CROSS-SECTIONAL ASSOCIATION BETWEEN WALKING ACTIVITY OF RESIDENTS AND THEIR ACCESSIBILITY TO DIFFERENT BUILDING USES

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ABSTRACT: Building use (BU) is an outcome of the land use design as it provides the information on how buildings are utilized. Accessibility to various BU from a residence is a factor that significantly influences the residents' walking activity (WA). In this context, the correlation between WA and the types of BU needs to be investigated. Thus, this study aimed to establish an association between residents' accessibility to different BU and their WA. Self-reported measures of the extent of daily and leisure WA (DWA and LWA) for a week were used as data for residents' WA with the location of their residence. Residents with a certain amount or more of weekly WA were classified to the high WA group for both DWA and LWA. The Zenrin Building Point Data (Z-BPD) were used as the BU data in the study area. Residents' accessibility to BU was defined by the number of BU at a certain distance from their residence using GIS software. The association was investigated using the logistic regression. While the associations of belonging to high DWA group and high BU accessibility group were established with significance for all BU groups, the associations of belonging to high LWA group and high BU accessibility group had hardly any significance. Among eight BU groups, the accessibility to medical group showed the strongest association with the high DWA group. The results imply that the accessibility to medical BU is a proxy to assess the better walking environment around a residence. In terms of the extent of the BU effect, the association with high DWA group became the strongest in a relatively further distance threshold (600 m and 800 m). The importance of better accessibility to BUs with a relatively long distance was suggested.

1. INTRODUCTION

The declining trend in the amount of walking activity (WA) is a growing issue in Japan. WA is one of typical examples of physical activity (PA). Low PA is associated with high obesity risk (Martinez-Gomez et al., 2019). However, high WA levels are associated with a reduced risk of type-2 diabetes (Fritz et al., 2006) and cardiovascular diseases (LaCroix et al., 1996). Among Japanese women, the average number of steps per day and the ratio of population with exercise habits decreased significantly over 10 years during the pre-pandemic period (Ministry of Health Labour and Welfare, 2019). In addition, the coronavirus pandemic has massively reduced the extent of walking activity in Japan (Obuchi et al., 2021). Public Health of England reported that the decline in PA amid the pandemic is notable among older adults whose population is on the rise in Japan (Ministry of Internal Affairs and Communications Statistics Bureau, 2021). The pandemic extended the gap in the amount of walking time among the population as the opportunities for daily walking activity (DWA) were reduced (Hunter et al., 2021). Therefore, the promotion of both DWA and leisure walking activity (LWA) is crucial for the WA recovery.

The built environment plays a role in improving and engaging in the PA, particularly in the context of active transportation and leisure time PA domains (Laddu et al., 2021). According to the survey by Alfonzo et al. (2008), around 70% of the sample reported that over half of their walking took place in their neighborhood. This result shows the importance of the built environment around the residence for the WA improvement.

There have been many studies on the relationship between the various aspects of built environment and PA or WA of residents in an area (Wang et al., 2021; Ahmadipour et al., 2021) with a variety of geographical and cultural contexts (Sallis et al., 2016; Ding et al., 2013). Land use, one aspect of the built environment, has a great impact on public health (Powell, 2005). Building use (BU) is the outcome of a land use design, and it provides the information on how buildings are utilized. Accessibility to different BUs is often associated with WA. Here, accessibility refers to the number or floor area of a BU within distance. Frank et al. (2007) suggested including the retail floor area ratio into walkability index, which is the composite measure of the built environment. The report by the Ministry of Land, Infrastructure, Transport and Tourism (2018) also suggested a positive relationship between the population scale of a city and the number of steps of residents due to higher accessibility of the daily service. The increase of pedestrians on a street provides economic benefits as the sales of retails on the street rise.

