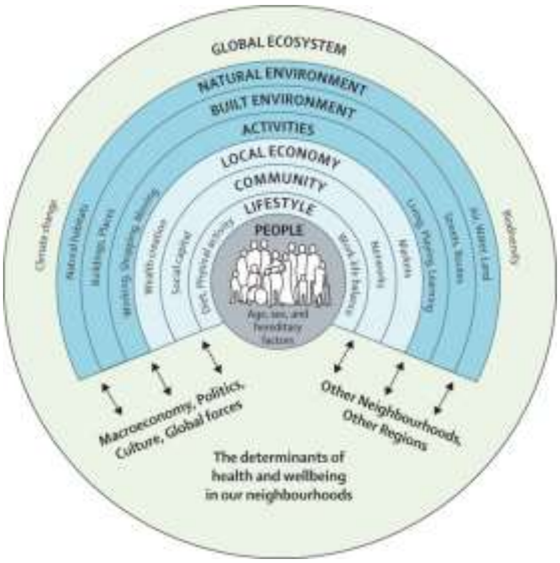

Figure 1-1. Determinants of health at the neighborhood level

Source: Rao et al. (2007)

recitation of Whitehead and Dahlgren (1991) 's framework

The world has experienced unprecedented urbanization, and megacities (greater than 10 million population) have sprung up in the past half-century (3). Seoul, the capital city of Korea, also became the one of the megacities.

Figure 1-2. The inverted U-shaped curve in the cost-benefits of urban agglomeration

Source: Sarkar and Webster (2017)

Notes: AB average net benefits, AC average costs. P1: Minimum density (low benefits and cost, low service and employment density, high transaction cost, poor public transport, car-dependent, low social support, higher exposure to green and blue space, reduced congestion and pollution). P2: Urban density sustaining lowest cost (higher benefits than P1 and with lowest costs). P3: Optimal urban density (highest density sustaining maximum benefits, high employment density and mix, minimum transaction cost, optimized services, optimized design, highly evolved public spaces, fully developed public transport, active travel behavior, highest sense of community and social capital). Towards P4: Higher density towards socially optimal city (higher density than P3 on account of skilled migrant work force, higher heterogeneity in social class, higher distributed net benefits, highest employment density and mix, very good services, good design, well developed public transport, active travel behavior, sense of community and social capital).
P5: Urban malaise (overcrowding, congestion, pollution, resources, services and infrastructure constrained beyond carrying capacities, higher deprivation and inequality, higher stress of urban stress, informal economy)

The agglomeration is beneficial for health and wealth among urban residents until the urban density increases to optimal threshold, however, the overcrowded urban environment leads to higher risks of both infectious and noncommunicable diseases (Figure 1-2) (4).

In the urban health which is invoked to combat the health problems according to urban agglomeration, BE is one of the crucial components. BE refers to the human-made setting for human activity including forms, layout and design, and the it's health impacts is just beginning to be reinvented (2, 5-10). Since it takes root in urban structure, the territory of the research on BE and public health is not isolated in the public health domain, but has to be expanded to urban policy and urban planning areas. Historically, the connection of urban planning and public health had combated the health problems involving environmental hygiene and infectious diseases (11). However, since 1900s, the 'voice' of public health on BE has been 'largely disappeared' as Perdue et al. pointed out (10), and Korea was not an exception to this trend.

Figure 1-3 shows many interconnected components of the BE can influence on health (12). They affect human health independently or dependently to each other. Moreover, people can also choose 'where they live' more suitable to maintain their lifestyle, called as 'self-selection' (13). The BE can be 'opportunities and barriers to more proximal social and material determinants of health' (14), and we may need to tailored focus on the deprived neighborhood who 'are more exposed to the damaging mechanism and has reduced resilience to damaging' (15).

Figure 1-3. The influence of built environment components on health

Source: Lavin et al. (2006)

Public health policies intervene 'how they live' and promote their healthier lives to combat health problems related to NCD. Surveillance data should provide supportive information for comprehensive under of health-related conditions and those risk factors (16). In particular, over the past years, interest in the use of multilevel analysis had grown, which was applied the investigation of the effects of neighborhood social environments on health outcomes using NCD surveillance data. However, the areal variability in health outcomes had often been small, and the neighborhood effect derived from the multilevel model was still under debate (17, 18).

The neighborhood scale analysis, as an alternative strategy to multilevel models, is based on incorporated historical, sociological and geographical information in defining neighborhoods (18). The concern about this approach has increased with emerging attention to local context as a nature of public health solutions since the late 1990s (19–21). The neighborhood scale analysis may help us to figure out the detailed mechanism which neighborhood environments affect the health of people who resides in a defined neighborhood. Moreover, we can interpret the results from the analysis in the neighborhood context, and intervene at the direct touchpoint.

Megacity Seoul and Health among Urban Population

South Korea and its capital city Seoul, have experienced rapid economic growth and urbanization, is a challengeable subject for a natural experiment to assess how BE influence public health. Since 1945, Korea's independence from Japanese rule, urban population was radically increased and the urban form and BE changed suddenly during less than one century. Figure 1-4 shows the urban formation of Seoul during last several decades (22).

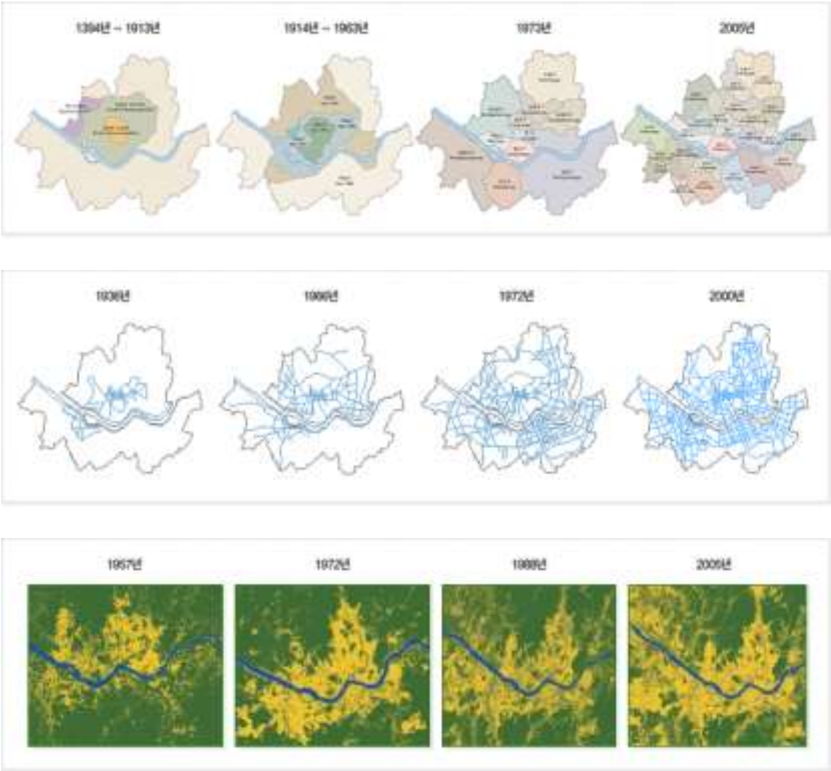

Figure 1-4. Urban formation of Seoul, 1930s-2000s. Administrative areas(head), road networks(middle), urban areas (bottom).
Source: Seoul Institute (2013)

Built Environment and Methodological Challenges

The first methodological challenge is how to define the 'neighborhood'. The geographic resolution of 'neighborhood' is not only for a public health intervention scale but also analytic units for geospatial analysis. However, clear distinctions between the terms 'neighborhood', 'community', and 'area' are usually not made. In health research, the terms 'neighborhood' and 'community' have often been used loosely to refer to a person's immediate residential environment. A nation-wide NCD surveillance, can produce health statistics at a local level, is Community Health Survey (CHS) established by Korea Centers for Disease Control and Prevention (KCDC) since 2008 (23). The CHS is similar to the Behavioral risk factor surveillance system (BRFSS) of the United States as a pioneering NCD surveillance focusing health behavior by the early 1980s (24). The population size of 'community' in CHS is about 0.4 million in Seoul (25), and extremely larger than a historical conception of the neighborhood called 'Doo-Rae' which was composed of from 10 households to one village and shared their lifestyle. There is a vague concept of neighborhood in modern society of South Korea, and contrasting characteristics coexist within a region due to high social density (26). To summarize, there are two issues on (1) how to define the neighborhood in the Korean context, and (2) how to implement the contextual concept on analysis and interpretation of pre-existing health surveillance data such as CHS.

The second methodological challenge is how to measure the environmental elements in a neighborhood. Unlike the multilevel analysis uses an aggregated characteristics such as number in a defined area, neighborhood scale analysis uses more individualized measures such as distance or accessibility as shown in Figure 1-3. In general, health research has used qualitative investigation such as eco-metrics on a limited population, and the results from these studies are restricted to generalize. Some of the researches used geographic information system (GIS) technics on a georeferenced location of individuals, and they could measure the environment in a larger population. Though that kind of studies can provide more generalizable information on effects of BE, they contain some issues of geocoding accuracy (27-30) and personal privacy (31-33). In an aspect of geocoding, the changes of the address system in late 2009 (34) has made burden of using the ready-surveyed address. And in an issue of personal privacy, the use of personally identifiable information such as residential addresses is limited based on 'personal information protection act' enforced in 2011 (35). To summarize, there are two issues on (1) how to measure the neighborhood characteristics in a large population, as desirable, recruited for existing surveillance such as CHS, and (2) how to obtain information of geographically high-resolution within legal guidelines.

Objectives of the present study

This research aimed to determine the BE correlates on public health applying spatial analysis of community health surveillance data through three empirical analyses and to suggest healthy urban planning model based on empirical analysis and literature reviews. Figure 1–5 shows the conceptual framework of this research. The framework was reproduced from Frank & Engelke (2005), in which focused on the flow from BE to public health through human activity, and Gelomino et al. (2015), in which focused on how urban policies affect on BE and social context and how social context make inequality among people with a same environment.

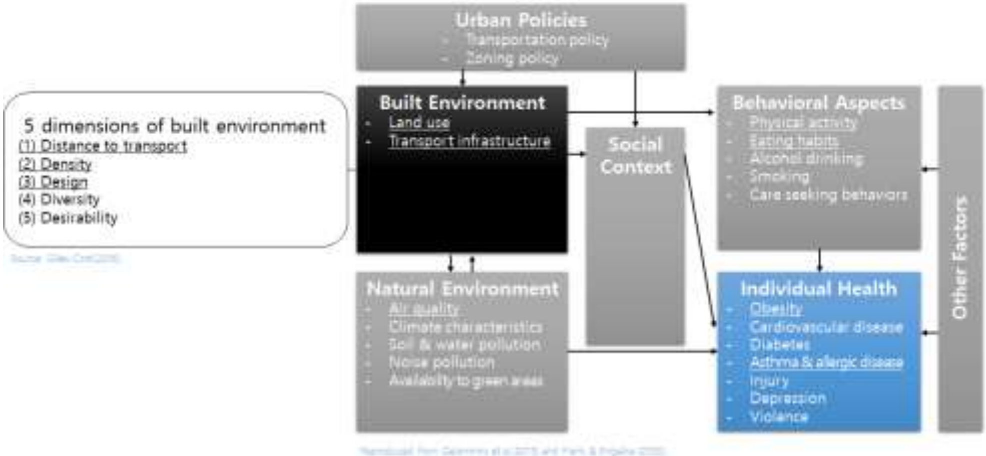

Figure 1–5. Conceptual framework of the research

In Chapter 2, the association of neighborhood BE (accessibility to public transport) on health behavior (walking practice and duration) was explored using data of subjects who participate Community Health Survey for four years (2011–14 in Seoul. The locations of subject were spatial randomly assigned on the combined layer with land-use and administrative boundary, based on their housing types (detached house, apartment) and districts (424 of dongs). In Chapter 3, the association of built and living environment and health behavior on health outcome (obesity) was explored. The damaging influence of BE may affect in children and elderly. In Chapter 4, the association of neighborhood BE (road density, road proximity) on health outcome (allergy and atopic diseases) using another data, a data on 31,576 children recruited for 'Seoul Atopy Friendly School' projects, to understand the effects of BE on children as a vulnerable population. The results from three empirical studies will be interpreted combined in the hypothetical framework shown in Figure 1-6.

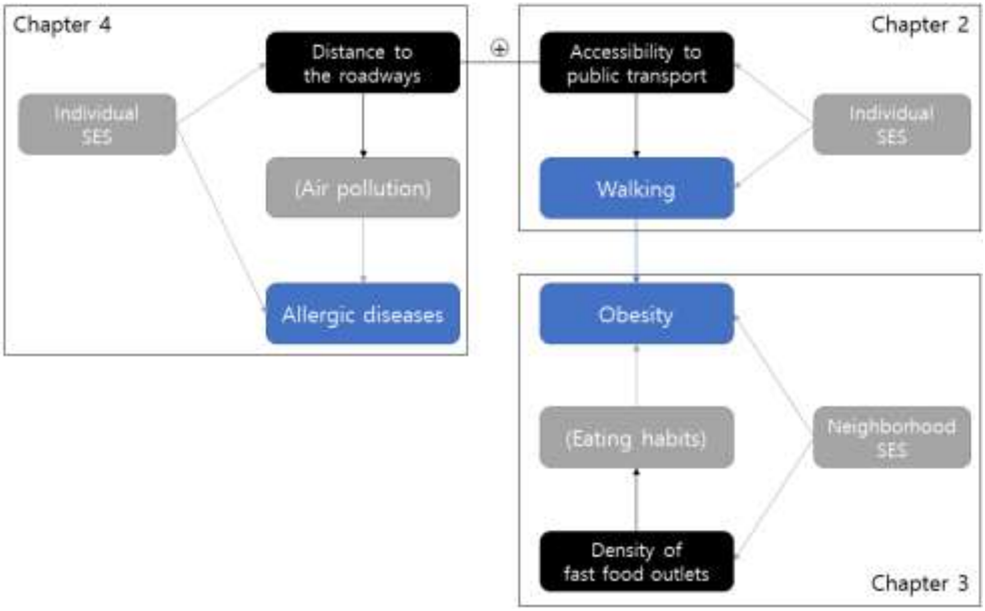

Figure 1–6. Hypothetical framework of empirical studies

The summary of methodological approaches in empirical analyses are shown in Figure 1–7.

	Analysis 1	Analysis 2	Analysis 3
Surveillance	Community Health Survey (CHS)		Seoul Atopy Friendly School Survey
	2011-2014	2011, 2013	2010
Population	Adults aged 19 or older (N=92,357) 	Adults aged 19 or older (N=45447) 	Children aged 1-12 years (N=24,040) 
Location of residence	Unknown (Random property allocated)	Unknown (Not allocated)	Residential addresses
Exposure	Accessibility to public transport	Density of fast food outlets	Proximity & Density of major roads (≥6 lanes)
Outcome	Walking behavior	Obesity (BMI≥25kg/m²)	Atopic dermatitis, asthma, allergic rhinitis

Figure 1–7. Methodological approaches of the research

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Chapter 2. Built Environment and Walking

2-1. Introduction

According to nationally representative data from Korea, the prevalence of physical activity (PA) in the adult population consistently decreased from 68.5% in 2005 to 47.2% in 2013 (Figure 2-1). Particularly, there has been a declining trend of walking. The decreasing trend of walking is in proportion to the growth in personal motorized travel (1), and seems to continue without the introduction of new policies (2).

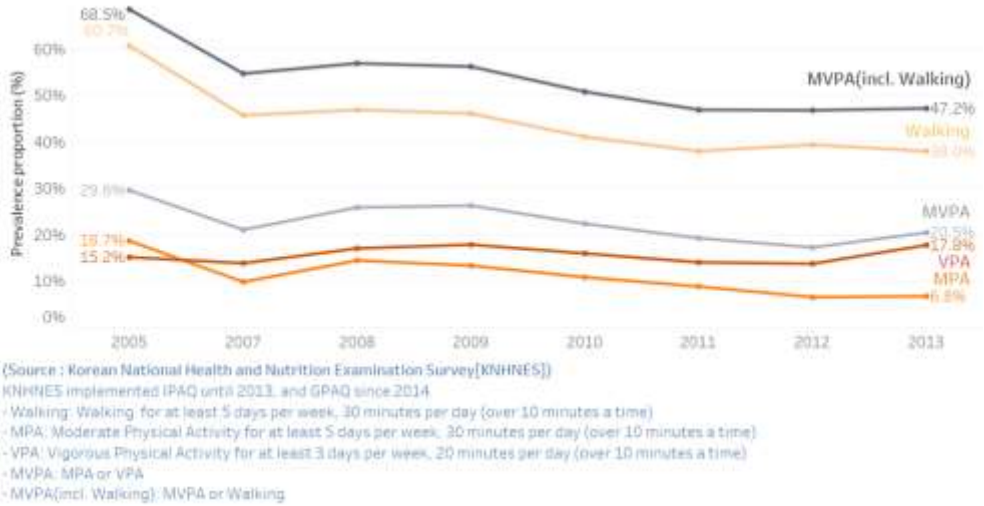

Figure 2-1. Decreasing trends in the age and sex-adjusted prevalence of physical activity of adult population (aged 19 years or older) in South Korea, 2005-2013

The choice of mode of transportation depends on the feasibility, relative costs, and the benefits to the individual (1). In other words, one walks more when they perceive that walking trips become easier in a sense, and recent public health strategies have focused on designing walkable neighborhoods to encourage walking (3).

The components of ‘walkability’ or ‘walkable environment’ can be classified into three categories: land use, network or urban form, and pedestrian environment (4, 5). These three may influence the walking behavior in general. We need to know the specific attributes of walking by type or purpose of walking in order to improve walking practice efficiently.

To encourage people to walk at sufficient levels (meet physical activity recommendations), the improvement of the built environment (BE) needs to consider long distance trips such as commuting. In a trajectory study that investigated walking pattern, about 70% of Seoul residents walked for transit to public transport (bus or subway) (4). Although automobiles are a major mode of transport among residents of Seoul (7), following the modification of the public transportation system in the early 2000’s, some private drivers have switched to using the subway for commuting trips (8). A large body of evidence supports the contribution of subway trips to walking (9). The present study also focuses on the accessibility to the subway station as an attribute of walking among residents of Seoul.

Since walking manifests itself at the individual level, the individual level rather than an aggregated one is the proper unit for analysis. Though the availability of individual accessibility data in a large scale is very limited, the use of a more sophisticated geographical unit rather than an administrative unit needs to be considered since most physical activity is spatially constrained and bound by one's time budgets and physical limitation (1). Few studies have examined the effect of public transport on walking in Seoul by using the number or density of stations at the neighborhood level. The present study went a step further, and considered the sub-unit of administrative unit according to the housing type.

