Original Research Article

Association of Neighborhood Food Environment and Physical Activity Environment With Obesity: A Large-Scale Cross-Sectional Study of Fifth- to Ninth-Grade Children in Japan

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Abstract

Objective: This study examined the relationship between neighborhood food and physical activity environment, and obesity among elementary and junior high school students in Japan. **Methods:** The participants were fifth- to ninth-grade children

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(n=7277), who were attending municipal schools in Japan. Percent overweight (POW) was calculated using their age, gender, height, and weight, which were collected through a questionnaire. A POW of < 20% was considered non-obese, while ≥ 20% was considered obese. Furthermore, using a geographic information system, we investigated the density of convenience stores, fast-food stores, casual restaurants, supermarkets and department stores, parks, sports facilities, stations, and intersections in the school district. Additionally, from the census, we obtained information regarding the population density of the municipality where the participants' schools were located. Multiple logistic regression analysis was used to examine the relationship between obesity and food environment (the food environment model), between obesity and physical activity environment (the physical activity environment model), and among obesity, food, and physical activity environment (the food and physical activity environment model). **Results:** In the food environment model and the food and physical activity environment model, the density of convenience stores showed a significant positive association. In the physical activity environment model, the density of stations showed a significant negative association. **Conclusion:** This study's findings can contribute to the development of appropriate community interventions for improving children's health in Japan and similar areas.

Keywords
adolescent, children, built environment, food environment, physical activity environment, obesity, overweight

What do we already know about this topic?

Obesity increases the risk of several diseases and death, and childhood obesity also causes various health disorders. In developed countries, especially in Europe and the United States, many studies have examined the relationship between the weight status of children and neighborhood-built environments. Owing to cultural differences, people's lifestyles in Japan may differ greatly from those in Europe and the United States; consequently, the relationship between the neighborhood environment and obesity in Japan may differ from the one found in those countries.

How does your research contribute to the field?

This study examined neighborhood food and physical activity environment's relationship with obesity among elementary and junior high school students in Japan. Concerning neighborhood food environment, having many nearby locations to purchase unhealthy foods and beverages, such as convenience stores, was associated with more obesity in elementary and junior high school students. Concerning neighborhood physical activity environment, having many nearby public transportation facilities, such as train stations, was associated with less obesity in elementary and junior high school students. Having many nearby locations to purchase unhealthy foods and beverages, such as convenience stores, was positively associated with obesity, even when the effects of physical activity environment were considered.

What are your research's implications towards theory, practice, or policy?

In recent years, local governments worldwide, mostly in Europe, have been considering the healthy growth and development of children during urban planning. However, Japanese local governments have not been proactive in such efforts. This study can help local governments in Japan and similar areas promote the improvement of childhood health.

Introduction

Obesity is known to increase the risk of several diseases and death. Childhood obesity increases the risk of various health disorders, such as hyperuricemia,[1] sleep apnea,[2] and diabetes.[3] Additionally, the rate of transition to adult obesity from obesity in adolescence is 70%.[4] This high rate underlines the importance of keeping body weight within the healthy range during adolescence.

Increasing numbers of studies are examining the built environment of neighborhoods as a potential factor related to health outcomes. The built environment refers to the environment constructed by people, such as urban design and public transportation. In the built environment, indicators linked to diet and exercise are called the food and physical activity environment, respectively.[5] Recent studies have explored the relationship between food and physical activity environments and obesity in children. For example, there are systematic reviews on the association between childhood obesity and convenience stores,[6] fast-food restaurants,[7] full-service restaurants,[8] supermarkets,[9] green spaces including parks and sports facilities,[10] public transportation,[11] and street connectivity.[12] However, they all reported mixed results. Additionally, most studies have been conducted within

specific countries and regions, and very few have been conducted in Japan—thus, limiting its applicability to the Japanese population. In Japan, the lifestyle is very different from that of other countries where many studies have been conducted in the past, and the relationship between the neighborhood environment and health may also be different. For instance, although the proportion of children in Japan, compared to the rest of the world, who have active transportation is very high, their screen time is high.[13,14]

Thus, this study aimed to clarify the relationship between neighborhood food and physical activity environment and obesity among elementary and junior high school students in Japan.