The studies about the effect of built environment have been mainly targeting PA as an outcome. Frank et al. (2019) conducted a longitudinal study to reveal the effective distance of a greenway to residents' PA. The authors found that the benefits from the greenway declined with a distance from 100 m to 500 m by altering the distance threshold from the greenway for the assessment. Yasunaga et al. (2016) conducted a cross-sectional study between the accessibility of BU and PA of residents and revealed that meeting the 23 METs-h/week of moderate-to-vigorous intensity PA was significantly and positively associated with the number of supermarkets/convenience stores in the neighborhood. Although the type of BU affecting the WA of residents was assessed in this study, the extent of the effect in terms of distance was not understood well. Neither of the precedent studies investigated the relationship between BU and residents' WA as residents' PA was the focus of the study. A study focusing on WA is thus required because a type of WA (DWA or LWA) matters when investigating the effect of BUs. Another question that needs to be answered is what distance threshold is the best to define the accessibility of BUs since those who have high accessibility to BU should be different based on the distance threshold to define the accessibility.

This study thus aimed to associate the DWA and LWA of residents with the accessibility to different types of BU around the residence. In addition, the distance threshold to evaluate the accessibility to BUs was altered to determine the distance where a BU becomes the most influential to residents' WA.

2. METHODS

2.1 Study Sample

This study uses data from the questionnaire regarding WA conducted by Yamada around the Kusatsu River Park (KRP) (Kanai et al., 2019). The questionnaire was administered in the fall of 2017, aiming to examine the influence of the opening of KRP to WA of residents living within approximately 800 m from the park. A total of 1,100 letters containing two parts of the questionnaire were posted to the randomly selected households. No reference to the objective of the questionnaire was provided in the questionnaire to avoid the bias of participants. KRP is located in Kusatsu city, Shiga Prefecture, Japan. The study area plays an important role as a traffic junction because the JR Biwako line and National Route 1 pass through the middle of the city (Figure 1).

Out of 1,100 (a total of 538 households), 765 residents answered the questionnaire (48.9% households response rate); then, the participants whose responses were inappropriate or inadequate (n = 102) were excluded from the sample. Participants who lived less than a year in their residence (n = 38) were also excluded from the sample as this study aims to investigate their change in WA for a year. The final sample contains the residents of the entire study area of the questionnaire (Figure 2).

Figure 1. A map of the study area in Kusatsu, Shiga

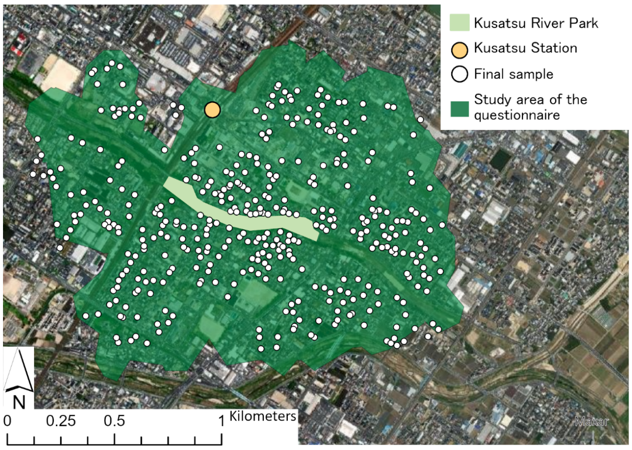

Figure 2. Area of the questionnaire and the final sample

2.2 Measures

The WA of residents was assessed using the questionnaire measures. For WA, the participants were asked the frequency (days/week) and time (minutes/day) of their daily and leisure WA in a past week. Participants self-reported their age, sex, marriage status, health condition, post-secondary educational (PSE) attainment, employment status, driving status, and cycling status as personal attributes.

The sample was classified based on the parameters of personal attributes and WA for the analysis in the following chapters. Table 1 shows the criteria for the classification by each parameter. All the parameters were binarized based on the criteria. For the classification of high and low DWA group, DWA ≥ 120 minutes/week was used as a threshold. In addition, 120 minutes/week was the median of the sample in which the residents with no DWA were excluded. Similarly, LWA > 0 minutes/week was used as a threshold for the classification of high and low LWA group.

