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Cross-sectional and prospective associations of neighborhood environmental attributes with screen time

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Cross-sectional and prospective associations of neighborhood environmental attributes with screen time

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Abstract

Objectives: This study examined cross-sectional and 2-year prospective associations of perceived and objectively-measured environmental attributes with screen time among middle-aged Japanese adults.

Design: Prospective cohort study

Setting: Nerima and Kanuma City of Japan

Participants: Data were collected from adults aged 40 to 69 years living in 2 cities of Japan in 2011 (baseline: n=1011; 55.3±8.4 years) and again in 2013 (follow-up: n=533; 52.7% of baseline sample).

Measures: The exposure variables were five GIS-based and perceived attributes of neighborhood environments (residential density, access to shops and public transport, footpaths, street connectivity), respectively. The outcome variables were baseline screen time (TV viewing time and leisure-time Internet use) and its change over two years. Multilevel generalized linear modelling was used.

Results: At baseline, mean screen time was 2.3 hour/day. There were cross-sectional associations of objective (exp(β):1.11; 95%CI: 1.01, 1.22) and perceived (1.12; 1.02, 1.23) good access to public transport, perceived good access to shop (1.18; 1.04, 1.36), and perceived good street connectivity (1.11; 1.01, 1.23) with higher time spent in screen time at baseline. On average, participants slightly decreased screen time from 2.3 to 2.2 hour/day (p=0.238) over two years. No objective and perceived environmental attributes were significantly associated with change in screen time.

Conclusions: Activity-supportive neighborhood environmental attributes appear to be related to higher level of screen time cross-sectionally. Pattern of screen time might be maintained rather changed over time under the same neighborhood environments.

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Environmental intervention for promoting physical activity may need to consider the potential negative health impact on screen time in Japan.

Key words: screen time, built environment, prospective

Strengths and limitations of this study

1. This study used both cross-sectional and prospective design to provide more confirmative evidence on this issue.
2. This study utilized both subjectively and objectively-measured environmental measures, which could better understand what specific conditions of built environment people actually live in and how people perceive and realize these specific environmental attributes could influence their time spent in screen time
3. The outcome variable, self-reported screen time, may be subject to recall bias.
4. A potential confounder - self-selection of neighborhoods was not examined in this study.

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Introduction

Sedentary behavior, defined as any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents while in a sitting or reclining posture, has been recognized a novel risk factor for health [1]. Literature has shown the deleterious associations between sitting time and all-cause mortality, cardiovascular disease, type 2 diabetes, overweight/obesity, specific types of cancer and mental health, independent of physical activity [2,3]**;**. In particular, among several domains of sedentary behavior, screen-based sedentary behavior is highly prevalent and increasing rapidly among adults partly because of easily available media-related technologies [4]**.** Research has reported screen time (TV viewing and leisure-time Internet use) is associated with negative health outcomes [5-7] and has been found to be a predominant component of leisure-time sedentary behavior in adults [8,9]. Therefore, with the increasing engagement of screen time [4,10], there is an urgent need to develop effective strategies to reduce screen time for disease and obesity prevention.

From the ecological perspective, it is crucial to better understand environmental determinants of screen time to develop population-based interventions for a long-term impact [10,11]. However, previous studies examining associations between built environment attributes and screen-based sedentary behavior are limited in several significant ways. Most of these previous studies were cross-sectional design [12-14], reporting from Australia [12,15] and the United States [13,14], as well as more focusing on only TV viewing and objectively-measured walkability [12,13,15]. These previous studies have reported that lowly walkable neighbourhood environment is associated with higher TV viewing time [12,14,15], whereas one study has found no

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associations [13]. However, it remains unclear what specific conditions of built environment people actually live in and how people perceive and realize these specific environmental attributes could influence their time spent in screen time. Thus, in order to strengthen the basis of evidence for developing environmental interventions, further studies examining longitudinal relationship between specific built perceived and objectively-measured neighborhood environment attributes and screen time in adults are needed. In particular, limited studies have focused on Asian countries, it is crucial to further examine how both perceived and objectively-measured environmental attributes are related to changes in screen time in different density, cultural and environmental contexts. These findings would be important to inform policy makers and intervention designers for developing strategies to reduce the increase in screen time through environmental approaches. Therefore, the present study examined cross-sectional and 2-years prospective associations of objective and perceived environmental attributes with screen time in middle-aged Japanese adults.