In advance, this study aimed to attempt the use of community health surveillance data for on-going monitoring of the influence of BE on walking. Most previous studies explored the environmental correlates within a certain period, and were led by urban planning research groups (10-18). To monitor the improvement of walking levels according to BE reformation and grasp the differences between population groups, the contribution of the field of public health is required.

Using the Community Health Survey (CHS) during 2011 to 2014, this study aimed to assess the association between neighborhood BE and individual walking behavior among residents of Seoul, focused on accessibility to subway stations.

2–2. Data and Methods

Data and Participants

Data on our sample of subjects were derived from the 2011–2014 Korean CHS for PA and individual covariates. The target population of the CHS includes all adults (aged 19 years or older) living in South Korea, and residents of each sampling location are the target sample. The CHS is continuously conducted annually between August and October, and subjects are asked questions from modules on demographics, health behaviors, health status, accessibility to health services, incidents and addiction, and quality of life (19). Regarding research ethics, the CHS is reviewed annually for approval by the Korea Centers for Disease Control and Prevention (KCDC) since 2008.

In this study, 92,357 subjects living in Seoul were included in the analysis over four years. In principle, the KCDC has provided the administrative unit of individuals at the community level (si/gun/gu). However, the analysis was conducted at the neighborhood level (dong) by using data provided by Seoul Institute, which were obtained from universities participating in the CHS for their own research. The CHS sampled subjects by a multistage stratification sampling scheme based on housing type (apartment or detached house) and 424 neighborhoods (area: 2.85 km^2, population size: 48,000, in average, in 2014) of Seoul as shown in Figure 2–2 (19). It has recruited about 900 subjects from twenty-five communities (24.2 km^2, 0.4 million, respectively) in a year (19). Four-year cumulative samples accounted for about 1% of Seoul residents and provided a unique opportunity to investigate the association between neighborhood characteristics and walking.

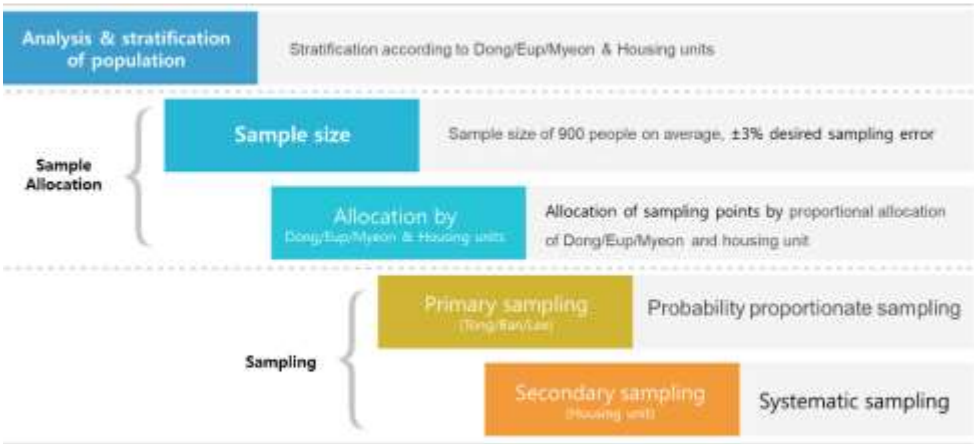

Figure 2-2. Sampling scheme of Korean Community Health Survey

Source: chs.cdc.go.kr (20)

Geographical data on public transport (bus stops and subway stations), the administrative boundary map, and the building register information in Seoul at the end of 2014 were obtained from the Korea National Spatial Data Infrastructure Portal (http://market.nsdi.go.kr/main/index.do).

Outcome Measurements

The CHS used the short form of the International Physical Activity Questionnaire (IPAQ) for the assessment of walking. The IPAQ is composed of frequency (days per week) and duration (minutes per day) of walking. "Sufficient walking" was defined as "walking over 10 minutes at a time for at least 5 days per week and more than 30 minutes each day." The responses of sufficient walking are categorized into "yes (1)" or "no (0)." Based on the IPAQ scoring protocol, weekly walking duration (minutes/week) is also converted to continuous scores by incorporation of walking frequency (days/week) and walking minutes per day (minutes/day). If one responded "20 more hours' duration of walking," the response was coded as "don't know/not sure."

Individual-Level Variables

Individual-level data were collected from the CHS, and the following variables were included in the analysis: For socio-demographic variables, ages were divided into 6 groups (19-29, 29-39, 39-49, 49-59, 59-69, 70 and over). With regard to educational attainment, the participants were asked the level at which their education was completed, which was classified into three educational categories: primary education or lower, secondary education (middle school or high school graduate), and college graduate or higher. To evaluate the influence of occupational sedentary characteristics on physical inactivity, the categories of job were classified into four occupational categories: managers/professionals/clerks, service and sales workers, skilled workers (including farmers, craft and related workers, and elementary occupations), and others (including armed forces, students and housewives).

Questions regarding housing type (detached house or apartment) and car driving status were asked. To assess health status, questions regarding whether one had acute/chronic disorders or accidents during the preceding 2 weeks, was stressed or feeling depressed during daily life, and self-rated health status were asked.

Accessibility to Subway Station

Unlike the walking behavior variables and covariates collected at the individual level in the CHS, the objective accessibility was not captured in the surveillance data. Furthermore, the addresses of subjects were geographically masked in the CHS, and only their administrative units and housing type were available.

Intuitively it is expected that the higher resolution of spatial units would improve the distributional approximation. Unlike previous studies that used the neighborhood units as the finest analysis unit (46, 48, 49, 56), this study applied more detailed units using the information of housing type of subjects.

The accessibility to the subway station was calculated using the nearest straight distance (m) between the centroids of subway station (P_l) and the sampling point p_{ijk}, where the i^{th} subject with housing type *j (1: detached house, 2: apartment)* in the k^{th} neighborhood might live.

- Sampling points of individual: $P_{ijk}\left(x_{ijk}, y_{ijk}\right)$
  - i=1 to n_{jk}: for number of study subjects, $\sum_{k=1}^{424}\sum_{j=1}^{2} n_{jk} = 92{,}357$
  - j=1(detached house) or 2(apartment): for housing types
  - k=1 to 424: for administrative neighborhoods
- Centroid of subway stations: $P_l\left(x_l, y_l\right)$
  - l=1 to 286: for number of subway stations in Seoul as of December 5^{th} 2014
- Accessibility of subway stations: d_{ijk}
  - Distance from building centroids: $d_{ijkl} = d\left(p_{ijk}, p_l\right) = \sqrt{(x_{ijk} - x_l)^2 + (y_{ijk} - y_l)^2}$
  - Minimum distance for building centroids: $d_{ijk} = d_{min}\left(p_{ijk}\right) = min_{l\in(1,\ldots,286)} d_{ijkl}$

Since geocoded addresses of the study subjects were not available, this study assumed that the sampling points were selected according to spatial random sampling approaches (22). When the assumption was not violated, the sampling points of p_{ijk} were randomly selected from the coordinates of centroids of buildings $P_{i,jk}$ with replacement. Figure 2-3 shows part of the process of estimating the accessibility to public transport from dwelling places.

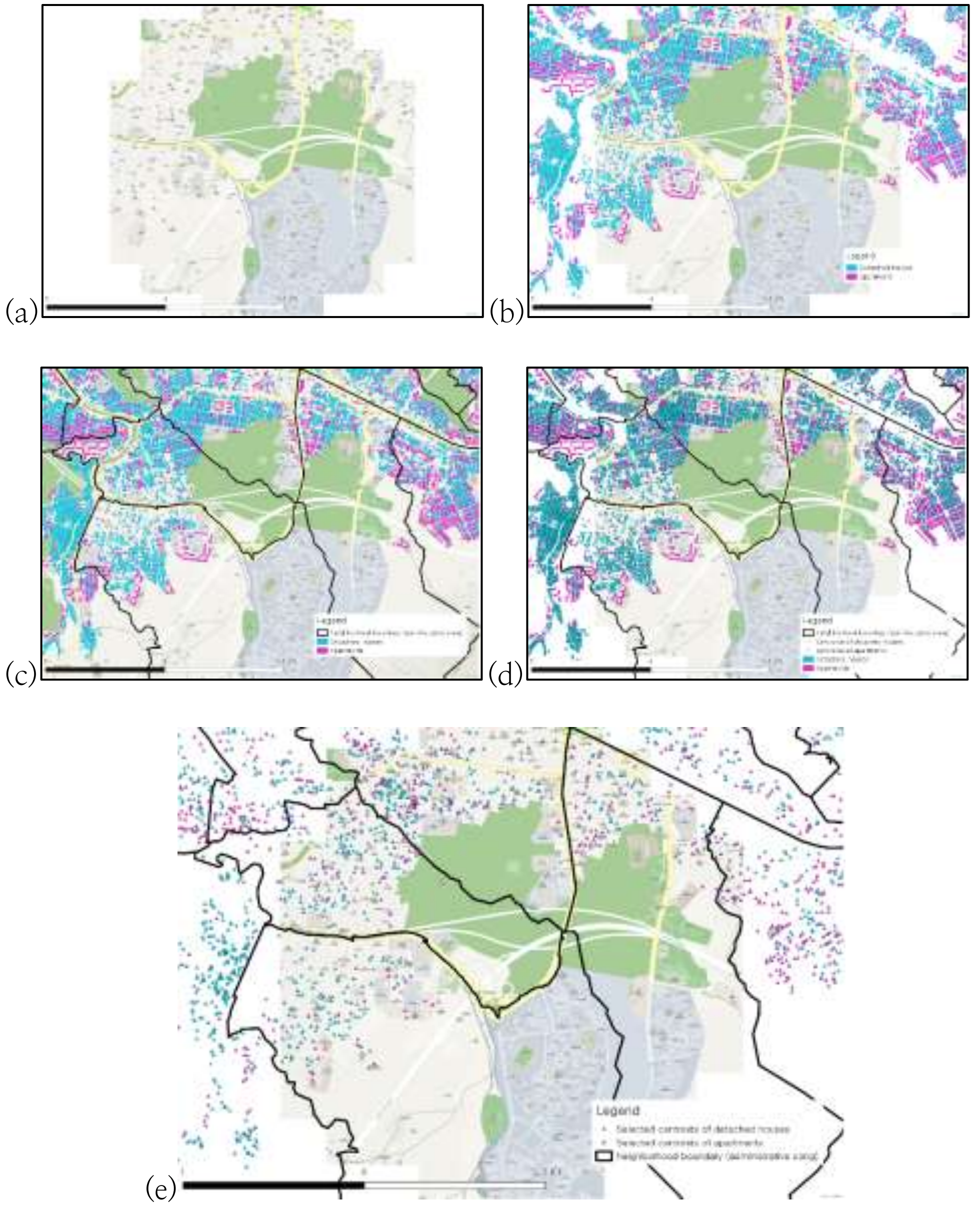

Figure 2-3. Random property allocation process in Gwanakgu, Seoul

Firstly, the residential building register information was geocoded according to the housing types (a→b), and intersected by neighborhoods (c). The coordinates of centroids of buildings were extracted from polygons to points $P_{i'jk}$ (d). The example of the spatial distribution of sampling points p_{ijk} were shown in (e).

- Centroid of buildings: $P_{i'jk}\left(x_{i'jk}, y_{i'jk}\right)$
    - i'=1 to n'$_{jk}$: for number of buildings, $\sum_{k=1}^{424}\sum_{j=1}^{2} n'_{jk} = 483{,}411$
    - j=1(detached house) or 2(apartment): for housing types
    - k=1 to 424: for administrative neighborhoods
    - $p_{ijk} \in P_{i'jk}$

The distance between mean centroids of points and subway stations can be used to represent the accessibility to subway station in a neighborhood. Since the spatial random sampling approach based on the x- and y-coordinates of the points, the mean centroid of p_{ijk} ($\widehat{m_{jk}}$) approximates the mean centroids of $P_{i'jk}$ ($\overline{m_{jk}}$). The minimum distance between subway station and mean centroids was calculated as below:

- Distance 1: minimum distance between subway station and mean centroids
    - Mean centroids sampling points: $\widehat{m_{jk}} = \left(x_{jk}, y_{jk}\right) = \left(\frac{\sum_{i=1}^{n_{jk}} x_{ijk}}{n_{jk}}, \frac{\sum_{i=1}^{n_{jk}} y_{ijk}}{n_{jk}}\right)$

- Mean centroids building centroids: $\overline{m_{jk}} = (x_{jk}, y_{jk}) = (\frac{\sum_{i'=1}^{n'_{jk}} x_{i'jk}}{n'_{jk}}, \frac{\sum_{i'=1}^{n'_{jk}} y_{i'jk}}{n'_{jk}})$
- $\widehat{m_{jk}} \approx \overline{m_{jk}}$
- Distance from mean centroids: $d_{jkl} = d(\overline{m_{jk}}, p_l) = \sqrt{(x_{jk} - x_l)^2 + (y_{jk} - y_l)^2}$
- Minimum distance: $d_{min}(\overline{m_{jk}}) = min_{l \in (1,\dots,286)} d_{jkl}$, jk=1 to 831

The subway stations were located along the borders of neighborhoods, and gave several options of utilization. However, the first approach restricted the accessibility to the nearest station from a mean centroid of neighborhood. As an alternative approach to overcome this restriction, the mean distances between subway stations and building centroids were applied. The unweighted mean of distance between building centroids and subway stations are unbiased estimates of unweighted sample mean of distance between sampling points and subway stations (d_{ijkl}). The mean distance between subway station and building centroids was calculated as follows:

- **Distance 2**: mean distance between subway station and building centroids
  - Distance from sampling points: $d_{ijkl} = d(p_{ijk}, p_l) = \sqrt{(x_{ijk} - x_l)^2 + (y_{ijk} - y_l)^2}$
  - Distance from building centroids: $d_{i'jkl} = d(p_{i'jk}, p_l) = \sqrt{(x_{i'jk} - x_l)^2 + (y_{i'jk} - y_l)^2}$
  - Minimum distance for sampling points: $d_{ijk} = d_{min}(p_{ijk}) = min_{l \in (1,\dots,286)} d_{ijkl}$
  - Minimum distance for building centroids: $d_{i'jk} = d_{min}(p_{i'jk}) = min_{l \in (1,\dots,286)} d_{i'jkl}$
  - Mean distances: $\overline{d_{jk}} = \frac{\sum_{i'=1}^{n'_{jk}} d_{i'jk}}{n'_{jk}}$, jk=1 to 831

■ $\widehat{d_{jk}} = \frac{\sum_{i=1}^{n_{jk}} d_{ijk}}{n_{jk}} \approx \overline{d_{jk}} = \frac{\sum_{i'=1}^{n'_{jk}} d_{i'jk}}{n'_{jk}}$

ArcMap ver.10.3 (ESRI Inc., 2011) and QGIS Desktop 2.18.14 (Quantum GIS Development Team, 2017) were implemented for the spatial data management.

Data Analysis

Subject characteristics and prevalence of sufficient walking were presented as frequencies with proportion, and mean walking duration per week according to individual covariates as means with standard deviation (SD). Odds ratios (ORs) were estimated using a conditional logistic regression model to quantify the association between individual covariates and walking practice. To account for the issue of self-selection, the averaged distance to subway stations by individual covariates were described.

Odds ratios (ORs) of prevalence of sufficient walking for accessibility to subway stations and walking practice were obtained in a primary model, confounding model, and multilevel model. For the weekly walking duration, simple and multiple linear regression were implemented, as well as a multilevel model. The effects of subway station were estimated by stratifying the distance to public transport (subway stations: 〈500 m, 500-1000 m, 1000-1500 m,

$\geq$1500 m), and the association between accessibility and predicted value from the model was explored graphically. R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria) was used in the analysis.

2-3. Results

Participants' General Characteristics

In total, 92,253 among 92,357 subjects responded to the questionnaires asking about walking behavior, and 65.5% of them walked for five or more days per week and 73.0% walked for more than 30 minutes per day (Table 2-1). Although they met the independent criteria for walking frequency and duration, 50,002 (54.1%) of the subjects met the definition of sufficient walking.

Table 2-1. Walking frequency and duration of 92,253 subjects, 2011-2014

Frequency (Days/week)	0	1	2	3	4	5	6	7
N	7575	3363	6179	9366	5278	11595	5596	43345
(%)	8.2	3.6	6.7	10.1	5.7	12.6	6.1	46.9
mean duration (SD)	-	55.3 (61.3)	47.3 (48.2)	50.0 (46.9)	54.9 (51.5)	53.9 (59.8)	71.0 (89.2)	71.0 (80.4)
sufficient walking (%)	-	-	-	-	-	8860 (76.4%)	4586 (82.0%)	36556 (84.3%)
Duration (Minutes/day)	<30	30-60	60-90	90-120	120-150	150-180	180-210	210≤
N	16684	31485	20227	3340	6476	422	2570	3459
(%)	17.9	33.8	21.7	3.6	6.9	0.5	2.8	3.7
mean frequency (SD)	4.9 (2.1)	5.4 (1.9)	5.6 (1.9)	5.5 (1.8)	5.7 (1.9)	5.7 (1.9)	5.9 (1.8)	6.1 (1.6)
sufficient walking (%)	-	22304 (70.8%)	14956 (73.9%)	2369 (70.9%)	4953 (76.5%)	322 (76.3%)	2110 (82.1%)	2988 (86.4%)

Descriptive statistics of the study subjects are provided in Table 2-2. About 90% of respondents were 19-69 years old, and regarding educational attainment, a large majority of the sample had attained at least secondary education. About 30.4% had comparatively sedentary jobs (managers, professionals or clerks), and 39.1% did not have jobs (housewives, students, or military workers). More than half of them lived in apartments and drove cars. About 9.5% of them experienced diseases or accidents during the preceding two weeks of the survey.

The prevalence of walking slightly increased over four years. Subjects with female sex, age of 70 years and older, college education and over, sedentary job or no job, feeling of stress or depression, morbidity during the preceding 2 weeks, or self-reported ill-health walked less, and apartment residents and subjects driving cars also had lower prevalence of walking. The average weekly walking duration was 358.1 minutes (SD = 473.4). Walking duration was obviously different according to housing type, sex, educational attainment, and occupation.

Table 2-3 shows the result of the conditional logistic regression using individual covariates. The odds of prevalence of sufficient walking was lower than 31.8% in subjects driving cars. Housing type, sex, age, educational attainment, occupation, and self-reported health affected the prevalence of sufficient walking and weekly walking duration.