Methods

Study Participants

A questionnaire survey about health and health behaviors was administered to adolescents in various parts of Japan by 18 researchers belonging to 15 research institutes. Each researcher asked the local school or board of education, and we collected questionnaires from 21 491 fifth-to twelfth-grade students attending 76 schools (1 school in a large municipality, 35 in medium-sized municipalities, 16 in small municipalities, and 24 in a town or village) covering the Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, and Kyushu regions. No school refused to participate in the survey. The schools surveyed in this study included municipal and national elementary and junior high schools, and prefectural, national, and private high schools. However, high schools and national elementary and junior high schools in Japan have no defined school districts. Therefore, since the density of the built environment per school district cannot be calculated, we excluded 9473 high school students, 3598 national elementary and junior high school students. Additionally, we excluded 1143 incomplete responses from the analysis. The final analysis included 7277 fifth-to ninth-grade students attending 48 schools (1 school in a large municipality, 13 in medium-sized municipalities, 11 in small municipalities, and 23 in a town or village) in 14 prefectures (Figure 1).

Investigation of Individual Variables, Calculation of Percent Overweight, and Classification of obesity

From 2018 to 2019, a questionnaire was used to record the students' date of birth, date when the questionnaire was completed, gender, height, and weight. Age was calculated from the date of birth and the date when the questionnaire was completed. Percent overweight (POW) was calculated from age, gender, height, and weight using a standard weight-based criterion.[15] This value was calculated using the formula [(actual weight)-(standard weight)]/(standard weight)×100 and drawing from the standard weight provided by the Japanese Ministry of Education, Culture, Sports, Science, and Technology statistical report data (2000)[16] as the standard value. This is an index of the percentage by which the weight studied differs from the sex- and age-matched ideal standardized body weights of children in Japan. In clinical practice in Japan, POW has been the most commonly used measure to assess childhood obesity. The BMI percentile or BMI z-score is recommended, worldwide, for the determination of childhood obesity. However, Sugiura and Murata[17] pointed out that cutoff values in the BMI percentiles have not been defined for the Japanese population. It has also been shown that even for adolescents with optimal weight by sex

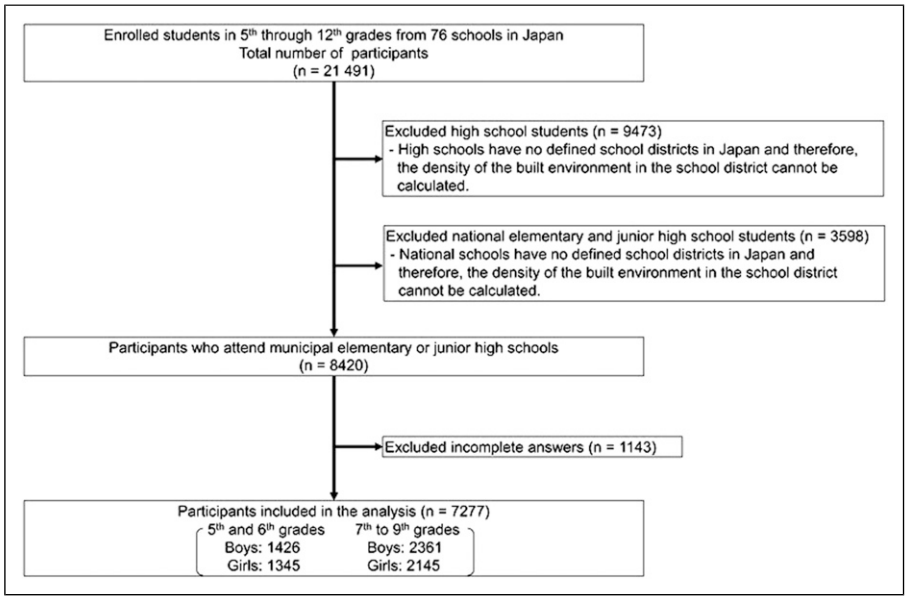

Figure 1. Participant selection.