Materials and methods

Participants

The present study is a prospective cohort study with two waves of data collection: baseline in 2011 and follow-up in 2013. This study used data from a part of the Healthy Built Environment in Japan (HEBEJ) project. At baseline, a total of 3,000 residents aged 40 to 69 years and living in 2 cities in Japan (Nerima City, part of the Tokyo metropolitan area with 716,124 residents and an area of 48 km^2; Kanuma City, a regional city with 102,348 residents and an area of 491 km^2) were randomly selected from the registry of residential addresses based on gender, age group, and residential city. The baseline survey was completed by 1,076 residents (response rate:

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35.9%). Excluding the missing data, the final sample was 1011 for the cross-sectional analyses. After two year, 533 (52.7 % of the baseline respondents) completed the follow-up survey.

Outcome variable

Participants reported their time spent in the television viewing and leisure-time internet use over a usual week, respectively, which was measured at both baseline and follow-up survey using items with reasonable validity and reliability [16]. The validity and test–retest reliability of the items was both moderate [17]. The outcome variable was calculated by multiplying the number of days participants screen time (the sum of television viewing and leisure-time internet use time) by the average amount of time spent doing so per day. For cross-sectional associations, the outcome variable was baseline screen time per day. For prospective associations, the outcome variable was change of screen time per week from baseline to follow-up survey.

Exposure variables

The exposure variables of this study were five perceived and five objectively-measured environmental attributes at baseline, selected on the basis of walkability components and other environmental attributes from previous reviews [18,19]. The perceived measures included population density, sidewalk availability, access to public transportation, access to destinations and street connectivity. They were identified using the Japanese version of the IPAQ-E with a 4-point Likert scale (*strongly agree*, *somewhat agree*, *somewhat disagree*, and *strongly disagree*), which has been shown to have good reliability [20]. These five perceived environmental attributes were categorized into "agree" (*strongly agree* and *somewhat agree*) and

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"disagree" (*somewhat disagree* and *strongly disagree*). Objective environmental attributes was measured using Geographic Information Systems (GIS). The following five measures were calculated for each participant within a 800-m radius buffer of their residential address (this buffer area corresponded to a neighborhood setting, which was also used to obtain participant's perceptions): (1) population density (the number of population per square kilometer); (2) sidewalk availability (the length of roads with sidewalks (m) per square km); (3) access to public transportation (the total number of train stations and bus stops per square km); (4) access to destinations (the total number of 30 destination types including convenience store, supermarket, hardware shop, fruit store, dry cleaning store, coin laundry, clothing store, post office, library, book store, fast food store, café, bank , restaurant, video shop, video rental shop, pharmacy, drug store, the hairdresser's, park, gym, fitness club, sports facility, kindergarten, elementary school, junior high school, high school, 2-year college, 4-year college, university based on a previous study and International Physical Activity Questionnaire-Environmental Module (IPAQ-E) [20,21]; (5) street connectivity (the total number of intersections per square kilometer). These five objectively-measured environmental attributes were dichotomised using the median.

Sociodemographic variables

Data on respondents' gender (men, women), age (40–49, 50–59, or 60–69 years), current marital status (married, unmarried), educational level (less than 13 years, 13 years or more), employment status (full-time employment, not full-time employment), household income (less than 5 million yen, or 5 million yen or more), body mass index (less than 25kg/m^2, 25kg/m^2 and higher) and residential area (Nerima city and Kanuma city) were included.