Table 1. Criteria for the classification of the sample by parameters

Parameters		0	1
Personal attributes	Age	< 60	≥ 60
	Sex	Male	Female
	Marriage status	Married	Single
	Health condition	Others	Relatively healthy or better
	PSE attainment	Not	Attained
	Employment status	Unemployed	Employed (regular/non-regular)
	Driving status	Others	Frequent
	Cycling status	Others	Frequent
Walking activity	Daily	< 120 hours/week	≥ 120 hours/week
	Leisure	None	Once or more/week

2.3 Data for building use

Data for BU were obtained using the Zenrin Building Point Data (Z-BPD), a record of the information about all the buildings in Japan. The data include the location of buildings and the number of businesses in different categories in each building. In this study, the categories in Z-BPD were further classified into eight BU. Table 2 shows the Z-BPD categories and the example of facilities included in each BU group. Z-BPD is obtained for Kusatsu city and Ritto city to cover the analysis area, which is within 800 m from all the residence in the survey. The Z-BPD for each year contains the data of buildings in June. Therefore, the Z-BPD for 2018 was used as the data for land use of 2017 in October.

Table 2. Classification of Z-BPD categories and example of facilities in each BU group

BU Groups	Category in Z-BPD	Example
Restaurant	Restaurants	Restaurants Cafes Bars
Shop	Shops (food, cloth, daily goods)	Groceries Clothes shops Daily item shops
Service	Service (rental, ceremonial, daily use, car, other) Sports facilities, amusement Hotels, Real estate agent	Barbers Hotels Real estate agent
Store	Stores	Department stores Supermarket Convenience stores
Financial	Finance/Insurance	Banks Securities company Insurance company
Medical	Healthcare/Welfare	Hospitals Drug stores Chiropractors
Educational	Education	Schools Clam schools Language schools
Public	Public	Library Public hall Police

Figure 3 shows the area of extraction as well as all the extracted BUs. As seen from the figure, the extracted BUs were concentrated near the station and the main streets. In such an area, the accessibility to business is high. In contrast, the businesses were sparse in the west of the study area, which is a low-rise residential area. In that area, the accessibility to local business is low. In this study, the accessibilities to eight BU groups in four distance thresholds (200, 400, 600, and 800 m) were obtained in terms of the number of BUs within the distance thresholds. Let us take an example of accessibility for the "Restaurant" group within 400 m. Figure 4 shows the BU location for the "Restaurant" group and the reach of 400 m from a residence. To assess the accessibility from the residence to "Restaurant," the number of "Restaurants" within 400 m was counted. The counting was operated in QGIS 3.16.11. In the same manner, the number of "Restaurants" for all the residences was counted to classify the sample to high/low accessibility group based on the median. The high-accessibility group who had a greater number of BU than median was defined as an experiment group, while the low-accessibility group with a smaller number of BU than median was defined as a control group. The median of the number of BUs for each distance threshold is presented in Table 3. The number of BU was counted in different distance thresholds to understand the distance where the BU has the greatest influence on residents' WA.