Table 2-2. Characteristics and walking behavior of 92253 subjects, 2011-2014

	Total		Sufficient walking		Walking duration	
	N	(%)	n	(%, PR)	mean	(SD)
Total	92253	(99.9)	50002	(54.1)	358.1	(473.4)
Survey year						
2011	23084	(25.0)	12433	(53.9)	353.7	(469.4)
2012	23033	(24.9)	11985	(52.0)	349.5	(469.1)
2013	23132	(25.0)	12855	(55.6)	357.0	(458.6)
2014	23004	(24.9)	12729	(55.3)	372.1	(495.7)
Housing type						
Apartment	51618	(55.9)	22658	(43.9)	317.7	(397.7)
Detached house	40635	(44.0)	27344	(67.3)	395.2	(530.9)
Sex						
Male	40635	(44.0)	22811	(56.1)	402.5	(536.1)
Female	51618	(55.9)	27191	(52.7)	323.6	(415.2)
Age group						
19-29	14771	(16.0)	9057	(61.3)	367.8	(484.4)
30-39	18547	(20.1)	9423	(50.8)	318.9	(452.5)
40-49	18991	(20.6)	9638	(50.8)	347.8	(483.1)
50-59	17540	(19.0)	9566	(54.5)	391.4	(525.2)
60-69	12498	(13.5)	7241	(57.9)	390.7	(460.3)
70 or older	9906	(10.7)	5077	(51.3)	335.0	(371.3)
Educational attainment						
Primary education or lower	12073	(13.1)	6530	(54.1)	399.4	(513.6)
Secondary education	32053	(34.7)	18385	(57.4)	402.6	(536.7)
College graduate or higher	39579	(42.9)	20367	(51.5)	296.3	(367.7)
Occupation						
Managers/professionals/clerks	28104	(30.4)	14694	(52.3)	292.9	(369.6)
Service and sales workers	13473	(14.6)	7776	(57.7)	462.8	(660.6)
Skilled workers	14366	(15.6)	8330	(58.0)	513.1	(694.4)
Others	36128	(39.1)	19100	(52.9)	309.9	(306.9)
Car driving						
Yes	42253	(45.7)	21245	(50.3)	345.2	(470.9)
No	50000	(54.1)	28757	(57.5)	368.8	(475.2)
Psychological stress						
Stressful	27006	(29.2)	14021	(51.9)	371.7	(525.6)
Non-stressful	65201	(70.6)	35964	(55.2)	352.6	(450.6)
Depressed feeling						
Depressed	6979	(7.6)	3523	(50.5)	369.9	(522.3)
Non-depressed	85241	(92.3)	46468	(54.5)	357.2	(469.3)
Morbidity last 2 weeks						
Yes	8814	(9.5)	4314	(48.9)	356.0	(491.4)
No	83416	(90.3)	45682	(54.8)	358.3	(471.6)
Self-reported health						
Good	39429	(42.7)	22790	(57.8)	367.2	(468.5)
Bad	52820	(57.2)	27211	(51.5)	351.0	(477.1)

Table 2-3. Odds ratio of sufficient walking and coefficients of weekly walking duration for individual variables in multivariate model, 2011-2014

		Sufficient walking OR (95% C.I.)	Walking duration β (95% C.I.)
Survey year			
	2011 (Ref.)	–	–
	2012	0.956 (0.918, 0.996)	0.9 (−8.6, 10.4)
	2013	**1.097 (1.054, 1.142)**	7.9 (−1.4, 17.3)
	2014	**1.098 (1.054, 1.143)**	**27.6 (18.2, 36.9)**
Housing type			
	Apartment (Ref.)	–	–
	Detached house	**1.149 (1.114, 1.184)**	**33.8 (26.7, 40.9)**
Sex			
	Male	**1.256 (1.215, 1.298)**	**68.5 (60.8, 76.1)**
	Female (Ref.)	–	–
Age group			
	19-29 (Ref.)	–	–
	30-39	**0.766 (0.730, 0.804)**	**−25.6 (−36.6, −14.6)**
	40-49	**0.753 (0.718, 0.790)**	**−27.9 (−39.0, −16.8)**
	50-59	**0.858 (0.815, 0.903)**	**−14.5 (−26.4, −2.7)**
	60-69	0.993 (0.935, 1.055)	−12.6 (−26.4, 1.3)
	70 or older	**0.741 (0.692, 0.793)**	**−50.3 (−66.2, −34.5)**
Educational attainment			
	Primary education or lower (Ref.)	–	–
	Secondary education	**0.766 (0.730, 0.804)**	**−25.6 (−36.6, −14.6)**
	College graduate or higher	**0.753 (0.718, 0.790)**	**−27.9 (−39.0, −16.8)**
Occupation			
	Managers/professionals/clerks	**1.084 (1.041, 1.128)**	4.9 (−4.3, 14.2)
	Service and sales workers	**1.234 (1.178, 1.294)**	**139.8 (129.0, 150.7)**
	Skilled workers	**1.222 (1.163, 1.283)**	**167.7 (156.4, 179.1)**
	Others (Ref.)	–	–
Car driving			
	Yes	**0.682 (0.659, 0.706)**	**−29.5 (−37.3, −21.6)**
	No (Ref.)	–	–
Psychological stress			
	Stressful	**0.929 (0.900, 0.959)**	**23.6 (16.2, 30.9)**
	Non-stressful (Ref.)	–	–
Depressed feeling			
	Depressed	**0.924 (0.875, 0.976)**	12.2 (−0.7, 25.0)
	Non-depressed (Ref.)	–	–
Morbidity last 2 weeks			
	Yes	**0.854 (0.813, 0.897)**	3.8 (−7.8, 15.5)
	No (Ref.)	–	–
Self-reported health			
	Good	**1.264 (1.227, 1.301)**	**25.9 (19.1, 32.7)**
	Bad (Ref.)	–	–

Accessibility to public transport

Descriptive statistics of the accessibility to subway station are provided in Table 2-4, and the correlation of two measures are shown in Figure 2-4. The mean distances were 625.6 m (SD = 320.3) and 625.3 m (SD = 367.0) for methods 1 and 2, respectively. Despite the similar mean distances, the median distance and range of distance were about 30 m longer in distance 1. The accessibility was different by housing type, age, educational attainment, occupation, morbidity during the preceding 2 weeks, and self-reported health. The distances measured using mean centroids were less than the mean distance when the distance was less than 500 m (Figure 2-4).

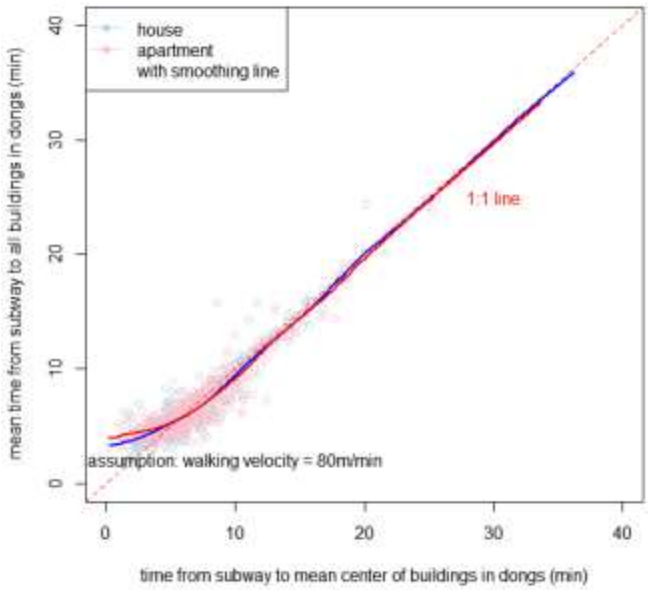

Figure 2-4. Correlation between distance from mean centroids of building centroids (x-axis) and mean distance from building centroids (y-axis)

* Walking distance-time transformation (minutes): Distance divided by 80m/min, averaged walking velocity in adult population

Table 2-4. Summary statistics of accessibility to subway station

		Distance 1 Mean (SD)	Distance 2 Mean (SD)
Total			
	Mean (SD)	625.6 (320.3)	625.3 (367.0)
	Median (Range)	535.4 (9.2, 2894.0)	508.9 (164.0, 2853.0)
Housing type			
	Apartment	600.5 (368.9)	605.3 (336.5)
	Detached house	648.6 (411.4)	643.7 (392.1)
Sex			
	Male	625.5 (391.3)	625.2 (368.5)
	Female	625.7 (393.6)	625.3 (365.8)
Age group			
	19-29	612.8 (382.7)	612.6 (358.0)
	30-39	613.0 (368.7)	613.3 (342.9)
	40-49	635.0 (403.2)	636.4 (376.3)
	50-59	633.1 (402.7)	631.8 (377.9)
	60-69	632.7 (400.9)	631.5 (376.0)
	70 or older	627.6 (397.7)	626.0 (373.9)
Educational attainment			
	Primary education or lower	634.4 (391.4)	631.2 (367.0)
	Secondary education	636.6 (394.7)	636.2 (370.5)
	College graduate or higher	613.0 (392.0)	613.9 (365.5)
Occupation			
	Managers/professionals/clerks	611.2 (387.1)	613.1 (360.7)
	Service and sales workers	628.1 (390.5)	626.6 (365.1)
	Skilled workers	634.8 (379.4)	632.2 (355.0)
	Others	632.3 (401.9)	631.8 (377.2)
Car driving			
	Yes	625.9 (397.5)	627.0 (370.8)
	No	625.3 (387.9)	623.8 (363.8)
Psychological stress			
	Stressful	625.3 (390.5)	624.8 (360.5)
	Non-stressful	625.6 (393.0)	625.4 (367.5)
Depressed feeling			
	Depressed	630.9 (385.5)	630.0 (360.5)
	Non-depressed	625.1 (392.9)	624.0 (367.6)
Morbidity last 2 weeks			
	Yes	653.9 (420.4)	656.0 (395.0)
	No	622.6 (389.1)	622.1 (363.8)
Self-reported health			
	Good	616.4 (389.1)	616.0 (363.4)
	Bad	632.4 (394.5)	632.2 (369.6)

* Distance 1: minimum distance between subway station and mean centroids

* Distance 2: mean distance between subway station and building centroids

Association between accessibility to public transport and walking

The prevalence of sufficient walking was significantly higher in the neighborhood with mean distance of 500–1000 m than that with mean distance of less than 500 m. Subjects living in the neighborhood with mean distance more than 1500 m walked about 10% less than the reference distance. On the other hand, the weekly walking duration was the longest in the neighborhood with 1000–1500 m distance when using distance 1 (accessibility from mean centroids). When using distance 2 (mean distance from all buildings), the estimates were similar to the results obtained using distance 1; however, walking duration was significantly higher in the neighborhood with mean distance of 500–1000 m also (Table 2–5). The results obtained using two distances were consistent after adjusting for the individual variables (Table 2–6), and the increment of walking duration was attenuated.

Table 2-5. Odds ratio of sufficient walking and coefficients of weekly walking duration for distance to subway stations, 2011-2014

		Sufficient walking OR (95% C.I.)	Walking duration β (95% C.I.)
Distance 1			
	〈500m (Ref.)	-	-
	500-1000m	1.053 (1.024, 1.083)	5.2 (-1.6, 12.0)
	1000-1500m	0.996 (0.950, 1.044)	44.6 (33.0, 56.2)
	1500m-	0.906 (0.843, 0.974)	6.5 (-11.4, 24.4)
Distance 2			
	〈500m (Ref.)	-	-
	500-1000m	1.053 (1.024, 1.083)	10.3 (3.4, 17.1)
	1000-1500m	1.009 (0.962, 1.057)	43.4 (31.8, 55.1)
	1500m-	0.899 (0.837, 0.966)	7.5 (-10.1, 25.2)

* Distance 1: minimum distance between subway station and mean centroids

* Distance 2: mean distance between subway station and building centroids

Table 2-6. Odds ratio of sufficient walking and coefficients of weekly walking duration for distance to subway stations adjusting individual variables, 2011-2014

		Sufficient walking OR (95% C.I.)	Walking duration β (95% C.I.)
Distance 1			
	〈500m (Ref.)	-	-
	500-1000m	1.058 (1.028, 1.090)	8.5 (1.6, 15.3)
	1000-1500m	0.981 (0.933, 1.032)	28.5 (16.7, 40.2)
	1500m-	0.880 (0.815, 0.951)	-1.9 (-19.9, 16.1)
Distance 2			
	〈500m (Ref.)	-	-
	500-1000m	1.056 (1.025, 1.088)	9.2 (2.4, 16.1)
	1000-1500m	0.998 (0.949, 1.050)	28.8 (17.1, 40.5)
	1500m-	0.873 (0.809, 0.942)	-3.3 (-21, 14.4)

* Distance 1: minimum distance between subway station and mean centroids

* Distance 2: mean distance between subway station and building centroids

In the multilevel neighborhood model, the intraclass correlation coefficients were 2.93% and 1.20% for prevalence of walking and walking duration, respectively (Table 2-7), and only increased walking duration was expected in the 1000-1500 m distance from the subway station.

The accessibility to the subway station showed a non-linear association with walking duration, and Figure 2-5 shows the association between distance to subway station and weekly walking duration. The duration of walking increased within 1.0-1.5 km to the subway station, and then decreased at a further distance.

Table 2-7. Odds ratio of sufficient walking and coefficients of weekly walking duration for distance to subway stations adjusting individual variables in neighborhood multilevel model, 2011-2014

		Sufficient walking OR (95% C.I.)	Walking duration β (95% C.I.)
Distance 1			
	<500m (Ref.)	-	-
	500-1000m	1.028 (0.970, 1.089)	6.0 (-5.0, 17.0)
	1000-1500m	0.941 (0.839, 1.055)	21.4 (0.7, 42.2)
	1500m-	0.897 (0.757, 1.064)	1.8 (-29.2, 32.8)
	ICC (%)	2.93	1.20
Distance 2			
	<500m (Ref.)	-	-
	500-1000m	1.015 (0.958, 1.077)	10.9 (-0.2, 21.9)
	1000-1500m	0.999 (0.896, 1.113)	23.7 (3.6, 43.9)
	1500m-	0.876 (0.745, 1.031)	-1.0 (-31.0, 29.0)
	ICC (%)	2.93	1.20

* Distance 1: minimum distance between subway station and mean centroids

* Distance 2: mean distance between subway station and building centroids

The weekly walking duration increment (minutes/week) for each 100 m distance increase from mean centroids were 1.156 (−4.995, 7.307), 0.405 (−6.269, 7.079), 14.667 (−0.364, 29.698), and −12.616 (−22.587, 2.645) in less than 500 m, 500−1000 m, 1000−1500 m, and more than 1500 m, respectively. Also, those for mean distances from building centroids were 5.726 (−4.738, 16.190), −0.168 (−6.424, 6.089), 21.719 (5.218, 38.220), and −10.137 (−20.617, 0.343), respectively (Figure 2−6).

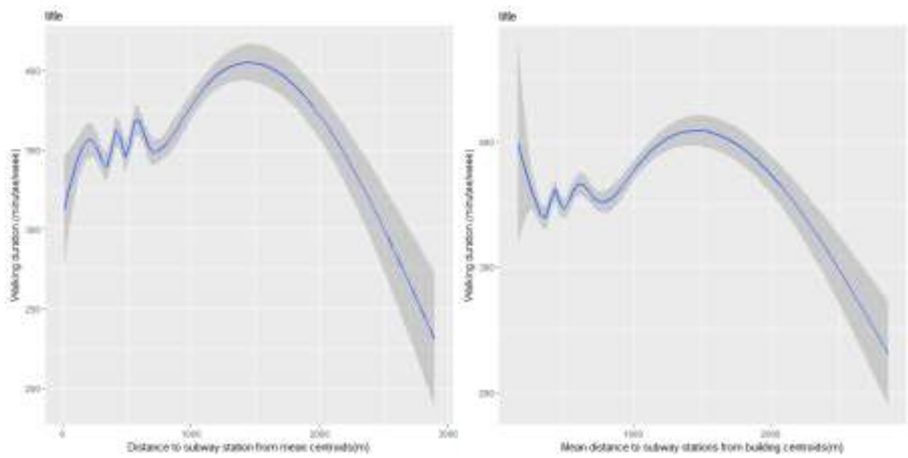

Figure 2−5 Non−linear association between accessibility to subway station and weekly walking duration by using distance from mean distance (left) and mean distance from all building centroids (right)

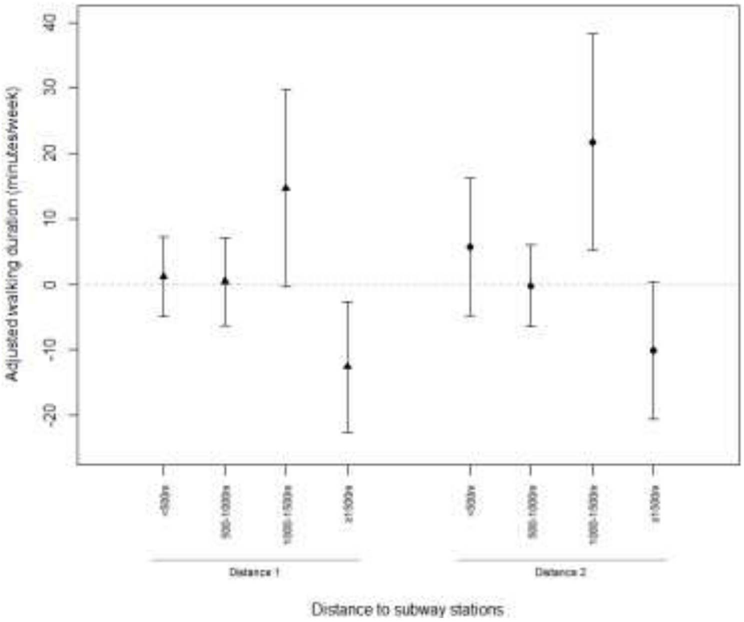

Figure 2-6. The weekly walking duration for 100m increase of distance to subway station estimated in neighborhood multilevel model

* Distance 1: minimum distance between subway station and mean centroids

* Distance 2: mean distance between subway station and building centroids

2-4. Discussion

The main purpose of this study was to explore the environmental attributes of walking in Seoul focusing on accessibility to subway station, and found a non-linear association with walking practice. The prevalence of sufficient walking meeting the PA recommendation was higher within a distance of 500-1000 m, and the weekly walking duration was significantly increased within a distance of 1000-1500 m. The walking frequency and duration were higher within 500-1000 m and in 1000-1500 m, respectively, and this caused the difference between prevalence and duration in the results.