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Statistical analyses

For cross-sectional associations, generalized linear modelling (GLM), specifying a gamma distribution and a log link, was utilized to examine cross-sectional associations of perceived and objectively-measured environmental attributes with screen time at baseline because the distribution of outcome variable was skewed. The covariates were adjusted for baseline demographic variables including gender, age, marital status, education attainment, household income, working status and MVPA**.** For prospective associations, GLM was also used to identify the relationships of perceived and objectively-measured environmental attributes at baseline with follow-up screen time over 2 years, adjusted for socio-demographic variables at baseline, screen time at baseline and employment status change. This approach is equivalent to modelling change in screen time and controls for regression to the mean, which has been used in previous study [15]. Residence area was utilized as the area level unit of all analysis. Results of each model are reported as antilogarithms of the regression coefficients (and their respective 95%CI). The expected proportional increase (for values > 1) or decrease (for values <1) in screen time for "environmental conditions that would support physical activity" environment (reference: "not support" category). Statistical analyses were conducted using STATA 13 (Stata Corp, College Station, Texas); the level of significance was set at $p < 0.05$.

Results

Basic characteristics of the baseline sample (n=1011) and follow-up sample (n=553) are presented in Table 1. On average, baseline screen time was 2.3 hour/day. At baseline, cross-sectional associations of objectively-measured (exp(β):1.11; 95%CI:

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1.01, 1.22) and perceived (exp(β):1.12; 95%CI: 1.02, 1.23) good access to public transport, perceived good access to shop (exp(β):1.18; 95%CI: 1.04, 1.36), and perceived good street connectivity (exp(β):1.11; 95%CI: 1.01, 1.23) with higher time spent in screen time were found. On average, participants slightly decreased screen time from 2.3 to 2.2 hour/day (p=0.238) over two years. For the prospective associations, no objectively-measured and perceived environmental attributes were significantly associated with change in screen time.

Table 1. Characteristics of baseline and follow-up respondents

	Sample for cross-sectional analyses (n=1011)	Sample for Prospective analyses (n=533)
Baseline		
Gender, % men	512(51.2)	276(51.8)
Age, mean (SD)	55.(84.3)	54.6(8.3)
Marital status, % married	844(84.3)	454(85.2)
Educational attainment, % with tertiary education	536(53.6)	308(57.8)
Household income, %		0
<¥5,000,000 p.a.	492(49.2)	244(45.8)
¥5,000,000 p.a. +	494(49.4)	283(53.1)
Refusing answer or missing	15(1.5)	6(1.1)
Work status, % non-working	743(74.2)	406(76.2)
Physical function, mean (SD)	49.9(6.1)	50(6.3)
BMI, mean (SD)	23(3.2)	22.9(3.3)
MVPA (hr/day), mean (SD)	9.3(13.4)	9.2(12.4)
Screen time (hr/day), mean (SD)	2.3(1.9)	2.3(1.9)
Follow-up		
Change in working status	-	
Keep working	-	388(72.8)
Start working	-	17(3.2)
Stop working	-	18(3.4)
No working	-	110(20.6)
Screen time (hr/day), mean (SD)	-	2.2(1.7)

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201 Table 2: Proportional change (95%CI) in screen time according to objective and perceived
202 environmental attributes at baseline (N=1011)

	Exp(B)	95%CI
Perceived		
Residential density (High)	1.02	0.93-1.13
Access to destination (Good)	1.12	1.02-1.23*
Access to public transportation (Good)	1.18	1.04-1.36*
Sidewalk (Yes)	1.06	0.97-1.17
Street connectivity (Good)	1.11	1.01-1.23*
GIS		
Residential density (High)	0.96	0.87-1.06
Access to destination (Good)	1.05	0.96-1.16
Access to public transportation (Good)	1.11	1.01-1.22*
Sidewalk (Yes)	0.99	0.91-1.10
Street connectivity (Good)	1.00	0.91-1.11

203 * $p < 0.05$

204 Generalized linear model (specifying a gamma distribution and using a log link)

205 Covariates: gender, age, marital status, education attainment, household income, employment status,
206 car ownership status, BMI and MVPA at baseline

207 Results of each model are reported as antilogarithms of the regression coefficients (and their respective
208 95%CI). The expected proportional increase (for values > 1) or decrease (for values <1) in screen time
209 for "environmental conditions that would support physical activity" (reference: "not support"
210 category).