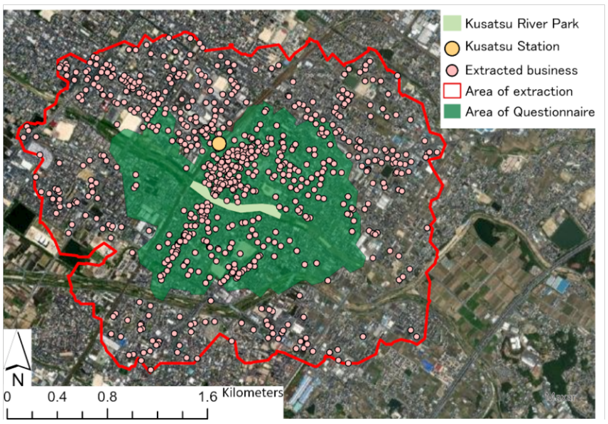

Figure 3. Area of extraction of BUs and extracted BUs

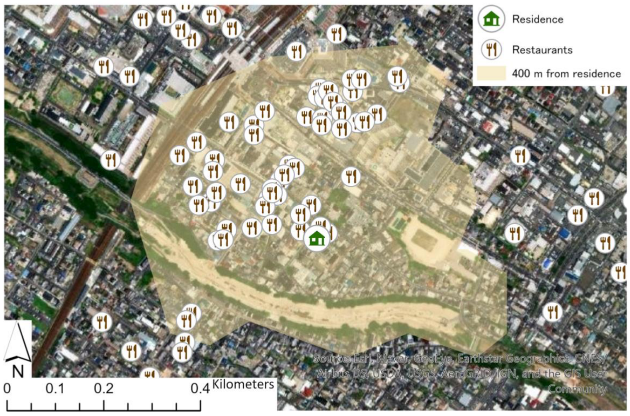

Figure 4. "Restaurants" within 400 m from residence

Table 3. Median of the number of BUs in each distance threshold

BU groups	200 m	400 m	600 m	800 m
Restaurant	2	12	37	83
Shop	4	22	48	106
Service	5	14	37	87
Store	0	2	5	13
Financial	0	2	5	13
Medical	4	13	29	54
Educational	2	9	23	49
Public	1	5	11	20

2.4 Statistical Analysis

The logistic regression models of generalized linear models were used to estimate the effect of the accessibility to BUs, to DWA and LWA of residents in terms of the odds ratio (OR). The outcome measures were regressed personal attributes terms and a target term. In the case of evaluating the effect of the high accessibility to "restaurant" BU in 400 m to residents' DWA, the outcome measure is the binary classification of whether the sample belongs to high DWA group (DWA ≥ 120 minutes/week), and the target term is the binary classification of whether the sample of belongs to high "restaurant" accessibility group of the 400 m distance threshold. The regression analyses were performed using R 4.1.2 by changing the outcome terms (high DWA group and high LWA group) and the target term (high accessibility groups for eight BUs in four distance thresholds) one by one. Akaike's Information Criterion (AIC) was used to interpret the goodness of the prediction of a model because the better model returns the smaller AIC number.

3. RESULTS

The results for DWA are summarized in Table 4. Almost all BU accessibility terms were positively associated with the high DWA group with significance. Among the BU groups, the "medical" group had the biggest OR and the OR hit the maximum at the 600 m distance threshold (OR = 1.18; 95% CI = 1.09, 1.27) by giving the smallest AIC of all the models (831.22). High accessibility to commercial BUs such as "restaurant," "shop," and "service" showed consistent association over distance thresholds. Although almost all the BU accessibility terms were significantly associated with the high DWA group of residents, a few BU types did not show the significant association at the 200 m distance threshold ("store," "educational," and "public"). Especially "educational" and "public" showed a smaller OR compared to the other BU types overall.

Table 4. Logistic regression results of the BU accessibility terms for DWA

	OR for achieving DWA ≥ 120 min/week (95% CI) < AIC >			
	200 m	400 m	600 m	800 m
Restaurant	1.13*** (1.05, 1.22) < 839.56 >	1.15*** (1.06, 1.24) < 836.69 >	1.16*** (1.08, 1.25) < 834.65 >	1.13*** (1.05, 1.22) < 838.72 >
Shop	1.12*** (1.04, 1.21) < 840.65 >	1.12*** (1.04, 1.21) < 840.85 >	1.14*** (1.05, 1.23) < 838.41 >	1.16*** (1.07, 1.25) < 834.92 >
Service	1.14*** (1.06, 1.23) < 838.05 >	1.13*** (1.05, 1.22) < 839.71 >	1.15*** (1.06, 1.24) < 837.14 >	1.15*** (1.07, 1.24) < 836.01 >
Store	1.06 (0.98, 1.15) < 847.20 >	1.11*** (1.03, 1.21) < 842.71 >	1.16*** (1.07, 1.25) < 835.54 >	1.15*** (1.06, 1.24) < 836.89 >
Financial	1.08** (1.00, 1.17) < 845.40 >	1.16*** (1.07, 1.25) < 835.71 >	1.13*** (1.05, 1.22) < 839.94 >	1.09*** (1.02, 1.18) < 844.00 >
Medical	1.18*** (1.09, 1.27) < 832.06 >	1.15*** (1.07, 1.24) < 836.13 >	1.18*** (1.09, 1.27) < 831.22 >	1.13*** (1.04, 1.21) < 840.07 >
Educational	1.04 (0.96, 1.12) < 848.75 >	1.11*** (1.03, 1.20) < 841.75 >	1.14*** (1.06, 1.23) < 837.79 >	1.15*** (1.06, 1.24) < 837.10 >
Public	1.01 (0.93, 1.09) < 849.52 >	1.07* (0.99, 1.15) < 846.40 >	1.12*** (1.04, 1.20) < 840.84 >	1.03 (0.96, 1.11) < 848.85 >