Studies on validation of the IPAQ questionnaire found considerably high reliability of walking frequency and relatively low validity of walking duration (25, 24). The interpretation of the effects of walking duration may be controversial. Kim et al. (2005) estimated that one walks for 440 m (7.43 minutes) for public transit per day in a trajectory study (16), and this was quite shorter than the responses given by subjects in this study. However, if one walks mainly for commuting, he/she perceives relatively accurate walking distance and duration in order to make walking efficient.

Rissel et al. (2012) estimated a range of 8-33 additional minutes of walking as being attributable to public transport use in a systematic review (25), and the current study showed consistent results. This result is also consistent with that reported by Sung et al. (2014a) who identified the association between neighborhood-level densities of subway stations using the 2007-2011 Korea National Health and Nutrition Examination Survey data in 149 neighborhoods in Seoul (13).

Sung (2014b) showed non-linear association between walking duration and BE factors, including distance to bus stops (14); however, this study is the first to provide empirical evidence of the non-linear association between walking and distance to subway station in Korea. The accessibility to subway station is associated with connecting walking practice (26, 27). The accessibility to bus stops also has a similar meaning, but the effect is relatively obscure because of the dense network of bus transport in Seoul and the proximity between residence and bus stops; most of the residences are located within 10 minutes walking distance from the bus station (28).

Previous studies examined the effect of areal level of PA environment in South Korea, while the present study assessed the influence of public transport access on walking duration at a more detailed geographical level using residential building register information and housing type of subjects. This study identified that moderate distance to public transport improves the walking duration significantly. This result is inconsistent with previous studies that reported the linear effect of proximity, and this may come from using different areal catchments.

PA reduces the risk of physical or psychological diseases and helps to maintain health (6). Ding et al. (2016) estimated that globally, $53.8 billion of health-care costs, $13.7 billion in productivity losses, and 13.4 million disability-adjusted life-years were attributed to PA in 2013 (7). In particular, high-income countries bear 80.8% of the health-care costs and 60.4% of productivity losses. Walking comprises a substantial part of PA in the adult population (8), and is "an easy activity to begin and maintain as part of a physically active lifecycle" (29).

However, the walkable environment has a mixed effect on health. As reported by Malambo et al. (2016), the proximity of transportation is positively associated with PA; however, it is also associated with the accessibility to fast-food outlets and the exposure to air pollution – i.e, $PM_{2.5}$ (30), and similar results were reported by Chaney et al. (2017) (31). Therefore, the health impacts of compactness of the urban environment have to be monitored with multi-dimensional research under more comprehensive views.

Previous studies which evaluated walkability in South Korea usually evaluated environmental factors or urban planning elements, which were empirically proven in the background of Western countries, on all-purpose walking, and only a few studies specified purposes of walking based on pilot questionnaire surveys in restricted geographical areas (Table 2-1) (10-28). In the field of public health, only a few studies have assessed the association between individual behavior and administrative areal level factors using multilevel models (32). Future studies on multidimensional aspects of walkable environment effects on diverse health outcomes will be needed.

This study examined the associations between environmental factors and walking, although it had some limitations. First, the influence of BE was assessed not on the real distance from subject residence but the representative distances considering the respondent's housing type in a neighborhood. However, this approach may encourage researchers using existing public health data in a circumstance where the utilization of personal location is prohibited by legal acts. When a complete geocoded address is available, it may be possible to assess the health impact of accessibility to public transport including bus stops and to utilize network distance which can provide a more sophisticated estimation of the effect size.

The present study assumed that the differences in walking behavior across the neighborhoods and housing type were greater than those within the neighborhood and same housing type. The second limitation is rooted in this point. Even though the current study assessed the effect of accessibility of public transport adjusting for individual covariates, the utilization of public transport may differ across the population. Particularly, the utilization of public transit and walking behavior of vulnerable populations and its health effect on them needs to be studied in the future.

Another limitation is attributed to the cross–sectional design, which made it impossible to evaluate the causal relationship between BE and individual healthy lifestyle and "self–selection" mechanism in this study. As shown in Table 2–4, more affluent and healthier populations live in proximity to subway stations, and this may confound the association of the health outcome attributed by walking, such as obesity, and the accessibility to public transport. Several methodologies, i.e. – instrumentally variable techniques or structural equational models can be considered to account for the self–selection problem in future studies.

Despite these limitations, this study found out the influence of accessibility to public transport on walking behavior using more detailed measurement of proximity less than administrative boundaries. Another strength of this study is the large sample, which allowed us to understand the effect of environmental factors on obesity in great detail.

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Chapter 3. Built Environment and Obesity

3-1. Introduction

Obesity, one of the most significant health risk factors, is of great concern internationally (1). The worldwide prevalence of obesity has nearly doubled since 1980, according to the World Health Organization (WHO) (2). Obesity results in a host of health consequences such as cardiovascular disease, diabetes, hypertension, and causes social ramifications including depression and psychological pain (3,4).

In South Korea, the obesity rate in 2015 was 33.2%, which resulted in an astronomical figure of socioeconomic costs of up to $55 billion in 2013, 2.2 times higher compared to 2005 (5). In Seoul, the capital of South Korea, the obesity rate was not high compared to other megacities in Western countries such as New York. However, the rate has consistently increased from 20.7% in 2008 to 23.6% in 2014 (6), and this was the highest obesity rate among Asian countries. Moreover, there were differences in obesity rate between men and women where men's obesity rate was 39.7%, higher than the 26% of women in 2014, and disparities among administrative districts were also highlighted as a problem regarding obesity in Seoul.

In the past, policies combating obesity in Seoul usually focused on improving individual health behaviors, reducing food intake and increasing physical activities, and educating about health promotion. Health authorities intervened through health centers in each administrative district; however, the obesity rate has increased continuously, reflecting the ineffectiveness of these policies. In this context, there has been a global surge in the emphasis on the impact of built environment (BE) on obesity and comprehensive approaches have emerged since the 2000s, such as the ecological model of health determinants, considering factors from the individual to environmental level to prevent obesity (7–18). That is, this concept supposes that the BE and lifestyle of urban residents affects their health status and one of the assumptions is that unexpected health problems have appeared due to rapid global urbanization. In line with the ecological model, Health City projects have started in several cities in Europe that try to change the health environment by finding health determinants and coordinating and intervening in relevant policies (19). The Seoul Metropolitan government joined the Alliance for Health Cities (AFHC) in 2004, and now 23 out of 25 administrative districts ('gu's) participate as Health City members; however, the aim of Health City didn't feed into urban planning in either Seoul or each administrative district.

As a result of increasing urbanization, people have no choice but to live in confined spaces, and also, environments that decrease the physical activities of urban residents have appeared, and car usage has increased as the distance between residences and workplaces has widened (20, 21). Old downtown areas usually fall short of pedestrian amenities and open spaces, and these areas typically have poor street patterns. Further, an unhealthy food environment, such as easy access to high–calorie foods and negative perception of nonhomogeneous neighborhoods, makes urban residents likely to be obese (22, 23). Seoul also has a damaging environment to health because the population density is very high and open spaces are limited. Regarding the food environment, there are many fast food stores and street food establishments, and people can order any food through 24–h delivery services at any time.

As previously mentioned, the obesity rate of Seoul has steadily increased, and the disparities among neighborhoods have grown. Against the backdrop of this situation, this chapter was conducted to provide the grounds for building a healthy environment in Seoul, and it explored both the individual and BE components of obesity in Seoul based on the ecological model of health.

3-2. Data and Methods

Participants and Individual-Level Variables

This chapter examined the research hypothesis on the 45,447 samples derived from the 2011 and 2013 CHS for obesity and individual covariates. For socio-demographic variables, age groups were divided at 10 years intervals (10 – 29, 30 – 39, 40 – 49, 50 – 59, 60 – 69, over 70), and household income groups were classified as five quintiles where the first group was the lowest income group and the fifth group was the highest income group. With regard to educational attainment, the participants were asked the level at which their education was completed, which was classified into four educational categories: lower than middle school, high school graduate, college graduate, and graduate school or higher.

For health behavior, current smoking status (whether respondents smoked or not), high-risk drinking (yes/no based on adequate drinking), and drinking period were asked. High-risk drinking referred to men drinking over seven glasses of beer or women drinking over five glasses of beer at one drinking party for more than two days a week. Walking rate was also included in this study, i.e., whether respondents walked over 30 min for more than 5 days in a week or not, as well as the time people spent watching TV and surfing the Internet during leisure time in the last week. We divided people according to whether they spent more/less than 3 h a day watching TV and surfing the Internet. For vegetable and fruit intake, we classified respondents according to whether they consumed fruits or vegetables more than once in a day in the last one month or not, and asked regarding high salt intake in daily life based on yes/no. For health status, we asked whether one was stressed during daily life, and used a measure of self-reported health in which a person recognized him/herself during daily life based on good/bad.

Outcome Measurements

Body mass index (BMI; weight in kilograms divided by height in meters squared) is based on self-reported height and weight. According to the definition of the World Health Organization for the Western Pacific Region (WPRO), individuals with BMI of 25 kg/m^2 or more were classified as obese and those with a BMI less than 25 kg/m^2 as non-obese (24, 25). Respondents were also divided into groups based on their subjective perception of overweight and obese and intention to control weight.

Environment-level Variables

We divided environmental-level variables into three categories: physical activity environment, food environment, and urban environment. Physical activity environment variables included the area of parks in a person's living spheres, number of physical training centers per 10,000 persons, rate of commute by cars, and satisfaction with walking environment. The area of parks in a person's living spheres in the Seoul Survey is calculated by dividing the sum of the areas of urban nature parks, neighborhood parks, children's parks, mini-parks, sport parks, culture parks, historic parks, and waterside parks (meters squared) by population. Satisfaction with walking environment in the Seoul Survey is the degree of satisfaction with walking in the neighborhood and downtown Seoul, which ranged from 0 to 10 points.

Food environment variables included the food insecurity index, number of fast food stores per 10,000 persons from the Freedom of Information and Transparent Survey, and number of fried chicken stores per 10,000 persons from the Seoul Employer Survey. The food insecurity index, in the Seoul Survey, is the rate of people who answered, "I often fell short of food due to economic burden in the most recent one year".

Urban environment variables included urbanization rate, social trust, fiscal self-reliance ratio, crime rate, and the number of beds per 10,000 persons. Urbanization rate, from Seoul Statistics, is calculated by dividing the sum of residential, commercial, and manufacturing areas out of use districts by the area of administrative districts. Social trust, from the Seoul Survey, is the degree of trust for family, neighborhood, complete strangers, foreigners, and government offices, which ranged from 0 to 10. Fiscal self-reliance ratio, from the Clean Plus website, was calculated by dividing one's income (sum of local taxes and non-tax receipts) by the size of the general accounting budget. Crime rate, from the Seoul Metropolitan Police Agency, was calculated by dividing the number of violent crimes (murder, robbery, rape, larceny, violence) by 100,000 persons. For the number of beds per 10,000 persons, the source was from Health Insurance Review and Assistance Service, and the beds of hospitals and clinics were included in the calculation.

Data Analysis

Multilevel analysis has emerged as an analytical strategy that allows the simultaneous examination of group-level and individual-level factors. The use of multilevel analysis raises theoretical and methodological issues related to the theoretical model being tested, conceptual distinction between group- and individual-level variables, ability to differentiate "independent" effects, reciprocal relationships between factors at different levels, and the increased complexity that these models apply(26). As mentioned earlier, there were obesity disparities among administrative districts in Seoul, thus, multilevel logistic regression was used to estimate the determinants of obesity measured at the individual and environmental level to comprehend the reasons for these disparities. Four models were staged for each outcome: Model 1, the null model, did not contain any covariates in order that both the individual and environmental level variance in the outcomes could be assessed in the absence of any explanatory variables. Model 2 contained only the individual-level covariates; Model 3 contained only the environmental-level covariates; and finally, Model 4 contained the individual-level and environmental-level covariates. A model for these estimation methods is described in the following equation where Y_{ij} is obesity, X_{ij} are individual i's characteristics residing in j district, and Z_j are environmental characteristics of j district:

$$\text{logit}\{P_r\left(Y_{ij} = 1 \middle| X_{ij}, Z_j\right) = \gamma_{00} + \gamma_{10}X_{ij} + \gamma_{01}Z_j + \gamma_{11}X_{ij}Z_j + U_{1j}X_{ij} + U_{0j} + \varepsilon_{ij}$$

3-3. Results

Participants' General Characteristics

Descriptive statistics of the study sample are provided in Table 3-1. In total, 45,447 Seoul citizens were included in the study, which included 20,147 men and 25,300 women. Age and household income groups of respondents were evenly distributed. For educational attainment, a large majority of the sample was high school-graduated and college-graduated. More male respondents (40.4%) were smokers than female respondents (3.5%). Nearly half of the respondents among both men (56.6%) and women (53.3%) walked more than 5 days a week for a total of 30 min or more per day. Over 70% of the respondents did not watch the television or surf the Internet more than 3 h in a day, replied that they were not stressful, and thought themselves as healthy people. More female respondents (58.9%) consumed fruits than male respondents (43.7%). More respondents did not eat vegetables or high salt foods than those who did. The overall obesity prevalence of the sample was 29.8% for men and 16.7% for women.

Table 3-1. Descriptive characteristics of study sample.

	Total		Women		Men	
	N	(%)	N	(%)	N	(%)
Total	45,447	(100.0)	20,147	(100.0)	25,300	
Age group						
19-29	7,453	(16.4)	3300	(16.4)	4153	(16.4)
30-39	9,477	(20.9)	4353	(21.6)	5124	(20.3)
40-49	9,429	(20.7)	4201	(20.9)	5228	(20.7)
50-59	8,619	(19.0)	3633	(18.0)	4986	(19.7)
60-69	6,038	(13.3)	2691	(13.4)	3347	(13.2)
70 years or older	4,431	(9.7)	1969	(9.8)	2462	(9.7)
Household income						
First group	10,387	(22.9)	4292	(21.3)	6095	(24.1)
Second group	7,815	(17.2)	3536	(17.6)	4279	(16.9)
Third group	8,891	(19.6)	4031	(20.0)	4860	(19.2)
Fourth group	8,242	(18.1)	3733	(18.5)	4509	(17.8)
Fifth group	10,112	(22.3)	4555	(22.6)	5557	(22.0)
Educational attainment						
Primary education or lower	9,880	(21.7)	3327	(16.5)	6553	(25.9)
Secondary education	16,014	(35.2)	7266	(36.1)	8748	(34.6)
College graduate	17,043	(37.5)	8049	(40.0)	8994	(35.5)
Graduate school or higher	2,510	(5.5)	1505	(7.5)	1005	(4.0)
Current smoking						
Yes	9,011	(19.8)	8130	(40.4)	881	(3.5)
No	36,436	(80.2)	12,017	(59.6)	24,419	(96.5)
Sufficient walking						
Yes	24,901	(54.8)	11,413	(56.6)	13,488	(53.3)
No	20,546	(45.2)	8734	(43.4)	11,812	(46.7)
Television viewing or internet surfing						
Yes	11,978	(26.4)	5276	(26.2)	6702	(26.5)
No	33,470	(73.6)	14,871	(73.8)	18,599	(73.5)
Fruit intake						
Yes	23,703	(52.2)	8812	(43.7)	14,891	(58.9)
No	21,744	(47.8)	11,335	(56.3)	10,409	(41.1)
Vegetable intake						
Yes	16,209	(35.7)	6711	(33.3)	9498	(37.5)
No	29,238	(64.3)	13,436	(66.7)	15,802	(62.5)
High salt intake						
Yes	12,337	(27.1)	6561	(32.6)	5776	(22.8)
No	33,110	(72.9)	13,586	(67.4)	19,524	(77.2)
Psychological stress						
Non-stressful	32,193	(70.8)	14,379	(71.4)	17,814	(70.4)
Stressful	13,254	(29.2)	5768	(28.6)	7486	(29.6)
Self-reported Health						
Good	6,186	(13.6)	2217	(11.0)	3969	(15.7)
Bad	39,261	(86.4)	17,930	(89.0)	21,331	(84.3)
Overweight or obesity (BMI ≥25 kg/m^2)						
Low weight	2,735	(6.0)	454	(2.3)	2281	(9.0)
Normal weight	32,466	(71.4)	13,681	(67.9)	18,785	(74.2)
Obese	10,246	(22.5)	6012	(29.8)	4234	(16.7)

Multilevel Analyses

Individual and environmental factors associated with BMI are shown in Tables 3-2 and Tables 3-3. Model 1 shows the associations between obesity and individual factors including sociodemographic characteristics, health behavior, and health status. For men, age, income, education attainment, smoking, high-risk drinking, drinking period, walking, high salt intake, stress, and self-reported health were associated with obesity. For women, age, income (only for the 5th quintile), education attainment, smoking, high-risk drinking, time spent watching TV and surfing the Internet, fruit intake, high salt intake, stress, and self-reported health had associations with obesity. Model 2 shows the influence of environmental factors on obesity. For men, the number of physical training centers was significantly associated with obesity whereas the number of fast food stores was significant for women. Model 3 shows the correlations between obesity and factors from the individual to environmental level.

Table 3-2. Individual and environmental factors affecting obesity of men in Seoul based on multilevel analysis results.

	Model 1			Model 2			Model 3		
	Est.	S.E.	Pr>|t|	Est.	S.E.	Pr>|t|	Est.	S.E.	Pr>|t|
(Intercept)	1.520	0.086	<.0001	0.362	0.721	0.624	0.686	0.699	0.346
Individual-level predictors									
Age group									
19-29 (Ref.)									
30-39	0.584	0.064	<0.0001				0.578	0.064	<0.0001
40-49	0.411	0.085	<0.0001				0.403	0.085	<0.0001
50-59	0.183	0.113	0.104				0.175	0.113	0.122
60-69	0.019	0.145	0.893				0.029	0.145	0.840
70 years or older	0.459	0.181	0.011				0.475	0.181	0.009
Household income									
First group (Ref.)									
Second group	0.018	0.055	0.741				0.016	0.055	0.776
Third group	0.127	0.053	0.017				0.124	0.053	0.020
Fourth group	0.143	0.055	0.009				0.140	0.055	0.011
Fifth group	0.112	0.054	0.039				0.115	0.054	0.034
Educational attainment									
Primary education or lower (Ref.)									
Secondary education	0.017	0.055	0.758				0.018	0.055	0.741
College graduate	0.145	0.057	0.011				0.153	0.058	0.008
Graduate school or higher	0.190	0.078	0.015				0.202	0.079	0.010
Current smoking									
Yes	0.188	0.035	<0.0001				0.188	0.035	<0.0001
No (Ref.)									
High risk drinking									
Yes	0.299	0.037	<0.0001				0.298	0.037	<0.0001
No (Ref.)									
Drinking period	0.008	0.003	0.026				0.008	0.008	0.003
Sufficient walking									
Yes	0.080	0.033	0.014				0.081	0.033	0.014
No (Ref.)									
Television viewing or internet surfing									
Yes	0.081	0.038	0.032				0.082	0.038	0.030
No (Ref.)									