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Table 3: Proportional change (95%CI) in screen time over 2 years according to objective and perceived environmental attributes, after adjusted for baseline leisure-time sitting for transport (N=533)

	Exp (B)	95%CI
Perceived		
Residential density (High)	1.11	0.97-1.27
Access to destination (Good)	1.00	0.88-1.14
Access to public transportation (Good)	1.08	0.89-1.3
Sidewalk (Yes)	0.99	0.87-1.12
Street connectivity (Good)	1.06	0.92-1.22
GIS		
Residential density (High)	1.05	0.92-1.2
Access to destination (Good)	1.07	0.94-1.23
Access to public transportation (Good)	1.02	0.9-1.16
Sidewalk (Yes)	1.11	0.98-1.26
Street connectivity (Good)	1.08	0.94-1.24

* $p < 0.05$

Generalized linear model (specifying a gamma distribution and using a log link)

Covariates: gender, age, marital status, education attainment, household income, BMI, leisure-time sitting for transport and MVPA at baseline, change in employment status and car ownership

Results of each model are reported as antilogarithms of the regression coefficients (and their respective 95%CI). The expected proportional increase (for values > 1) or decrease (for values <1) in screen time for "environmental conditions that would support physical activity" (reference: "not support" category)

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Discussion

To our knowledge, this is the first study to examine both cross-sectional and prospective associations between neighborhood environments and screen time using both perceived and objective measures of specific neighborhood environmental attributes among middle-aged Japanese adults in an Asian country. The results of this study support previous finding on built environment attributes of neighborhoods that are related to physical activity also may play an important role in influencing sedentary behavior independently [12,14,15,22] and further extend the results for revealing both perceived (good access to public transport, access to shop, and street connectivity) and objectively-measured (good access to public transport) physical activity-supportive environmental attributes are related to higher levels of screen time cross-sectionally. These findings would be important to inform policy makers and intervention designers that when designing environmental approach to promote physical activity, it would be crucial to consider its negative impact on screen time, at least in Japan.

Contrary to expectations, adults who live in neighborhood environment with GIS-measured good access to public transportation, and perceived good access to destinations, good access to public transportation, good street connectivity was positively associated with higher levels of screen time, which have been found to be positively related to higher levels of physical activity [18,23]. The present results were also inconsistent with previous studies which have reported the inverse associations between high walkable environment and screen-based sedentary time from Western countries [12,14,15]. Only one Belgium study reported similar result with the present study that high walkable environment is positively associated with

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total sitting time [22]. The possible speculation for these results could be that physical activity-supportive neighborhood environment (e.g. there are so many shops, train stations, and bus stops within 1.6km radius of their house) could reduce the time spent in commute and daily errand, and thus adults may have more leisure-time to engage in screen time. Although there is limited evidence in existing literature to draw the conclusion and possible mechanism regarding the inverse associations between environment and screen time, the present study may have several important implications. First of all, the perceptions of environmental attributes should be considered to be predictors of screen time for future studies. Moreover, further evidence in Asian countries using specific environmental measures are needed due to the difference in residential density, culture and built environment between Western countries and Asian country. Finally, examining the relationships among environmental factors, physical activity and sedentary behavior concurrently would be the priority to better understand the potential positive or negative health effects of environment on both physical activity and sedentary behavior for the policy initiatives.

Another novel finding is that no prospective associations of screen time over 2 years with objective and perceived environmental attributes. The possible explanation for this result could be that the follow-up duration of this study was only two years and screen time is a highly domestic behaviour for adults during leisure time, which may maintain for years unless the adjustment of home environment or the change in employment status. Therefore, the present study might provide a preliminary understanding on built environmental determinants of screen time for developing effective population-based interventions [10,11]. Therefore, to further confirm the prospective associations, studies with a longer follow-up time are needed in the future.

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This study has several limitations. First, the outcome variable - self-reported screen time may be subject to recall bias. Thus, future studies should consider measuring screen time using objectively measurement to provide more confirmative evidence. Second, a potential confounder - self-selection of neighborhoods was not examined in this study. Despite such limitations, the strengths of this study were the both cross-sectional and prospective design and the utilization of five both subjectively and objectively-measured environmental components, which could provide more confirmative evidence on this issue.