and age, their BMI was calculated to be higher as their height increased. For these reasons, the Japan Society for the Study of Obesity[18] recommend using the POW. Therefore, it was used in this study to determine childhood obesity. Based on this calculation, participants with ≥ 20 POW were classified as the obese group and those with < 20 POW were classified as the non-obese group, per the Guidelines for the Management of Obesity Disease in Children and Adolescents 2017 from the Japan Society for the Study of Obesity.[18]

Investigation of Neighborhood Food and Physical Activity Environment Factors

The area data of school districts in Japan (Geo-K LLC., 2018) and the point data of neighborhood food environment (convenience store, fast-food restaurant, casual restaurant, supermarket, and department store) and physical activity environment (park, sports facility, station, and intersection) (Zenrin Co., Ltd., 2019) were mapped on the geographic information system (ArcGIS® Pro 2.5.1, Esri Japan Corp., Tokyo). A number of studies have examined the relationship between these items and obesity. In the food environment, convenience stores, fast-food restaurants, and casual restaurants are considered to promote unhealthy food choices, while supermarkets and department stores are considered to promote healthy food choices. In the physical activity environment, parks and sports facilities are considered to support physical activity in that area, and train stations and 8intersections are considered to provide better access to destinations and increase opportunities for walking, bicycling, and using public transportation to go out. Systematic reviews of the relationship between these individual items and childhood obesity have been published.[6-12] Dixon et al.[19] conducted a scoping review, which summarized the systematic reviews and meta-analyses of the association between the built environment and physical activity, dietary intake, and obesity, where these items were listed as variables that had been included in previous reviews. Therefore, these eight variables were investigated in this study. From the map, the number of food and physical environment elements in the school district of each participant was objectively tabulated. The tabulated numbers were divided by the area of the school district to calculate the density of each food and physical activity environment element within an area of 1 km^2. All analyzed schools were in different school districts, with no overlaps.

Investigation of Other Factors

Studies have shown that rural areas have more overweight children than urban areas do.[20,21] There are no standard definitions for urban and rural areas. However, population density is often used to evaluate the urbanization status in the public health paper.[22] We obtained information on the population density of the municipality where the participants' schools were located (population census in Japan, 2015).[23]

Statistical Analysis

First, age, gender, population density, and density of food and physical activity environment elements between the non-obese and obese groups were compared using the Chi-square test and Mann–Whitney U test. Subsequently, the relationship between obesity in children and their food and physical activity environment was examined using multivariate logistic regression analysis, which was divided into "the food environment model," "the physical activity environment model," and "the food and physical activity environment model." The food environment model used the following as explanatory variables: density of four food environment elements (convenience stores, fast-food restaurants, casual restaurants, and supermarkets and department stores) and adjusted factors (age, gender, and population density of municipalities). The physical activity environment model used the following as explanatory variables: density of four physical activity environment elements (parks, sports facilities, stations, and intersections) and adjusted factors (age, gender, and population density of municipalities). The food and physical activity environment model used the following as explanatory variables: density of four food environment elements (convenience stores, fast-food restaurants, casual restaurants, and supermarkets and department stores) four physical activity environment elements (parks, sports facilities, stations, and intersections), and adjusted factors (age, gender, and population density of municipalities). In all logistic regression models, POW was used as the objective variable (0: "non-obese group" [Reference], 1: "obese group"). All analyses were performed using IBM SPSS Statistics V.26.0 (IBM Corp, Armonk, New York, USA), and the statistical significance level was set to $p<.05$.

Ethical Considerations

Written explanation was provided to the participating school principals about the purpose, method, benefits, and risks of the study. Additionally, written assurance was provided regarding the protection of personal information, anonymity of data, and that the answers would have no bearing on school grades. It was also explained that returning a filled questionnaire would be considered as informed consent to participate. The study was approved by the Doshisha University of Human Subject Research Ethics Committee (approval number: 17095).