Table 3-2. Individual and environmental factors affecting obesity of men in Seoul based on multilevel analysis results (Cont.).

	Model 1			Model 2			Model 3		
	Est.	S.E.	Pr>|t|	Est.	S.E.	Pr>|t|	Est.	S.E.	Pr>|t|
Fruit intake									
Yes	0.001	0.035	0.968				0.002	0.035	0.960
No (Ref.)									
Vegetable intake									
Yes	0.015	0.036	0.672				0.015	0.036	0.668
No (Ref.)									
High salt intake									
Yes	0.237	0.034	<0.0001				0.236	0.034	<0.0001
No (Ref.)									
Psychological stress									
Non-stressful (Ref.)									
Stressful	0.095	0.036	0.008				0.095	0.036	0.008
Self-reported Health									
Good (Ref.)									
Bad	0.112	0.056	0.047				0.111	0.056	0.048
Environment-level predictor									
The number of fast food stores				0.012	0.022	0.592	0.007	0.022	0.765
The number of fried chicken stores				0.363	0.184	0.073	0.393	0.178	0.048
Fiscal self-reliance ratio				0.009	0.005	0.136	0.006	0.005	0.273
The area of parks				0.013	0.012	0.305	0.011	0.012	0.364
The number of sports facilities				0.142	0.056	0.027	0.127	0.054	0.038
The rate of commute by cars				0.001	0.001	0.330	0.002	0.001	0.100
Satisfaction on walking environment				0.012	0.009	0.203	0.012	0.008	0.170
Food insecurity rate				0.188	0.091	0.061	0.217	0.088	0.029
Urbanization rate				0.011	0.051	0.825	0.040	0.049	0.431
Social trust				0.128	0.071	0.097	0.102	0.069	0.165
Crime rate				0.000	0.000	0.159	0.000	0.000	0.462
The number of beds				0.002	0.005	0.654	0.001	0.005	0.778
Random effects									
σ^2	0.005	0.003	0.064	0.003	0.003	0.223	0.002	0.003	0.316

Table 3-3. Individual and environmental factors affecting obesity of women in Seoul based on multilevel analysis results.

	Model 1			Model 2			Model 3		
	Est.	S.E.	Pr>|t|	Est.	S.E.	Pr>|t|	Est.	S.E.	Pr>|t|
(Intercept)	2.341	0.106	<0.0001	2.617	0.710	0.003	3.209	0.847	0.003
Individual-level predictors									
Age group									
19-29 (Ref.)									
30-39	0.709	0.085	<0.0001				0.702	0.085	<0.0001
40-49	0.970	0.088	<0.0001				0.964	0.088	<0.0001
50-59	1.063	0.098	<0.0001				1.062	0.098	<0.0001
60-69	1.317	0.112	<0.0001				1.317	0.112	<0.0001
70 years or older	1.121	0.134	<0.0001				1.121	0.134	<0.0001
Household income									
First group (Ref.)									
Second group	0.037	0.061	0.543				0.031	0.061	0.611
Third group	0.005	0.062	0.936				0.010	0.062	0.870
Fourth group	0.069	0.066	0.296				0.072	0.066	0.272
Fifth group	0.257	0.068	0.000				0.247	0.068	0.000
Educational attainment									
Primary education or lower (Ref.)									
Secondary education	0.291	0.057	<0.0001				0.280	0.057	<0.0001
College graduate	0.759	0.071	<0.0001				0.732	0.071	<0.0001
Graduate school or higher	1.129	0.152	<0.0001				1.086	0.153	<0.0001
Current smoking									
Yes	0.265	0.108	0.014				0.255	0.108	0.018
No (Ref.)									
High risk drinking									
Yes	0.199	0.092	0.031				0.199	0.092	0.030
No (Ref.)									
Drinking period	0.002	0.002	0.374				0.002	0.002	0.323
Sufficient walking									
Yes	0.020	0.040	0.617				0.021	0.040	0.598
No (Ref.)									
Television viewing or internet surfing									
Yes	0.314	0.044	<0.0001				0.311	0.044	<0.0001
No (Ref.)									

Table 3-3. Individual and environmental factors affecting obesity of women in Seoul based on multilevel analysis results (Cont.).

	Model 1			Model 2			Model 3		
	Est.	S.E.	Pr>|t|	Est.	S.E.	Pr>|t|	Est.	S.E.	Pr>|t|
Fruit intake									
Yes	0.091	0.043	0.033				0.088	0.043	0.040
No (Ref.)									
Vegetable intake									
Yes	0.035	0.043	0.421				0.031	0.043	0.479
No (Ref.)									
High salt intake									
Yes	0.323	0.045	<0.0001				0.324	0.045	<0.0001
No (Ref.)									
Psychological stress									
Non-stressful (Ref.)									
Stressful	0.176	0.044	<0.0001				0.176	0.044	<0.0001
Self-reported Health									
Good (Ref.)									
Bad	0.219	0.055	<0.0001				0.218	0.055	<0.0001
Environment-level predictor									
The number of fast food stores				0.062	0.021	0.014	0.036	0.026	0.187
The number of fried chicken stores				0.108	0.181	0.563	0.134	0.217	0.548
Fiscal self-reliance ratio				0.000	0.005	0.985	0.001	0.006	0.905
The area of parks				0.019	0.012	0.139	0.022	0.014	0.153
The number of sports facilities				0.119	0.057	0.058	0.076	0.069	0.288
The rate of commute by cars				0.002	0.001	0.157	0.001	0.002	0.449
Satisfaction on walking environment				0.006	0.009	0.495	0.009	0.010	0.383
Food insecurity rate				0.049	0.087	0.579	0.136	0.104	0.214
Urbanization rate				0.069	0.050	0.193	0.045	0.060	0.466
Social trust				0.086	0.070	0.242	0.018	0.083	0.829
Crime rate				0.000	0.000	0.748	0.000	0.000	0.835
The number of beds				0.001	0.005	0.843	0.004	0.006	0.589
Random effects									
σ^2	0.014	0.007	0.029	0.001	0.003	0.364	0.002	0.005	0.342

The regional density of fast–food outlets was marginally positively associated with obesity in male and female after adjusting regional fiscal self–reliance ratio (Figure 3–1). In contrast, the regional fiscal self–reliance ratio was marginally negatively associated with obesity in male and female after adjusting density of fast–food outlets (Figure 3–2).

Male	Female
Fiscal self–reliance ratio	

The density of fast food stores (/km^2)

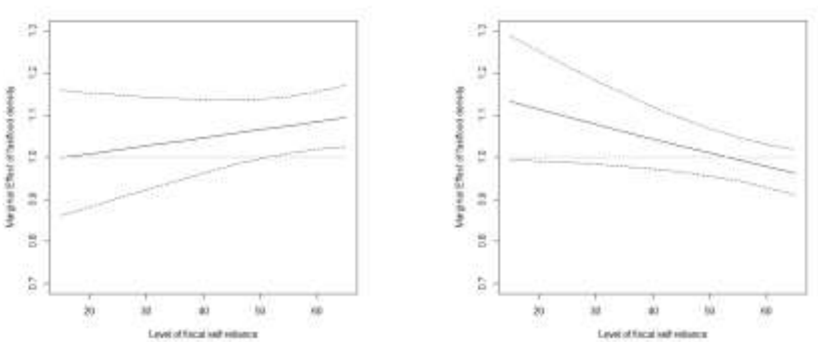

Figure 3–1. Odds ratio of obesity for density of fast–food stores adjusting fiscal self–reliance ratio

Male	Female
The density of fast food stores (/km^2)	

Fiscal self–reliance ratio

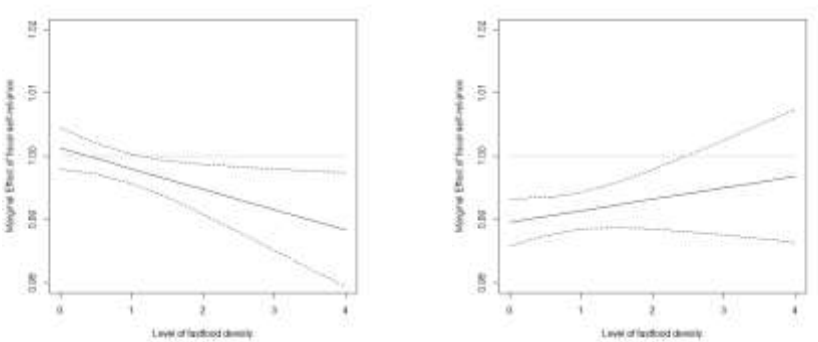

Figure 3–2. Odds ratio of obesity for density of fast–food stores adjusting density of fast–food stores

3-4. Discussion

The main purpose of this chapter was to explore both the individual and environmental determinants of obesity in Seoul focusing on physical activity and food environments. When controlling individual covariates, for men, proximity to park was negatively associated with obesity. Considering that park is an open spaces to encourage people to exercise, the higher the number of parks in neighborhood there were, the lower the probability of men's obesity (27-29). In Seoul, most men commuted across the districts and tried to find places for exercise after work; and they may find the places for high-intensity of activity near the working place or home. However, proximity to public facility for physical activity did not correlated with obesity in this study. This result may be caused by inappropriate choice of geographical units in which areal level differences are not likely to be observed (30); nonetheless, suggests that public facilities need to be changed to more attractive place where people can do more intensive activity anytime in there.

Further, the present study demonstrated that the community-level density of fast food stores was associated with the probability of women' s obesity. The result was in line with earlier studies using fast food stores as a proxy for food environment influences on obesity (11, 29, 31-33), which found that higher restaurant density was associated with higher BMI among local residents. However, the significance was only limited to the big five fast food stores; and there was high density of places similar to fast food stores, i.e., selling high-calorie foods and leading to obesity in Seoul. Similar results have been reported in recent studies (34). This was principally because these restaurants are located in more affluent areas in which individuals were on average wealthier and more educated, and people living in there are also thinner and healthier. Then, why are the big five fast food stores significantly associated with obesity? Although the skepticism towards western fast food, individuals with inconsistent food intakes may have irregular food consumption pattern, leading to periods of under-consumption followed by compensatory overconsumption (35-41), or from consuming inexpensive foods with high energy density when less money is available to spend on food (106, 107). This was in contrast with our previous finding that higher food insecurity rate statistically decreased obesity probability (44).

This study also examined the correlation between environmental factors and obesity perception as well as weight control intention, however, did not detect meaningful findings. Only for obese men, who living in a community with higher density of big five fast food stores less intended to weight loss. This result supports that there are unmeasured social environment associating food environments, and further studies is needed to comprehend the community embracing physical, social, and historical environments.

Obesity is often influenced by food and beverage policy, taxation, transportation, and especially urban policy with individual responsibility (45). Therefore, effective management of obesity can be accomplished through cooperation between different departments. This study suggested that food policies need to be implemented to broader geographical scope rather than neighborhood level. This study identified community-level health risk factors; therefore, the results could be used as basic data for establishing local health care plans, each administrative district in Seoul establishes its local health care plan every four years. Moreover, further research is needed, especially studies with longitudinal designs or based on respondents' living areas, to determine whether modifications in the environment may aid in curbing the current obesity epidemic.

This study examined the associations between environmental factors and obesity, although it had some limitations. First, the analysis was based on respondents' residential areas; however, some people spend more time around their work places than residential areas. Thus, there are several possible environmental factors in workplaces that could affect respondents' obesity more than those of residential areas, which we could not consider due to data limitations. Another limitation is attributed to cross-sectional survey, the causal association among obesity status, obesity perception and weight control attempts are ambiguous and it makes difficulties in the interpretation.

For an instance, walking associated with obesity and weight control intention in a different direction, however, obesity and weight control intention are positively correlated each other. Other physical activity variables also show similar relationship. As far as expect, accumulation of longitudinal data through natural experiment such as Health City project may improve the understanding on how intervene the obesity problem more efficiently. Despite some limitations, this study is the first in Seoul that includes various areal level environmental variables to catch the target area for implementation of health policy combating obesity, by using variables of accessibility in comparison with other studies that considered only aggregated environmental variables such as density. This study also promotes the comprehensive understanding of obesity problems and its associating factors by investigating for obesity perception and weight loss intention as well as obesity prevalence. Another strong point of this study is the large sample, which allowed us to understand the effect of environmental factors on obesity in great detail.

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Chapter 4. Built Environment and Allergic Diseases

4-1. Introduction

Allergic diseases are the most common non-communicable disorders of children and adolescents worldwide. Although prevalence varies by country and region, about 20-40% of children primarily suffer from symptoms of these diseases (1-3), which affect both physical and social activities of children as well as their families (4-6). The prevalence reached a plateau or began to decrease in several countries, as understanding and management of these diseases advanced (7-10). However, many other countries persistently showed increasing trends (11).

In addition to host risk factors for allergic diseases including genetic, behavioral, and socioeconomic components, air pollution was suggested as an environmental risk factor. In particular, recent studies focused on traffic-related air pollution (TRAP) which largely contributes to urban air pollution and possibly affects adverse health effects for large population. Epidemiologic studies reported the associations of allergic diseases for exposures to TRAP estimated by using pollutant surrogates such as nitrogen dioxide (NO_2) and fine particulate matter ($PM_{2.5}$) (12-15). Other studies used direct measures of traffic including traffic volume and distance to the nearest road, focusing on traffic other than various pollutant sources, and showed inconsistent or consistent findings with those using air pollutants (15-20). Recent toxicological studies also advanced the understanding of biological mechanism of TRAP on onset and exacerbation of allergic diseases (21). The pathogenic pathway of TRAP on respiratory allergic diseases such as asthma had been elucidated, and the evidence of TRAP induced atopic diseases were also gradually cumulated in experimental studies and epidemiologic studies (22–24).

Despite numerous attempts to identify the causal association between TRAP exposures and allergic outcomes, particularly for non-asthmatic diseases, epidemiologic findings remained inconsistent (25). This inconsistency might be attributed to limited study population with respect to age, space, and socioeconomic environment. First, many previous studies of TRAP and allergic diseases included children with narrow age ranges between 0 month and 17 years (25). However, studies that assessed the effects of TRAP in children with 1 or 2 age range showed only marginal associations of allergic diseases (13–15, 26). Studies of children with limited age range may not allow us to observe phenotypes of various allergic diseases based on the natural history of atopic manifestations. Early onset of atopic eczema, and following asthma and allergic rhinitis with increased age in childhood were reported in many previous studies (27). Second, studies were not based on the population recruited by spatial sampling (25) and their limited spatial coverage may not provide sufficient spatial heterogeneity of traffic exposures across the study areas. Furthermore, some studies reported that children in the lower socioeconomic status (SES), in both individual and regional conditions, experienced higher exposure to air pollution and larger impact on health than their counterpart in the higher SES (28, 29). Magnitude and significance of the association may depend on diverse socioeconomic background of both household and residential area.

The Seoul Atopy Friendly School Project provided a unique opportunity to investigate the association between TRAP exposures and allergic outcomes. The city of Seoul in South Korea initiated this project to assess the prevalence and risk factors of allergic diseases in children residing in Seoul. The project recruited more than 30,000 children aged 0 to 13 and collected information on demographic characteristics, risk factors, and allergic outcomes including their home and school addresses. Seoul, the capital of South Korea, is one of the densely populated metropolitan cities with ten million people in 605 km^2. The city reported high air pollution ($PM_{2.5}$ annual average concentrations of 25 $\mu g/m^3$ in 2010) (30) possibly affected by heavy traffic on dense road networks. Using the Seoul Atopy Friendly School Project survey in 2010, the purpose of this chapter is to assess the association between exposure to TRAP and prevalence of allergic diseases. Furthermore, we investigated whether the association is modified by household and regional SES of children.

4-2. Data and Methods

Study population

The Seoul Atopy Friendly School Project survey data in 2010 for 31,576 children after de-identification was provided from the Seoul Medical Center in Seoul, Korea. Details of the survey have been described previously (31). This cross-sectional survey recruited children from 170 schools including 136 elementary schools and 34 children's daycare centers to cover all 25 districts in Seoul.

From 31,576 children, those who did not meet the inclusion criteria were excluded (Figure 4-1). The excluded children did not complete questionnaire (N=6,211, 19.7%), were aged less than 1 year or older than 12 years (118, 0.4%), did not live in Seoul (212, 0.7%), and had inaccurate addresses (419, 1.3%). Thirty nine percent of children in the Seoul Atopy Friendly Project survey lived on the third floor or higher with 15 % living even higher than the tenth floor. The average height of a story in multi-dwelling units (MDU) is about 2.8 m in Seoul (32). Since the concentration of air pollutants emitted from roads possibly decreases as building height increases (33), children living on the 4th floor (height of about 8 m from the ground) or over (9,275, 38.6%) were also excluded. These exclusions resulted in 14,765 (46.8%) children for the analysis.

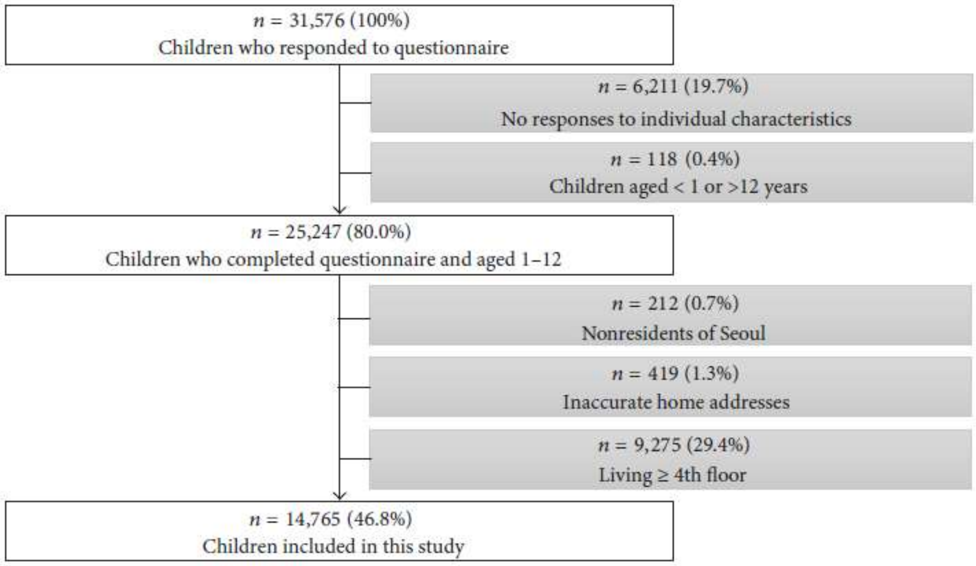


Figure 4-1. Schematic diagram of the study population selected for the present analysis using Seoul Atopy Friendly School Project survey in 2010

Questionnaire data

The questionnaire consisted of two main items: 1) socio-demographic and physical characteristics including daycare-center or school, residential address, sex, age, height, weight, household monthly income, and history of breastfeeding; and 2) allergic symptoms related to atopic eczema, asthma, allergic rhinitis, and food allergy based on the modified International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire. The parents or guardians completed the written questionnaire.