*p<0.1; **p<0.05; ***p<0.01

Table 5 shows the distance threshold with the lowest AIC for every BU group with the OR of the target term and AIC of the model. Overall, the assessment of the BU accessibility terms with bigger distance thresholds helped the reduction of AIC because out of eight BU groups, four and three groups had the smallest AIC at 600 and 800 m distance threshold, respectively. The "financial" group was the only group which model had the lowest AIC at 400 m or the smaller distance threshold.

Table 5. Distance threshold with the smallest AIC of the BU accessibility terms for DWA

	Distance with the lowest AIC	OR[1] (95% CI) < AIC >
Restaurant	600 m	1.16*** (1.08, 1.25) < 834.65 >
Shop	800 m	1.16*** (1.07, 1.25) < 834.92 >
Service	800 m	1.15*** (1.07, 1.24) < 836.01 >
Store	600 m	1.16*** (1.07, 1.25) < 835.54 >
Financial	400 m	1.16*** (1.07, 1.25) < 835.71 >
Medical	600 m	1.18*** (1.09, 1.27) < 831.22 >
Educational	800 m	1.15*** (1.06, 1.24) < 837.10 >
Public	600 m	1.12*** (1.04, 1.20) < 840.84 >

*p<0.1; **p<0.05; ***p<0.01

[1]OR for achieving DWA ≥ 120 min/week

The results for LWA are shown in Table 6. Again, the association of the high LWA group with the BU accessibility terms was not observed as strongly as that of the high DWA group. For "Service" and "Store" group, the positive association with the high LWA group with significance ($p < 0.1$) was observed at a 400 m distance threshold (OR = 1.08; 95% CI = 1.00, 1.16 and OR = 1.08; 95% CI = 1.00, 1.18).

Table 6. Logistic regression results of the BU accessibility terms for DWA

	OR for engaging into LWA (95% CI) < AIC >			
	200 m	400 m	600 m	800 m
Restaurant	1.01 (0.94, 1.09) < 877.81 >	1.03 (0.95, 1.11) < 877.44 >	1.03 (0.95, 1.12) < 877.27 >	1.06 (0.98, 1.14) < 876 >
Shop	1.00 (0.93, 1.08) < 877.91 >	1.02 (0.94, 1.10) < 877.73 >	1.03 (0.95, 1.11) < 877.46 >	1.00 (0.93, 1.08) < 877.9 >
Service	1.03 (0.96, 1.12) < 877.22 >	1.08* (1.00, 1.16) < 874.47 >	1.03 (0.95, 1.11) < 877.41 >	1.03 (0.95, 1.11) < 877.38 >
Store	1.05 (0.97, 1.14) < 876.35 >	1.08* (1.00, 1.18) < 874.40 >	1.04 (0.96, 1.12) < 876.97 >	1.03 (0.95, 1.11) < 877.36 >
Financial	1.07 (0.99, 1.15) < 875.28 >	1.05 (0.97, 1.13) < 876.61 >	1.06 (0.98, 1.15) < 875.94 >	1.09** (1.01, 1.18) < 872.59 >
Medical	1.03 (0.95, 1.11) < 877.45 >	1.04 (0.96, 1.12) < 877.07 >	1.05 (0.97, 1.13) < 876.51 >	1.05 (0.97, 1.13) < 876.41 >
Educational	0.99 (0.92, 1.07) < 877.86 >	1.02 (0.94, 1.10) < 877.67 >	1.04 (0.96, 1.12) < 876.94 >	1.02 (0.95, 1.11) < 877.54 >
Public	1.00 (0.93, 1.09) < 877.90 >	1.04 (0.97, 1.13) < 876.76 >	0.97 (0.90, 1.05) < 877.33 >	0.95 (0.88, 1.02) < 875.90 >