Results

Participant attributes

Table 1 shows a comparison of gender, age, population density, and density of food and physical activity environment elements between the non-obese and obese groups. Approximately 7% of participants were obese. The obese group had a significantly higher proportion of boys and a

Table 1. Descriptive statistics of participants and comparison of gender, age, population density, and density of each food environment and physical activity environment elements between non-obese and obese groups (n = 7277[a])

	Total n = 7277	Non-obese n = 6772	Obese n = 505	
	n(%)	n(%)	n(%)	p-value for Pearson's chi-square test
Gender				
Boy	3787 (100.00)	3461 (91.39)	326 (8.61)	<.001
Girl	3490 (100.00)	3311 (94.87)	179 (5.13)	
	Mean ± SD[b]	Mean ± SD[b]	Mean ± SD[b]	p-value for Mann-Whitney U test
Age (years)	13.05 ± 1.43	13.07 ± 1.43	12.81 ± 1.47	<.001
Population density (/km^2)	2036.27 ± 2478.45	2048.43 ± 2485.31	1873.27 ± 2380.94	.484
Density of elements in each school district[c]				
Convenience stores	0.86 ± 0.76	0.86 ± 0.76	0.87 ± 0.81	.590
Fast-food restaurants	0.09 ± 0.19	0.09 ± 0.19	0.06 ± 0.16	.016
Casual restaurants	0.18 ± 0.27	0.19 ± 0.27	0.15 ± 0.25	.002
Supermarkets and department stores	0.78 ± 0.72	0.78 ± 0.73	0.75 ± 0.64	.714
Parks	0.27 ± 0.36	0.27 ± 0.36	0.28 ± 0.39	.612
Sports facilities	0.10 ± 0.16	0.10 ± 0.16	0.10 ± 0.17	.078
Stations	0.10 ± 0.16	0.10 ± 0.16	0.09 ± 0.16	.060
Intersections	0.27 ± 0.32	0.27 ± 0.32	0.28 ± 0.34	.895

[a]Unweighted n.
[b]SD: standard deviation.
[c]Number of each element within 1 km^2.

lower age (p<.001). The density of casual restaurants (p=.016) and fast-food restaurants (p=.002) was higher for children in the obese group than those in the non-obese group. No significant difference was found in the density of physical activity environment elements and population density.

Relationship of Obesity With Neighborhood Food and Physical Activity Environment

Using multivariate logistic regression analysis, adjusted odds ratios were calculated for each neighborhood food and physical activity environment element with non-obesity and obesity as the objective variable (Table 2).

In the food environment model, only the density of convenience stores within the school district showed a significant positive relationship (p=.044). Obesity was not significantly associated with the density of fast-food restaurants (p=.168), casual restaurants (p=.195), and supermarkets and department stores (p=.469) within the school district. In the physical activity environment model, a significant negative relationship was found only for the density of stations within the school district (p=.046). Obesity was not significantly correlated to the density of parks (p=.142), sports facilities (p=.771), and intersections (p=.176) within the school district. Finally, in the food and physical activity environment model, there was a significant positive association between obesity and the density of convenience stores in the school district (p=.028), but the significant association with the density of stations in the school district, which was confirmed in the physical activity environment model, disappeared (p=.392). The density of fast-food restaurants (p=.302), casual restaurants (p=.076), supermarkets and department stores (p=.961), parks (p=.269), sports facilities (p=.097), and intersections (p=.320) had no significant relationship with obesity.

Discussion

This study aimed to clarify the relationship between neighborhood food and physical activity environments and obesity among elementary and junior high school students in Japan. The results showed that the density of convenience stores was positively associated with obesity in the neighborhood food environment and the density of stations was negatively associated with obesity in the physical activity environment. Additionally, the density of convenience stores was positively associated with obesity even when the physical activity environment was adjusted.