Prevalence of allergic diseases

Prevalence of allergic diseases was asked in three ways: 1) current symptom, 2) lifetime physician diagnose, and 3) current treatment. Since health-care utilization depended on various factors that may confound the effect of TRAP exposure (34), prevalence of current symptoms, as main outcomes, for three allergic diseases including atopic eczema, asthma, and allergic rhinitis were used in this chapter. The current symptoms were defined as 'symptoms in the past 12 months', indicating itchy rash, wheezing or whistling in the chest, sneezing or runny or blocked nose without a cold or flu for atopic eczema, asthma, and allergic rhinitis, respectively.

Assessment of risk factors

For basic socio-demographic and physical information, categorized variables were created. Continuous age was classified into four groups including 1-3, 4-6, 7-9, and 10-12 years. Body mass index (BMI) was calculated as weight (in kilogram) divided by squared height (in meter) by using height and weight. Then, BMI was classified into three groups of underweight (≤ 25 percentile), normal (25-85), and overweight or obese (≥ 85) based on BMI-for-age percentiles of the 2007 Korean growth charts developed by the Korea Center for Disease Control and Prevention in 2007

(35). Monthly household income was grouped into low (<1,720 USD), middle (1,720–3,440), and high household SES (≥3,440). Since more than the half of the mothers in South Korea ceased breastfeeding in 3 months after delivery (36), breastfeeding duration was categorized into three periods indicating never or <4 months, 4–11 months, and ≥12 months. For 25 districts in Seoul, eight residential areas (downtown and area 1 to 7) combining 2–4 adjacent districts were created (Figure 4–2).

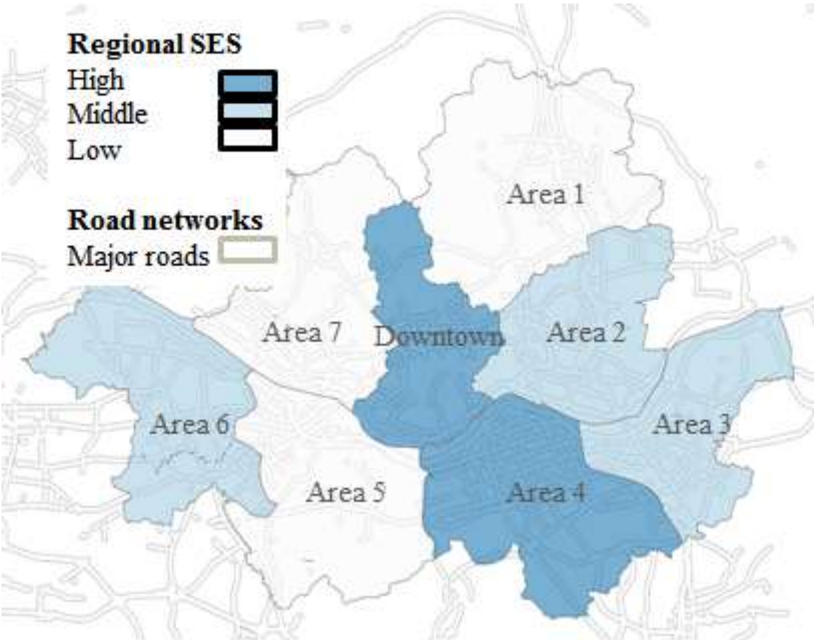


Figure 4–2. Map of eight residential areas and major roads defined as highways and roads with more than six lanes in Seoul.

Geocoding

Children's addresses for their homes and schools were geocoded to assess traffic-related exposure (Figure 4-3). Whereas children resided in MDU were assigned coordinates of a home address to the center of a specific building, a school address was assigned to the center of one or more school buildings. Geocoding was performed by using publicly-available web-based geocoding software, GeoCoder-Xr (Geoservice, Seoul, Korea).

Figure 4-3. Geographical location of children from the Seoul Atopy Friendly School Project survey during 2010

Assessment of TRAP exposure

Two TRAP exposure metrics including road proximity and road density for major roads were computed based on children's home and school addresses using road network data. Maps and attributes of road networks in Seoul were obtained from the Korean Transport Database (KTDB). Road networks consist of eight classes of roads: national highways, metropolitan city highways, general national roads, metropolitan city roads, government-financed provincial roads, provincial roads, district roads, and highway link lamps. Major roads were defined as national highways, metropolitan city highways, highway link lamps, and roads with more than six lanes in other five classes.

Road proximity was a categorical variable derived from the continuous distance to the nearest major road, and consists of four categories: ≤150m, 150–300m, 300–500m, and >500m. Road density was a continuous variable which is the sum of lengths for major roads within 300m circular buffers. Another variable was also created by multiplying the road lengths by numbers of lanes and road widths to reflect traffic volume. 300m distance is chosen as the distance affected by traffic, as previous studies showed exponential decrease of air pollution concentrations at 300m distant from the major roads (25). Computation procedure for distances and sums of road lengths were described in previously published work in details (37).

Geographic data processing and variable computation were computed in ArcGIS version 10.2 (ESRI Inc., Redlands, CA, USA).

Statistical analysis

Prevalence rates (PRs) of allergic diseases obtained for every stratum of individual characteristics were calculated as proportion (in percent) of children with current symptoms to the total number of children in each stratum.

Odds ratios (ORs) were estimated using logistic regression to quantify the association between each pair of two TRAP exposure metrics (road proximity and density) and three allergic outcomes (atopic eczema, asthma, and allergic rhinitis). Three confounder models assessed the association after adjusting for individual- and area-level confounders and random effects. Model 1 included age and sex only, whereas Model 2 additionally included BMI, household SES, and history of breastfeeding. In Model 3, as a primary model, two random effect terms at school and residential area were added to adjust for unmeasured confounding of schools and residential areas and to account for within-school and within-area correlation of outcomes. In main analyses, the effects of traffic exposure were assessed using home-based exposure metrics only, given the geocoding limitation of school addresses which may increase exposure measurement error (38).

The heterogeneity of associations by children's household and regional SES was also investigated using stratified analyses. Regional SES was re-classified from eight residential areas to three groups based on financial self-sufficiency proportion of revenue to expense in each district, in 2010. This district-specific financial self-sufficiency proportion was averaged for each of the eight residential areas. (range=32.5, 78.5%). Three regional SES groups included high (≥70%, downtown and area 4), middle (40-70, area 2, 3 and 6), and low (< 40, area 1, 5, and 7) regions (Figure 2). The stratified analysis by two types of SES was performed solely and jointly. For the analysis stratified by one type of SES, the other type of SES was adjusted in the analysis.

Sensitivity analyses

Six sensitivity analyses were performed to assess the impact of exposure measurement error and the data exclusion on the association in a primary analysis. First, the continuous distance was used instead of the categorical road proximity. To investigate the impact of misclassified traffic exposure estimates, this study investigated the association in 5,211 children living on the 4^{th} to 9^{th} floor and 4,064 children on the 10^{th} floor or over. Because a previous study reported that the ISSAC questionnaire provided validated data for children aged 6–7 years and 13–14 years (11) , this study restricted study population to 11,803 children aged 6 or above. The results were also presented using a more conservative prevalence definition available in the questionnaire based on lifetime physician diagnose. In a primary analysis, 3,394 children who did not report household income or breastfeeding duration which may result in the exclusion of a population subgroup with low or high socioeconomic characteristics were excluded. Children with missing data for those two variables were assigned to a new category, analyses were performed using 18,159 children.

Lastly, a combined exposure metric based on home and school addresses was used in this study. To reflect children's activities during school hours for approximately 8 hours, average traffic exposure estimates weighted by homes twice as much as schools was computed. Road proximity was calculated by using harmonic mean, whereas road density was computed as arithmetic mean.

The mixed effect logistic models were implemented using *lme4* package in R software version 3.3.2 (R Development Core Team, Vienna, Austria).

4-3. Results

General characteristics, TRAP exposures, and prevalence of allergic diseases

Table 4-1 shows the distribution of individual characteristics of the 14,765 children included to this analysis from the Seoul Atopy Friendly School Project survey. These children included 50% males and 26% preschoolers aged less than 6 years. Five percent of the children was overweight or obese, and more than a half had breastfeeding duration less than 4 months. Eighteen percent was classified into the low household SES, while 34% lived in the low SES area.

PRs for three allergic diseases were 16, 8, and 36% for atopic eczema, asthma, and allergic rhinitis, respectively (Table 4-1). PRs for individual and socioeconomic characteristics varied by three diseases. Atopic eczema was more prevalent in girls, 4-6 years of age, the normal BMI group, and children breastfed for more than 12 months. Children with asthma symptoms were more likely to be boys, 1-3 years, overweight, or breastfed for more than 12 months. Allergic rhinitis was also more prevalent in boys, but these children were older with 7-9 years, underweight, or breastfed less than 4 months. PRs for atopic eczema and allergic rhinitis were slightly lower or higher in children aged 6-12 years (PR=15.4, 95% confidence interval (CI) 14.7-16.0; 37.3, 36.4-38.1) than those of all ages (15.9, 15.3-16.5; 36.2, 35.4-36.9), whereas

PR for asthma was significantly lower (6.4, 6.0–6.9) than those for all children (8.0, 7.6–8.5). For household and regional SES, PRs for atopic eczema and asthma were high in the low and high household SES, respectively. In contrast, allergic rhinitis showed high PRs in the low regional or the high household SES (Table 4–1).

Table 4–2 shows the summary statistics of TRAP exposures. 30, 26, and 22% children lived in distance within 0–150, 150–300, and 300–500m to major roads, respectively. The mean of road density within 300m from children's homes was 7,200m^2 (SD=8,600, inter–quartile range (IQR)=13,120). Out of the 170 schools, 54% was located within 300 m to major roads, and the average road density was 7,200 m^2 (SD=8,500, IQR=11,430). Both road proximity and density were high in the high regional SES, but similar across low to high household SES (Table 4–3).

Table 4-1 Descriptive characteristics and prevalence of three allergic diseases for each individual characteristic in 14,765 children from the Seoul Atopy Friendly School Project survey during 2010 in Seoul, Korea

	Total		Prevalent cases (prevalence rate, %)					
	N (%)		Atopic eczema		Asthma		Allergic rhinitis	
	14,765	(100)	2,351	(15.9)	1,187	(8.0)	5,338	(36.2)
Sex								
Girls	7,356	(49.8)	1,198	(16.3)	468	(6.4)	2,341	(31.8)
Boys	7,409	(50.2)	1,153	(15.6)	719	(9.7)	2,997	(40.5)
Age								
1-3	1,322	(9.0)	223	(16.9)	235	(17.8)	369	(27.9)
4-6	2,447	(16.6)	450	(18.4)	271	(11.1)	890	(36.4)
7-9	5,453	(36.9)	898	(16.5)	386	(7.1)	2,089	(38.3)
10-12	5,543	(37.5)	780	(14.1)	295	(5.3)	1,990	(35.9)
Body fatness								
Normal	11,948	(80.9)	1,944	(16.3)	930	(7.8)	4,214	(35.3)
Overweight or obese	769	(5.2)	122	(15.9)	89	(11.6)	283	(36.8)
Underweight	2,048	(13.9)	285	(13.9)	168	(8.2)	841	(41.1)
Breastfeeding duration								
〈 4 months	8,042	(54.5)	1,124	(14.0)	597	(7.4)	2,977	(37.0)
4-11	3,876	(26.3)	637	(16.4)	318	(8.2)	1,342	(34.6)
≥ 12	2,847	(19.3)	590	(20.7)	272	(9.6)	1,019	(35.8)
Residential area								
Downtown	1,729	(11.7)	315	(18.2)	191	(11.0)	543	(31.4)
Area 1	1,803	(12.2)	270	(15.)	106	(5.9)	665	(36.9)
Area 2	3,010	(20.4)	552	(18.3)	366	(12.2)	1,048	(34.8)
Area 3	2,303	(15.6)	318	(13.8)	140	(6.1)	807	(35.)
Area 4	973	(6.6)	154	(15.8)	59	(6.1)	359	(36.9)
Area 5	1,282	(8.7)	196	(15.3)	73	(5.7)	492	(38.4)
Area 6	1,678	(11.4)	246	(14.7)	122	(7.3)	639	(38.1)
Area 7	1,987	(13.5)	300	(15.1)	130	(6.5)	785	(39.5)
Household SES								
High	5,545	(37.6)	770	(13.9)	423	(7.6)	2,120	(38.2)
Middle	6,539	(44.3)	1,097	(16.8)	532	(8.1)	2,367	(36.2)
Low	2,681	(18.2)	484	(18.1)	232	(8.7)	851	(31.7)
Regional SES*								
High	2,702	(18.3)	469	(17.4)	250	(9.3)	902	(33.4)
Middle	6,991	(47.3)	1,116	(16.0)	628	(9.0)	2,494	(35.7)
Low	5,072	(34.4)	766	(15.1)	309	(6.1)	1,942	(38.3)

*. Regional socio-economic status(SES) was categorized based on fiscal self-sufficiency of residential areas (see Figure 4-2)

Table 4-2 Summary statistics of TRAP exposures in 14,765 children

	N of children (%)							
	Total		Atopic eczema		Asthma		Allergic rhinitis	
Proximity	14,765	(100.0)	2,351	(15.9)	1,187	(8.0)	5,338	(36.2)
0-150m	4,494	(30.4)	724	(30.8)	314	(26.5)	1,601	(30.0)
150-300m	3,873	(26.2)	629	(26.8)	332	(28.0)	1,432	(26.8)
300-500m	3,284	(22.2)	536	(22.8)	261	(22.0)	1,193	(22.3)
>500m	3,114	(21.2)	462	(19.7)	280	(23.6)	1,112	(20.8)
	Mean (SD)							
	Total		Atopic eczema		Asthma		Allergic rhinitis	
Density (1,000 m^2)	7.2	(8.6)	7.5	(8.8)	6.7	(8.2)	7.1	(8.6)

Table 4-3 Summary of TRAP exposures by regional and household SES

		N (%)		Distance (m)		Density (km^2)	
				Mean	(SD)	Mean	(SD)
Total		14,765	(100)	320.75	(261.60)	7.16	(8.65)
Regional SES	Household SES						
High		5,545	(37.6)	256.76	(218.57)	9.27	(8.37)
Middle		6,539	(44.3)	273.56	(220.76)	8.23	(9.50)
Low		2,681	(18.2)	419.87	(302.56)	4.57	(6.73)
	High	2,702	(18.3)	324.55	(265.80)	7.11	(8.58)
	Middle	6,991	(47.3)	319.69	(261.75)	7.25	(8.71)
	Low	5,072	(34.4)	315.45	(252.29)	7.05	(8.65)
High	High	955	(6.5)	249.69	(218.02)	9.76	(8.51)
High	Middle	1,165	(7.9)	258.55	(223.33)	9.21	(8.25)
High	Low	585	(4.0)	264.68	(209.74)	8.58	(8.17)
Middle	High	2,588	(17.5)	270.68	(216.46)	8.21	(9.33)
Middle	Middle	3,129	(21.2)	274.72	(224.68)	8.34	(9.61)
Middle	Low	1,274	(8.6)	276.57	(219.81)	8.00	(9.60)
Low	High	2,005	(13.6)	429.63	(308.15)	4.43	(6.68)
Low	Middle	2,245	(15.2)	414.10	(299.30)	4.71	(6.80)
Low	Low	822	(5.6)	411.85	(296.77)	4.49	(6.64)

Associations of TRAP exposures and allergic diseases

For the three allergic diseases, this study found an association of atopic eczema prevalence with both traffic exposure indicators (Table 4-4).

Table 4-4 Associations between two TRAP exposures and three allergic diseases

	Model 1		Model 2		Model 3	
	OR[a]	95% C.I.	OR[b]	95% C.I.	OR[c]	95% C.I.
Proximity						
Atopic eczema						
≤150m	1.16	(1.02 - 1.32)	1.15	(1.01 - 1.31)	1.15	(1.01 - 1.32)
150-300m	1.17	(1.02 - 1.34)	1.17	(1.03 - 1.34)	1.17	(1.03 - 1.34)
300-500m	1.16	(1.01 - 1.33)	1.16	(1.01 - 1.33)	1.16	(1.01 - 1.34)
>500m	1.00		1.00		1.00	
Asthma						
0-150m	0.95	(0.80 - 1.13)	0.94	(0.79 - 1.12)	0.93	(0.78 - 1.11)
150-300m	1.13	(0.95 - 1.34)	1.12	(0.95 - 1.33)	1.11	(0.93 - 1.32)
300-500m	1.01	(0.85 - 1.21)	1.01	(0.84 - 1.21)	1.00	(0.83 - 1.20)
>500m	1.00		1.00		1.00	
Allergic rhinitis						
0-150m	0.96	(0.87 - 1.05)	0.96	(0.87 - 1.06)	0.97	(0.88 - 1.07)
150-300m	1.03	(0.93 - 1.14)	1.03	(0.93 - 1.14)	1.05	(0.95 - 1.16)
300-500m	0.99	(0.89 - 1.10)	1.00	(0.90 - 1.10)	1.00	(0.90 - 1.12)
>500m	1.00		1.00		1.00	
Density for an interquartile range increment (13,120m^2)						
Atopic eczema	1.08	(1.02 - 1.16)	1.08	(1.01 - 1.15)	1.08	(1.01 - 1.15)
Asthma	0.95	(0.87 - 1.05)	0.95	(0.87 - 1.04)	0.94	(0.86 - 1.03)
Allergic rhinitis	0.97	(0.92 - 1.02)	0.97	(0.92 - 1.03)	0.97	(0.92 - 1.03)

a. Odds ratio (OR) adjusted for sex and age; b. OR adjusted for sex, age, household monthly income, body mass index, and history of breastfeeding; c. OR adjusted for sex, age, household monthly income, body mass index and history of breastfeeding, random effects for school and residential area

In Model 1 adjusting for age and sex, OR of atopic eczema for an IQR increase in the sum of major road lengths within 300m from children's homes was 1.08 (95% CI=1.02–1.16). This association was consistent when individual characteristics were added in Model 2 (OR=1.08, 95% CI=1.01–1.15) and random effects in Model 3 (1.08, 1.01–1.15). Likewise, ORs for distances to the major road with ≤ 150m 150–300, and 300–500m were significantly higher than the distance >500m in Model 3 (1.15, 1.01–1.32; 1.17, 1.03–1.34; 1.16, 1.01–1.34). Associations of asthma and allergic rhinitis were not observed.