*p<0.1; **p<0.05; ***p<0.01

4. DISCUSSION

For DWA, all BU accessibility terms were positively associated for almost any BU type or any distance threshold. This is probably due to the similar pattern in the distribution of different BU types. Figure 3 indicates that BUs are concentrated near the station where the center of the commerce is located. The results imply that those who had better access to that area had a higher chance of belonging to a high DWA group as their DWA was stimulated by BUs in their proximity. Although all the BU types showed significant associations, there was a difference in the association strength. Among the BU groups, the accessibility to medical BU group had the strongest association with the high DWA group of residents, followed by restaurants and shops where the smallest AIC over distance thresholds was observed. Moreover, the accessibility to these BU groups showed consistent association with high DWA group over any distance threshold. It was because these BUs are spread all over the study area as the higher value of the median can be observed even in the small distance threshold (Table 3). The phenomenon of the accessibility to the commerce leading to residents' WA was reported in numerous studies. This paper revealed that a part of the causes for the increase of WA was the increase in DWA. For the accessibility to medical BU group, it is interesting to see the strong association with high DWA group as it is not considered as the daily destinations for everybody. The result implies that the distribution of medical BU group in the area was a proxy to some other factors motivating people to walk for practical purposes.

The association between the BU accessibility terms and the high DWA group was the strongest for the distance threshold between 600 m and 800 m for most BU groups (Table 5). In this study, the distance threshold of 600 m is where those who walk for utilitarian purposes get the access to the city center. This can be assumed by the increase of OR at 600 m for "public" BUs, as the city hall where the "public" BUs are concentrated is located at the city center. These results imply that it is important that BUs at a relatively longer distance should be accessible by foot as those who walk more are influenced by the BUs at a 600–800 m distance.

For LWA, those in the high LWA group were not significantly associated with those with high BU accessibility in most of the cases. This may be because the engagement for LWA is affected by time constraint of the individuals and their preferences about a way to spend their free time. The BUs covered in this study were probably not the destination they want to have an access by foot during their free time.

5. CONCLUSION

Amid the interest to promote residents' WA, the accessibility to various BUs is considered as one of the influential factors. Although there have been many studies about the relationship between the built environment and physical activities, few studies focused on WA. Therefore, the relationship between the WA of residents and types of BU needs to be investigated. This study thus aimed to determine a relationship of residents' accessibility to different BU with their WA.

Self-reported measures of the amount of daily and leisure WA (DWA and LWA) for a week was used as data for residents' WA with the location of their residence. Residents with a certain amount or more of weekly WA were classified to high WA group for both DWA and LWA. Residents' accessibility to BU was defined by the number of BUs at a certain distance from their residence using GIS software. The association of the high walking group with the high BU accessibility group was investigated by logistic regressions.

As a result, the associations of belonging to the high DWA group and high BU accessibility group were significant for all BU groups. However, few associations of belonging to the high LWA group and high BU accessibility group were established with significance. Among the eight BU groups, the accessibility to medical group showed the strongest association with the high DWA group. In general, the accessibility to commercial BUs showed strong and consistent association with high DWA group of residents, and it bolstered the idea that the accessibility to the commerce leading to residents' WA by inducing DWA. In terms of the extent of the effect of BU, the association with high DWA group became the strongest in a relatively further distance threshold (600 m and 800 m). The results further implied that the accessibility to medical BU was proxy to assess a better walking environment around a residence. The study provided a new perspective toward the relationship of residents' WA and the built environment by noting the importance of the accessibility to BUs located at a further distance to promote the residents' DWA.

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