In this study, a significant positive odds ratio was observed for convenience stores in both the food environment model and the food and physical activity environment model, indicating that they are associated with obesity in children in

Table 2. Odds ratios and 95% confidence intervals showing the relationship between obesity and neighborhood-built environment elements using multivariate logistic regression analysis (n = 7277[a]).

	The food environment model[b]	The physical activity environment model[b]	The food and physical activity environment model[b]
	OR (95% CI)[c]	OR (95% CI)[c]	OR (95% CI)[c]
Density of outlets in each school district			
Convenience stores	1.184 (1.005–1.395)*		1.250 (1.024–1.525) *
Fast-food restaurants	0.579 (0.267–1.259)		0.640 (0.274–1.494)
Casual restaurants	0.681 (0.381–1.218)		0.560 (0.295–1.063)
Supermarkets and department stores	1.077 (0.882–1.315)		1.006 (0.799–1.267)
Parks		1.209 (0.939–1.557)	1.173 (0.884–1.557)
Sports facilities		0.894 (0.420–1.904)	2.206 (0.867–5.612)
Stations		0.543 (0.298–0.989) *	0.754 (0.392–1.449)
Intersections		1.333 (0.879–2.204)	1.254 (0.803–1.959)

[a]Unweighted n.
[b]Adjusted for age, gender, school district area, and population density.
[c]OR (95% CI): odds ratio (95% confidence interval).
*p<.05.

Japan. A systematic review of studies examining the association between convenience stores and childhood obesity reported that the relationship was inconclusive.[6] On the other hand, in Japan, the number of convenience stores has increased sharply in the last 30 years. Per the Ministry of Economy, Trade and Industry,[24] the number of convenience stores in 2019 reached 56 502. As of April 2021, the Japanese population was 125.2 million,[25] which means that there is one convenience store for every 2000 Japanese people. It makes them indispensable to the daily lives of Japanese people. It is reported that 8–14 year-olds in Tokyo visit convenience stores between 2 and 4 times a week.[26] Therefore, it is possible that children frequently use convenience stores as a source of nutrition intake. Another study in New Zealand observed that the consumption behavior of 11–14 year-olds in convenience stores reported that about 90% of the food and beverages purchased were unhealthy.[27] Several papers from other countries have reported that having many convenience stores nearby is associated with unhealthy dietary intake in children.[28-32] For example, it has been reported that increased availability of convenience stores was significantly and positively associated with fast-food and sugar-sweetened beverage consumption in 9–12 year-olds in Seoul, South Korea.[31] ampere systematic review concluded that there was a strong association between convenience stores and unhealthy weight-related behaviors.[6] Therefore, frequent visits to convenience stores in the neighborhood may be associated with unhealthy food intake and obesity among children in Japan.

Notwithstanding, in the physical activity environment model, station density was significantly negatively associated with childhood obesity. A systematic review of 25 cross-sectional studies and 2 longitudinal studies spanning 10 countries—which examined the association between access to public transportation and childhood obesity—found that more than half the studies found no association between access to public transportation and childhood obesity. However, of the remaining studies, there were more studies that found that better access to public transportation was associated with less childhood obesity than studies that found that better access to public transportation was associated with more childhood obesity. The authors of that review suggest that increased levels of access to public transportation may have a health-promoting effect and help prevent the development of childhood obesity.[11] Our study also supports this finding. Several studies have shown that the availability of public transportation, such as train stations, is positively associated with the amount of physical activity performed by children.[33-37] For example, girls aged from 5–12 years old in Australia who had difficulty using public transportation had fewer opportunities to walk and cycle.[33] The presence of public transportation may therefore be associated with more opportunities for physical activity, more physical activity, and less obesity in children in Japan.