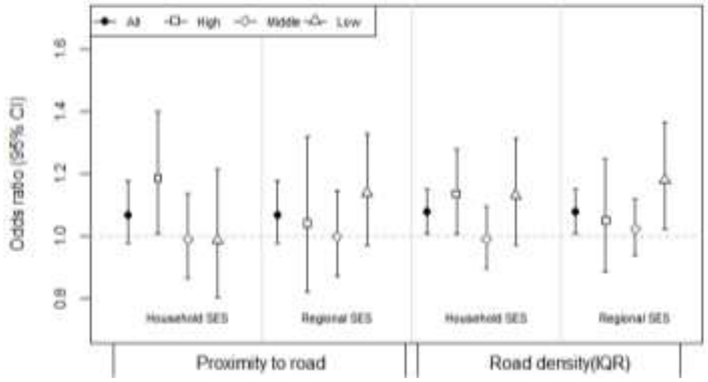
Figure 4–4 shows the associations between two TRAP exposures and three allergic diseases by household and regional SES of children. For atopic eczema, OR for an IQR increment of road density was high in the low regional SES (1.18, 1.02–1.37) and the high household SES (1.14, 1.01–1.28). In contrast, OR of allergic rhinitis was the highest in the low household SES (1.15, 1.02–1.31). There was no clear pattern for asthma (Supplemental material, Table S3 and Table S4). In a two-way stratification, OR of atopic eczema for road density (1.31, 1.04–1.66) was the highest in the high household and low regional SES, whereas OR of allergic rhinitis (1.49, 1.12–1.98) was the highest in the low household and low regional SES (Table 4–5).

In the sensitivity analysis, continuous distance instead of categorized distance gave consistent findings of the association with atopic eczema and no association with asthma and allergic rhinitis (Supplemental Table 4-1). When analysis is restricted to children living on the fourth floor or over, the association of traffic exposure and atopic eczema disappeared. However, the association of road proximity with asthma and allergic rhinitis in children living on the 10^{th} floor or over was found (Supplemental Table 4-2). The association was consistent with larger ORs for both of road proximity and density, when those who did not report household income and breastfeeding duration were added in analysis (Supplemental Table 4-3). Another sensitivity analyses for older children and different definition of allergic diseases also showed consistent results. In the analysis for 11,803 children aged 6 or over, the consistent associations with larger ORs for atopic eczema for both road proximity and density was found (Supplemental Table 4-4). Lifetime physician-diagnosed atopic eczema was also associated with road density and road proximity less than 300m but with lower ORs for road proximity (Supplemental Table 4-5). Incorporation of TRAP exposure at schools in addition to homes showed the association for road proximity with wider confidence intervals and no association for road density (Supplemental Table 4-6).

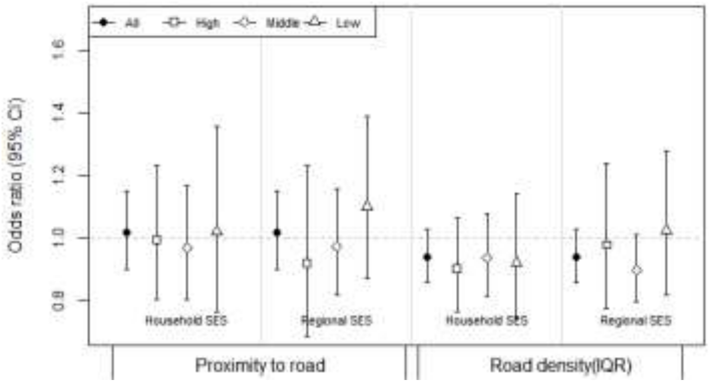
Table 4-5 Associations between two TRAP exposures and three allergic diseases from Model 3 by regional and household SES in 14,765 children

		Atopic eczema		Asthma		Allergic rhinitis	
		OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Proximity (≤300m)							
Regional SES	Household SES						
High	High	0.94	(0.60 – 1.47)	0.80	(0.48 – 1.33)	0.78	(0.56 – 1.03)
High	Mid	1.14	(0.81 – 1.60)	0.90	(0.58 – 1.39)	0.92	(0.69 – 1.23)
High	Low	0.95	(0.58 – 1.57)	1.06	(0.54 – 2.07)	1.27	(0.83 – 1.94)
Mid	High	1.18	(0.93 – 1.51)	1.00	(0.74 – 1.35)	1.06	(0.89 – 1.27)
Mid	Mid	0.90	(0.74 – 1.10)	0.95	(0.73 – 1.23)	0.92	(0.79 – 1.07)
Mid	Low	0.97	(0.71 – 1.32)	1.01	(0.69 – 1.48)	1.00	(0.78 – 1.29)
Low	High	1.27	(0.98 – 1.65)	1.11	(0.75 – 1.63)	1.11	(0.92 – 1.33)
Low	Mid	1.10	(0.87 – 1.39)	1.11	(0.79 – 1.57)	0.98	(0.82 – 1.17)
Low	Low	1.03	(0.72 – 1.46)	1.16	(0.65 – 2.08)	1.28	(0.95 – 1.72)
Density for an interquartile range increment (13,120m^2)							
Regional SES	Household SES						
High	High	0.99	(0.72 – 1.36)	0.91	(0.61 – 1.36)	0.81	(0.64 – 1.02)
High	Mid	1.10	(0.87 – 1.40)	0.99	(0.70 – 1.41)	0.87	(0.71 – 1.07)
High	Low	1.01	(0.69 – 1.47)	0.99	(0.57 – 1.71)	1.17	(0.86 – 1.60)
Mid	High	1.10	(0.94 – 1.28)	0.86	(0.70 – 1.06)	0.94	(0.83 – 1.06)
Mid	Mid	0.92	(0.81 – 1.05)	0.92	(0.78 – 1.10)	0.95	(0.86 – 1.06)
Mid	Low	1.18	(0.97 – 1.44)	0.90	(0.70 – 1.17)	1.03	(0.88 – 1.22)
Low	High	**1.31**	**(1.04 – 1.66)**	1.06	(0.73 – 1.53)	1.05	(0.88 – 1.26)
Low	Mid	1.14	(0.92 – 1.38)	1.00	(0.72 – 1.38)	0.96	(0.81 – 1.14)
Low	Low	1.08	(0.77 – 1.52)	1.09	(0.63 – 1.86)	**1.49**	**(1.12 – 1.98)**

(a) Atopic eczema



(b) Asthma



(c) Allergic rhinitis

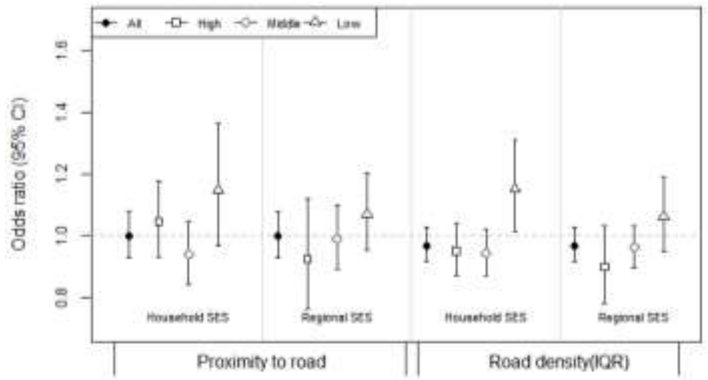


Figure 4-4. Associations between two TRAP exposures and three prevalent allergic diseases by household and regional SES.

4-4. Discussion

In this Chapter 4, it was examined the association of three allergic outcomes for two TRAP exposures estimated by proximity and density of major roads based on children's residences and compared the association across three household and regional SES in a large population of children aged 1 to 12 residing in a densely populated metropolitan city. Both road density and proximity were associated with atopic eczema, whereas no association was found with asthma and allergic rhinitis. These associations were generally stronger in children living in the lower SES region.

In this study proximity to the closest major road and density of nearby roads were used as proxies for exposure to TRAP to assess the associations between TRAP exposure and allergic diseases of children. Although many previous epidemiological studies of allergic diseases used exposures to traffic-related air pollutants such as $PM_{2.5}$ and NO_X, other studies also reported relationships using traffic indicators (39-44). These metrics help us focus on air pollution directly related to traffic, whereas it is difficult to isolate the impact of traffic when we use individual pollutants affected by various sources other than traffic (25, 45). Some studies reported even stronger associations using traffic indicators than those of air pollution concentrations predicted by exposure prediction models such as land use regression and dispersion models

(15, 46). Although other studies raised possible exposure misclassification of proximity models (39, 47), there have also been concerns about inconsistency in monitor-based air pollution estimates when monitoring networks are sparse (48).

Proximity and density of major roads based on road networks were used to represent traffic volume. Whereas previous studies of TRAP and allergic diseases mostly used proximity, this study added road density which showed stronger associations than those of road proximity in the results. In addition, products of numbers of lanes and line widths to road density were used in this study instead of sum of single line lengths. The improved representation to the amount of traffic for road density possibly resulted in stronger associations than those for road proximity. Daily traffic volume on the roads with six lanes or more (mean=84,310, SD=30,744), defined as major roads along with highways, was much higher than on the roads less than six lanes (42,584, 17,105) at 56 traffic monitoring sites operated by the Seoul Transport Operation and Information Service (49). In addition, air pollution concentrations measured at regulatory monitoring sites adjacent to the roads with six lanes or more were higher than concentrations at urban background monitoring sites in Seoul. The annual average concentrations of NO_2 and PM_{10} in 2010 at urban roadside sites in Seoul (52 ppb, and 55.50 $\mu g/m^3$, respectively) were much higher than those at urban background sites (34 ppb, and 48.96 $\mu g/m^3$, respectively) (50).

In this study, stronger associations with atopic eczema was found using improved TRAP estimates with reduced exposure measurement error. Children living within the same distance to large roads may be exposed to different levels of to TRAP depending on the vertical height of residences. The population affected by building heights would be large particularly in dense metropolitan areas where many people reside in MDU. In Seoul, 58% of households lived in MDU based on the 2010 Population census. Smaller ORs of atopic eczema for children living on the 4^{th} floor or above than those for children living on the low floors, observed in this study, possibly indicates the impact of exposure measurement error on the attenuation of effect estimates. However, ORs of asthma and allergic rhinitis were higher in children living on the 4^{th} floor or above. Moreover, there were the associations in children living on the 10^{th} floor or over and within 150–500 m from the closest major road. This unexpected pattern could be explained by vertical dispersion of pollutant flow disrupted by nearby buildings with downwind. Other explanations could include indoor pollutants such as semi-volatile polycyclic aromatic hydrocarbon, and/or different socioeconomic conditions of high floor residence (33, 51, 52). Study population who had large spatial coverage based on their residences and included the age range of 1 to 12 years possibly increased the ability to detect the association in this study. The Atopy School Friendly Project survey sampled more than 30,000 children from all 25 districts of Seoul, who may represent the population of children in Seoul. This rich sample might help assess fine-scale spatial variability of exposure to traffic. The wide age range along with availability of accurate address information could have provided diversity of allergic outcomes varying by age.

The association of TRAP with atopic eczema was observed, but there was no associations with asthma and allergic rhinitis. Although all three allergic diseases, examined in this study, had similar biological mechanisms for TRAP through their immune responses (53), there were a few studies focusing on the association with non-asthmatic allergic diseases, such as atopic eczema (13, 15, 17, 26, 54-56). A cohort study in Munich, Germany, found road proximity, defined by 50m to the closest major road, was associated with eczema prevalence in children aged 6 (56). However, another German study in a different city using similar study designs and exposure assessment approaches provided different findings (20). This inconsistency could be due to environments of study areas, children's age ranges, or limitation in exposure assessment. No associations of asthma, often reported for their associations in previous studies, also could be driven by misclassification. PR of asthma in this study based on the ISAAC questionnaire (8.0%) was higher than those in other countries, although this PR was similar to those in South Korea based on physician-diagnosed prevalence in the Korea Youth Risk Behavior Web-based Survey and audio-visual questionnaire (57-59). However, PR for children aged 6 or over (6.4%) was similar to PRs based on current symptoms reported in the ISAAC questionnaire in other countries (5.8 and 8.7 for age 6-7 and 13-14, respectively) (11). To reduce the impact of misclassified responses, the analysis was restricted to the children aged 6-12 (N=11,803) in the sensitivity analysis. PR of asthma was significantly lower (PR=6.4, 95% CI=6.0-6.9) than PR for all children (8.0, 7.6-8.5), different from atopic eczema and allergic rhinitis showing slightly lower or higher prevalence. In contrast, ORs of TRAP were consistent between two groups of children.

A suggested biological mechanism for the association of TRAP and atopic eczema was predisposing skin barrier dysfunction following by direct exposure of pollutants on skin. Previous toxicological studies showed that aryl hydrocarbon receptor (AhR) in cytosol of keratinocytes bound polycyclic aromatic hydrocarbons among diesel exhaust particles and activated the skin barrier dysfunction. Upon chemical binding, AhR may translocate into nuclei of a cell, and induce the transcription of gene associated with generation of barrier protein including filaggrin (FLG), reactive oxygen species (ROS), and other inflammatory cytokines. FLG mutation and inflammatory process activated by upregulated genes may result in atopic eczema (24, 60-63).

It was also found that children's regional SES modified the association of TRAP exposure on atopic eczema and allergic rhinitis after accounting for household SES. This implies that even under the same built environment including traffic exposure, the impact on the individual's health can be affected differentially by socioeconomic background of their residential areas. In the results, ORs of atopic eczema for TRAP was higher in children with high income family than with low income family in the same socioeconomically deprived areas with less exposure to traffic. Generally, the housing price of house nearby major roads is higher for its transportation accessibility in Seoul. Children with high income family may live close to major roads, even if they live in low SES region, and be exposed to high TRAP. Findings of different regional effects after adjusting for individual SES suggest that the improvement of socioeconomic environments possibly driven by public health policy implementation can reduce adverse effects of TRAP on allergic diseases of children.

The findings of this study should be interpreted with the following limitations. A cross-sectional survey is limited to explain the causal relationship between traffic exposure and allergic diseases. In addition, this study identified allergic diseases based on parent-reported questionnaires. Responses could have been dependent on parents' awareness on allergic symptoms which may result in outcome misclassification. There also might have been response distortions. For instance, parents could respond in a socially desirable direction. Lastly, because the survey questionnaires were not primarily designed for studies of TRAP-associated allergic diseases, this study did not include important confounders such as parental history of allergic diseases and environmental smoking exposure. Future cohort studies including rich information on these confounders should confirm the association between TRAP and allergic diseases.

References

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Chapter 5. Discussions

Discussions

The accessibility to public transport was positively but non−linearly associated with walking behavior of adult population in prevalence and duration in chapter 2. District density of fast−food outlets was marginally associated with adult obesity in chapter 3, and the preventive effect of walking on obesity was also observed.

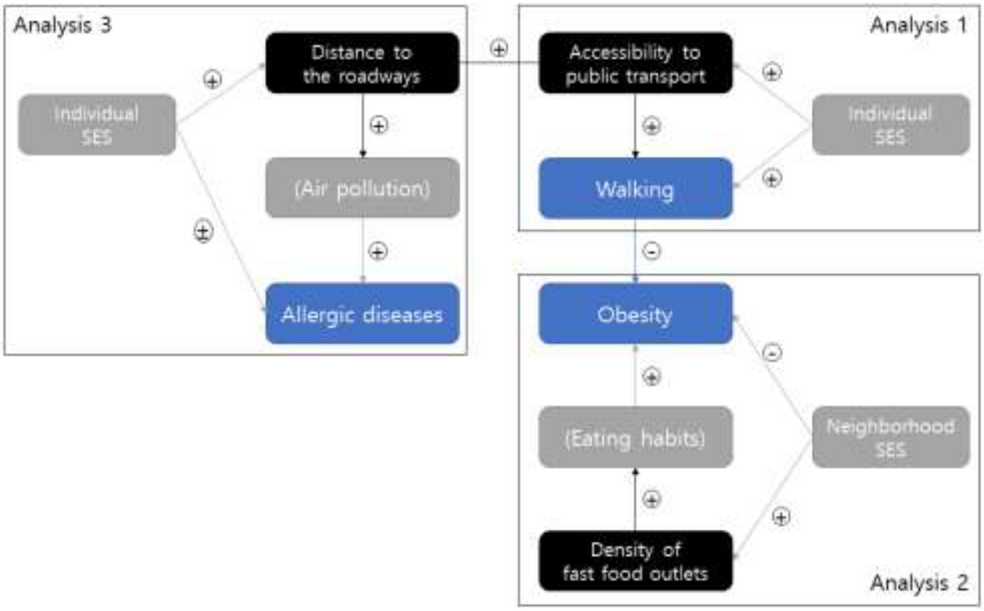

Figure 5−1. Directed acyclic graph showing the association between urban built environment and health

Proximity and density of traffic roadways were positively associated with prevalence allergic diseases, especially atopic eczema in children. In summary, compactness of urban environment in Seoul increased the accessibility to public transport, distance to the roadways, and the access to fast-food stores simultaneously. However, the health outcome was complexly presented to urban residents.

Recalling the conceptual framework of the current research, the negative effect of BE on health outcome was confirmed in this study, and it was consistent with previous studies. On the other hand, in the view of health behavior, BE has the positive aspect of physical activity and marginal effect on eating habits. The present study verified that BE could be a challenge and, at the same time, barrier the health of urban resident in Seoul.