Conversely, no significant association between station density and obesity was found in the food and physical activity environment model. The variance inflation factors of each explanatory variable were all less than 10 in each model, and there was no suspicion of multicollinearity. However, the correlation coefficients between the elements of the physical activity environment were small (the mean of the absolute values of the correlation coefficients = .245), while the correlation coefficients between the elements of the physical activity environment and the food environment elements were relatively large (the mean of the absolute values of the correlation coefficients = .346). Namely, the presence of a food environment may have confounded the association between stations and obesity. Most studies have focused on

one type of built environment, either the physical activity environment or the food environment. However, a review has hypothesized that the physical activity environment and food environment are correlated.[38] This study adopted both models in which the physical activity environment and the food environment were entered, respectively, and simultaneously, suggesting that the food environment and the physical activity environment may influence each other.

In recent years, local governments worldwide, mostly in Europe, have been considering the healthy growth and development of children during urban planning. For example, UNICEF has developed the Child Friendly Cities Initiative,[39] which aims to realize the rights of children at the local level. However, of over 3000 cities worldwide that are participating in this project, only five are from Japan. Thus, Japanese local governments have not been proactive in such efforts. This study can help local governments in Japan and similar areas promote the improvement of childhood health.

There are some limitations to this study. First, this is a cross-sectional study; therefore, we cannot be sure of the causality of the results. Second, we did not use random sampling. Instead, we sent questionnaires to schools that cooperated with the survey. Therefore, a selection bias cannot be denied. At present, however, it is difficult to investigate into personal information in Japan because of protection of the rights and interests of the individuals. Under such circumstances, collecting information on large numbers of children in a wide area of Japan is one of the strengths of this study in terms of avoiding as much bias as possible. Additionally, the results are not generalizable to national or private schools whose school districts could not be identified, as they were not included in the analysis. Third, the POW in this study was calculated using self-reported height and weight, which may differ from measured values. Fourth, there may be confounding factors. In this study, age, gender, and population density were used as adjustment factors. However, physical activity and obesity are influenced by many factors at the genetic, individual (e.g.,, physical activity and dietary preferences, membership in athletic teams and sports clubs, school type), and family level (e.g.,, parents' income and educational background, family's physical activity and dietary preferences). Moreover, although we selected eight built environment factors—based on previous studies and the availability—that are considered to be associated with obesity, we cannot deny the possibility that other built environment factors (e.g.,, sidewalks and mixed land use) not examined in this study may have had an impact, or that the impact of the selected built environment factors may have differed depending on more detailed classification. Additionally, it has been reported that social environment and socioeconomic status at the regional level are also related to health outcomes. Although the selection of the target schools was not specifically biased toward city or country, it may have influenced the results. Fifth, we used the criterion for obesity that has been used historically in Japan. As mentioned earlier, the Guidelines for the Management of Obesity Disease in Children and Adolescents 2017[18] also uses this criterion; however, at present, sufficient scientific evidence is lacking. Additionally, POW is a value calculated based on age, height, and weight alone and is not an index that reflects fat accumulation. Therefore, it is possible that children with significantly developed lean tissue were incorrectly classified into the obese group. Sixth, we defined the school district as a neighborhood based on previous studies[40] because, in Japan, children attending municipal schools need to live in their school district and most of their daily life takes place in the school district. However, there is no clear definition of neighborhood, and a neighborhood may be defined with a buffer from the place of residence or school. Therefore, the results may have differed due to differences in the definition of neighborhood. Finally, in this study, we did not use multilevel analysis because the intraclass correlation coefficient, that was calculated to evaluate the differences in the data between schools, was lower than .05. However, the design effect of the data sample in this study was approximately 14, which may have resulted in a small estimate of the standard error.

Conclusion

In fifth- to ninth-grade children in Japan, having many places nearby where they could buy unhealthy foods and beverages, such as convenience stores, was associated with more obesity, while having many nearby public transportation facilities, such as train stations, was associated with less obesity. Additionally, having many nearby locations where unhealthy foods and beverages could be purchased, such as convenience stores, was positively associated with obesity, even when the effects of physical activity environment were considered. This study's findings can contribute to the development of appropriate community interventions for improving children's health in Japan and similar areas.

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