Strengths and limitations

This study is meaningful due to extended use public health surveillance data and atopy-friendly school data, that was primarily designed for monitoring the prevalence of health behavior and status, in research on the health impact of BE with a large number of adults residing in the capital city Seoul. However, cross-sectional survey was limited to explain the causal association, and using of aggregated exposure variable could not differentiate the BE effect with other intercalated factors such as social context and individual behavior factors. Nevertheless, the current study overcame the limitations and clarified the environment attributes on important health problems such as physical inactivity, obesity, and allergic diseases.

Another limitation of this study is on the population issue. The majority of CHS were economically active population, and they spent their daytime not on dwelling places but at work. And their choice of utilization of BE varied by their personal preference and attitude, especially, they have lots of alternative options for health behavior in urban circumstance. Firstly, the effects of BE needed to be assessed in a vulnerable population, which inevitably utilizes the neighborhood BE, and they might be elderly, children, adolescent, and the disabled. Moreover, the effects of BE needed to be assessed in suburban or rural circumstance whether the impact is identical to the urban setting. National Health Examination data could be the option for pre-existing surveillance data.

Public health significance

Despite limitations, two of policy implications were proposed based on the results of empirical analysis and the combined interpretation of them. First, activation of walking can improve the obesity problems in Seoul. To activate walking, both transportation policy that activates the use of public transport and street planning that increases walking duration by varying the options of walking routes to public transport are implemented in parallel. Also, health promotion policies that enhance walking utilizing neighborhood built and working environment such as 'Step it up' campaign may be implemented at a broad-regional level such as Seoul.

Second, proximity to the transportation might increase the physical activity in adults, but it might threaten the walking safety, furthermore, contribute to respiratory or allergic diseases in a vulnerable population including children. To combat the problem of road proximity, urban planning policies need to turn into a reduction of road density rather than seeking compactness, fundamentally. Besides this gradual improvement which takes very long periods, preemptively, public policies-i.e. the 10^{th}-day-no-driving campaign, planting street trees, and so on - debilitating the health risk of built environment might be implemented at living-community levels.

The allocation of fast-food outlets was depended on profitability. Therefore, the strategy to attenuate the impact of BE might be not on BE itself but social context of health behavior. To combat the obesity epidemic, health city project, which cooperating of public health and urban planning fields.

In the view of public health surveillance data, future depends in part on developing consensus on critical surveillance content to invest in surveillance system infrastructure and to use surveillance data as the basis for decision making on BE associated health problem.

Appendices. Supplementary tables in Chapter 4

Supplementary table 4– 1 Associations between the distances from the closest major roads and three allergic diseases in 14,765 children

	Model 1		Model 2		Model 3	
	OR[a]	(95% CI)	OR[b]	(95% CI)	OR[c]	(95% CI)
Distance to nearest major roads for 300 meters increment						
Atopic eczema	**0.93**	**(0.88 – 0.98)**	**0.95**	**(0.90 – 1.00)**	**0.93**	**(0.89 – 0.99)**
Asthma	1.00	(0.93 – 1.07)	1.03	(0.96 – 1.11)	1.01	(0.94 – 1.09)
Allergic rhinitis	1.01	(0.97 – 1.05)	1.00	(0.96 – 1.04)	1.01	(0.96 – 1.05)

a. Odds ratio (OR) adjusted for sex and age; b. OR adjusted for sex, age, household monthly income, body mass index and history of breastfeeding; c. OR adjusted for sex, age, household monthly income, body mass index and history of breastfeeding, random effects for school and residential area

Supplementary table 4–2 Associations between two TRAP exposures and three allergic diseases from Model 3 by residential floor levels in 24,040 children

	All floors (N=24,040)		4–9th floors (N=5,211)		≥10 floors (N=4,064)	
	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Proximity						
Atopic eczema						
≤150m	1.04	(0.94 – 1.15)	0.81	(0.63 – 1.03)	0.86	(0.65 – 1.14)
150–300m	1.11	(0.99 – 1.23)	0.85	(0.66 – 1.10)	1.08	(0.80 – 1.45)
300–500m	1.10	(0.98 – 1.23)	0.86	(0.65 – 1.13)	1.07	(0.78 – 1.48)
>500m	1.00		1.00		1.00	
Asthma						
≤150m	1.01	(0.87 – 1.16)	1.15	(0.81 – 1.62)	1.48	(0.95 – 2.31)
150–300m	**1.17**	**(1.01 – 1.35)**	1.19	(0.83 – 1.69)	**1.86**	**(1.18 – 2.94)**
300–500m	1.12	(0.96 – 1.31)	1.36	(0.94 – 1.97)	**1.87**	**(1.15 – 3.04)**
>500m	1.00		1.00		1.00	
Allergic rhinitis						
≤150m	1.01	(0.93 – 1.10)	1.00	(0.82 – 1.21)	1.22	(0.97 – 1.53)
150–300m	1.07	(0.98 – 1.16)	0.98	(0.80 – 1.19)	**1.34**	**(1.05 – 1.70)**
300–500m	1.05	(0.96 – 1.15)	1.11	(0.90 – 1.37)	1.18	(0.91 – 1.54)
>500m	1.00		1.00		1.00	
Density for an interquartile range increment (13,120m^2)						
Atopic eczema	1.03	(0.97 – 1.08)	0.93	(0.83 – 1.05)	0.94	(0.83 – 1.07)
Asthma	0.96	(0.89 – 1.03)	0.97	(0.83 – 1.13)	1.01	(0.85 – 1.20)
Allergic rhinitis	0.99	(0.95 – 1.03)	0.96	(0.88 – 1.05)	1.04	(0.95 – 1.15)

Supplementary table 4-3 Associations between two TRAP exposures and three allergic diseases from Model 3 in 18,159 children including 14,765 in our primary analysis and 3,394 who did not respond to questionnaire for individual characteristics from the Seoul Atopy Friendly School Project Survey during 2010 in Seoul, Korea

	Atopic eczema		Asthma		Allergic rhinitis	
	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Proximity						
≤150m	1.21	(1.07 - 1.36)	1.01	(0.86 - 1.18)	0.97	(0.89 - 1.06)
150-300m	1.22	(1.08 - 1.38)	1.11	(0.95 - 1.30)	1.05	(0.96 - 1.15)
300-500m	1.18	(1.04 - 1.34)	1.05	(0.89 - 1.24)	1.02	(0.92 - 1.12)
>500m	1.00		1.00		1.00	
Density for an interquartile range increment (13,120m^2)						
	1.09	(1.02 - 1.15)	0.97	(0.89 - 1.05)	0.98	(0.93 - 1.02)

Supplementary table 4-4 Associations between two TRAP exposures and three allergic diseases from Model 3, and disease prevalence rates (PRs) in 11,803 children aged 6-12 years from the Seoul Atopy Friendly School Project Survey during 2010 in Seoul, Korea

	Atopic eczema		Asthma		Allergic rhinitis	
Odds ratios (ORs)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Proximity						
≤150m	1.28	(1.09 - 1.49)	0.98	(0.78 - 1.23)	0.98	(0.87 - 1.10)
150-300m	1.34	(1.14 - 1.57)	1.16	(0.92 - 1.46)	1.06	(0.94 - 1.19)
300-500m	1.24	(1.05 - 1.46)	1.06	(0.84 - 1.35)	1.03	(0.91 - 1.16)
>500m	1.00		1.00		1.00	
Density for an interquartile range increment (13,120m^2)						
	1.12	(1.03 - 1.21)	0.94	(0.83 - 1.06)	0.97	(0.91 - 1.03)
Prevalence rates (PRs)	PR	(95% CI)	PR	(95% CI)	PR	(95% CI)
All ages (N=14,765)	15.9	(15.3 - 16.9)	8.0	(7.6 - 8.5)	36.2	(35.4 - 36.9)
Aged 6-12 years (N=11,803)	15.4	(14.7 - 16.0)	6.4	(6.0 - 6.9)	37.3	(36.4 - 38.1)

Supplementary table 4-5 Associations between two TRAP exposures and lifetime physician-diagnosed allergic diseases from Model 3 in 14,765 children from the Seoul Atopy Friendly School Project Survey during 2010 in Seoul, Korea

	Atopic eczema		Asthma		Allergic rhinitis	
Odds ratios (ORs)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Proximity						
≤150m	1.11	(1.01 - 1.23)	0.98	(0.82 - 1.18)	1.02	(0.91 - 1.14)
150-300m	1.11	(1.00 - 1.23)	0.96	(0.80 - 1.16)	1.01	(0.91 - 1.13)
300-500m	1.04	(0.94 - 1.16)	1.02	(0.84 - 1.23)	1.06	(0.95 - 1.19)
〉500m	1.00		1.00		1.00	
Density for an interquartile range increment (13,120m^2)						
	1.10	(1.04 - 1.15)	0.88	(0.80 - 0.97)	0.99	(0.93 - 1.04)
Prevalence rates (PRs)	PR	(95% CI)	PR	(95% CI)	PR	(95% CI)
All ages (N=14,765)	15.9	(15.3 - 16.9)	8.0	(7.6 - 8.5)	36.2	(35.4 - 36.9)

Supplementary table 4-6 Associations between two TRAP exposures and three allergic diseases from Model 3 using TRAP exposure estimates based on home as well as school addresses in 14,765 children from the Seoul Atopy Friendly School Project Survey during 2010 in Seoul, Korea

	Atopic eczema		Asthma		Allergic rhinitis	
	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Proximity						
≤150m	1.20	(1.02 - 1.43)	0.98	(0.79 - 1.21)	0.92	(0.80 - 1.05)
150-300m	1.18	(1.00 - 1.41)	0.97	(0.78 - 1.21)	0.98	(0.86 - 1.11)
300-500m	1.17	(0.98 - 1.40)	0.97	(0.77 - 1.22)	0.99	(0.87 - 1.13)
〉500m	1.00		1.00		1.00	
Density for an interquartile range increment (9,164m^2)						
	1.05	(0.99 - 1.13)	0.94	(0.86 - 1.03)	0.96	(0.91 - 1.02)

국문초록

건조환경과 도시거주자의 건강
: 지역사회 공중보건 감시자료를 이용한 공간분석의 적용

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이 선 주

1. 연구의 배경 및 필요성

근린환경(neighborhood environment)은 물리적 환경과 사회경제적 환경으로 구성되며, 다양한 경로로 인간의 건강에 영향을 미친다. 물리적 환경 중 인간에 의해 만들어진 모든 환경을 건조환경(built environment)이라고 하는데, 이것은 특히 인구밀도가 높은 도시에 거주하는 도시거주자의 건강에 크게 영향을 미친다. 감염병의 유행을 해결하기 위해 시작된 도시건조환경의 건강영향에 대한 공중보건학적 관심과 개입은 19 세기 이후 감소하였으나, 최근에는 인간의 행동양식과 관련된 비감염성 질환을 해결하기 위해 다시 부각되고 있다. 그러나

이에 대한 대부분의 연구는 아직까지 일반인구의 신체활동 증가에 집중되어 있어, 논의의 범위가 보다 다양한 건강문제와 건강취약인구에 대한 영향 등으로 확장되어야 할 필요가 있다. 한국은 수도권의 인구편중이 심하며 수도권 인구밀도 또한 전세계적으로 높은 나라로 도시건조환경의 건강영향에 대한 다각적인 평가가 더욱 중요하다. 특히 수십년 사이에 일어난 도시의 급속한 팽창으로 인해 발생한 문제점들을 극복하기 위해 도시 공간의 재구성을 논의하고 있는 현 시점에서, 건강 중심의 도시 재구성을 적극적으로 논의하는 것이 바람직하다. 그러나 신체활동과 관련하여 서구도시에서 도출된 개별 환경요소를 소지역 단위에서 검증하는 연구가 주로 도시계획 분야를 중심으로 이루어지고 있어, 각 요소가 복합적으로 작용하여 파생되는 다양한 건강결과에 대한 연구와 평가는 아직 부족한 실정이다. 도시건조환경의 건강영향을 체계적으로 파악하고 평가하기 위해 지속적인 감시체계가 필요한데, 기존에 구축된 지역사회건강조사와 같은 공중보건 감시체계 자료가 이러한 연구에 적합한지 우선적으로 파악해 볼 필요가 있다. 더불어 이러한 자료에 공간분석과 지리정보시스템을 적용하면 보다 광범위한 지역에서 도시계획 요소와 건강과의 연관성을 파악할 수 있다.

2. 연구 목적

지역사회 공중보건 감시자료를 이용한 공간분석을 통해, 건강에 영향을 미치는 도시건조환경 요소를 탐색하고 그 요소 간 연관성을 파악하여 건강한 도시 재구성에 대한 공중보건학적 근거를 제시하고자 한다. 본 연구는 도시 건조환경이 건강행동과 건강결과에 미치는 영향을 평가하고자 하였다. 연구모형은 그림 1 에 제시된 바와 같으며, 본 연구에서는 그림 1 중 밑줄 친 부분에 대한 요소 간 연관성을 중점적으로 파악하였다. 건조환경을 측정하는 5 가지 측면 중 밀도, 거리, 접근성의 세 가지를 통해 다음의 세 가지 내용에 대한 분석을 실시하였다.

분석 1: 대중교통 접근성과 성인의 걷기 실천과의 연관성 분석

분석 2: 패스트푸드점 밀도와 성인의 비만 유병과의 연관성 분석

분석 3: 주요도로까지의 거리와 어린이의 알러지 · 아토피질환 유병과의 연관성 분석

3. 연구 방법

개인의 건강행동 및 유병상태에 대한 정보는 지역사회 공중보건 감시자료를 이용하였는데, 19 세 이상 성인을 대상으로 하는 지역사회 건강조사 자료(2011-2014, 92357 명)와 어린이집과 초등학교를 대상으로 하는 서울시 아토피천식 안심학교 설문자료(2010, 24040 명)를 분석에 이용하였다. 이에 영향을 미치는 건조환경 요인은 지리정보시스템을 이용하여 분석하였는데, 이러한 분석은

대부분 점 수준의 위치정보를 필요로 한다. 이를 위해 아토피천식 안심학교 설문조사 자료에서는 참여자의 실제 주소를 지오코딩하여 사용하였으며, 지역사회건강조사 자료는 1 차 층화 단위인 거주유형(단독주택, 아파트)과 읍면동(424 개 법정동, 2014 기준)에 따라 건축물정보와 행정구역도를 기반으로 특정 건조환경까지의 거리 또는 구 단위의 밀도 등을 사용하였다. 건조환경 요소 중 지하철역 등 대중교통까지의 접근성, 구 단위의 5 대 프랜차이즈 패스트푸드점(맥도날드, 롯데리아, 버거킹, KFC, 파파이스)의 밀도, 6 차선 이상의 도로와 고속도로 등을 포함한 주요도로까지의 거리와 주거지로부터 300m 이내의 도로밀도 등이 분석 1,2,3 에서 각각 사용되었다. 건조환경의 영향은 주당 보행시간(분), 체질량지수(BMI) 25kg/m^2 로 정의되는 비만, 한 해 동안 알러지 · 아토피질환 (아토피피부염, 천식, 알러지성 비염) 증상의 유병여부 등에 대해서 각 분석에서 파악되었다.

4. 연구 결과

대중교통까지의 접근성과 주당 보행시간은 비선형적 관계를 보였으며, 지하철역으로부터 1.0−1.5km 이내에 거주하는 사람은 지하철역까지의 거리가 100m 가 증가할 때 보행시간이 28.5 분(95% 신뢰구간=16.7 − 40.2) 증가하나, 1.5km 밖에 거주하는 사람은 오히려 보행시간이 1.9 분(−19.9 − 16.1) 감소하는

것으로 나타났다. 패스트푸드점의 밀도는 개인적 요인 및 지역적 요인을 보정하면 구 수준에서 비만의 유병과 약한 연관성을 보였다 (남성: 오즈비=1.01, 95% 신뢰구간=0.97-1.05; 여성:1.04, 0.99-1.09). 패스트푸드점의 밀도가 지역의 사회경제적 수준과 밀접하게 연관되어 지역의 재정자립도를 보정한 후 영향을 평가하면, 지역의 사회경제적 수준과 성별에 따른 차이는 있지만 패스트푸드점 밀도는 비만의 유병과 약한 연관성이 있는 것으로 나타났다. 주요도로로부터 건물의 3 층 이하에 거주하면서 150m, 150-300m, 300-500m 의 거리에 거주하는 어린이들에서는 아토피피부염의 유병이 500m 보다 멀리 거주하는 아이에 비해 각각 1.15(95% 신뢰구간=1.01-1.32), 1.17(1.03-1.34), 1.16(1.01-1.34)배 더 높은 것으로 나타났으며, 거주지의 반경 300m 이내 도로밀도가 13,120m^2 증가할 때 아토피피부염의 유병이 1.08(1.01-1.15)배 높은 것으로 나타났다. 천식과 비염의 유병도 10 층 이상에서 거주하는 어린이 중 도로로부터의 거리가 가까운 경우 높게 나타났으나 그 영향은 일관되지 않은 것으로 나타났다.

5. 고찰 및 제언

본 연구에서는 접근성, 밀도, 거리의 측면에서 측정된 도시 건조 환경이 걷기와 같은 건강행동 및 비만과 아토피 알러지 질환과 같은 건강결과에 미치는 영향을 공중보건감시자료에 공간분석을 적용하여 평가하였다. 분석결과를 바탕으로

다음과 같은 정책적 시사점을 도출하였다. 첫째, 최근 감소하고 있는 도시거주자의 신체활동은 보행 활성화를 통해 상당 부분 개선할 수 있으며, 개선방안 중 하나로 거주지로부터의 대중교통 접근성 조정을 고려할 수 있다. 둘째, 도시거주자의 비만은 근린 식이 환경으로부터 크지 않은 영향을 받고 있어, 다른 공중보건학적 개입도 동시에 고려해야 한다. 셋째, 접근성의 측면에서 도로와의 접근성은 근린의 대기오염을 증가시키며 이는 생활반경이 제한된 취약인구(어린이 등)에서 알러지 · 아토피질환 등 다른 건강문제를 야기할 수 있다. 종합하면 도시건조환경 중 접근성을 조정하면 신체활동을 증가시켜 비만 등 비감염성질환을 효과적으로 감소시킬 수 있으나, 일부 취약인구에서는 다른 비감염성질환을 증가시킬 수도 있다. 따라서 최근 도시가 겪고 있는 건강 문제를 개선하기 위해서는 서구 도시환경에서 도출된 도시계획 개념에 대해 우리 나라 환경에서의 충분한 검증이 필요하며, 이에 대한 공중보건학적인 관심과 적극적인 개입이 더욱 요구될 것으로 사료된다.

주요어 : 건조환경, 신체활동, 비만, 알러지 질환, 공중보건감시, 공간분석, GIS

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