Conclusion

Activity-supportive neighborhood environmental attributes appear to be related to higher level of screen time cross-sectionally. Pattern of screen time might be maintained rather changed over time under the same neighborhood environments. Environmental intervention for promoting physical activity may need to consider the potential negative health impact of screen time in Japan.

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Declarations

Ethics approval and consent to participate

Written informed consent was obtained from all respondents. This survey received prior approval from the Institutional Ethics Committee of Waseda University.

Consent for publication

Our manuscript did not include any details, images, or videos relating to individual participants. All participants agreed with that their self-reported data will be used for publication.

Availability of data and material

This study used data from a part of the Healthy Built Environment in Japan (HEBEJ) project. Data and material is available in Lab of Behavioral Sciences (Oka Koichiro), College of Sport Sciences at Waseda University (Address: 2-579-15 Mikajima Tokorozawa, Saitama 359-1192, Japan)

Contributorship statement

1. Study concept and design: Oka, Shibata, Ishii.
2. Acquisition, analysis, or interpretation of data: Liao, Shibata
3. Drafting of the manuscript: Liao, Shibata, Koohsari.
4. Critical revision of the manuscript for important intellectual content: Oka, Shibata, Ishii, Koohsari
5. Statistical analysis: Liao, Shibata.
6. Administrative, technical, or material support: Ishii, Koohsari
7. Study supervision: Oka, Shibata.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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Cross-sectional and prospective associations of neighborhood environmental attributes with screen time in Japanese middle-aged and older adults

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Abstract

Objectives: This study examined cross-sectional and 2-year prospective associations of perceived and objectively-measured environmental attributes with screen time among middle-aged Japanese adults.

Design: Prospective cohort study

Setting: Nerima and Kanuma City of Japan

Participants: Data were collected from adults aged 40 to 69 years living in 2 cities of Japan in 2011 (baseline: n=1011; 55.3±8.4 years) and again in 2013 (follow-up: n=533; 52.7% of baseline sample).

Measures: The exposure variables were five GIS-based and perceived attributes of neighborhood environments (residential density, access to shops and public transport, footpaths, street connectivity), respectively. The outcome variables were baseline screen time (TV viewing time and leisure-time Internet use) and its change over two years. Multilevel generalized linear modelling was used.

Results: On average, participants' screen time was not statistically different over 2 years (2.3 hours/day at baseline and 2.2 hours/day at follow-up; p=0.24). There were cross-sectional associations of objective (exp(β):1.11; 95%CI: 1.01, 1.22) and perceived (1.12; 1.02, 1.23) good access to public transport, perceived good access to shop (1.18; 1.04, 1.36), and perceived good street connectivity (1.11; 1.01, 1.23) with higher time spent in screen time at baseline. No objective and perceived environmental attributes were significantly associated with change in screen time.

Conclusions: Activity-supportive neighborhood environmental attributes appear to be related to higher level of screen time cross-sectionally. Pattern of screen time might be maintained rather changed over time under the same neighborhood environments.

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Environmental intervention for promoting physical activity may need to consider the potential negative health impact on screen time in Japan.

Key words: screen time, built environment, prospective

Strengths and limitations of this study

1. This study used both cross-sectional and prospective design to provide more confirmative evidence on this issue.
2. This study utilized both subjectively and objectively-measured environmental measures, which could better understand what specific conditions of built environment people actually live in and how people perceive and realize these specific environmental attributes could influence their time spent in screen time
3. The outcome variable, self-reported screen time, may be subject to recall bias.
4. Potential confounders such as self-selection of neighborhoods and home environment were not examined in this study
5. The final sample may not be representative of the populations of Nerima City and Kanuma City.

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Introduction

Sedentary behavior, defined as any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents while in a sitting or reclining posture, has been recognized a novel risk factor for health [1]. Literature has shown the deleterious associations between sitting time and all-cause mortality, cardiovascular disease, type 2 diabetes, overweight/obesity, specific types of cancer and mental health, independent of physical activity [2,3]. In particular, among several domains of sedentary behavior, screen-based sedentary behavior is highly prevalent and increasing rapidly among adults partly because of easily available media-related technologies [4]. Research has reported screen time (TV viewing and leisure-time Internet use) is associated with negative health outcomes [5-7] and has been found to be a predominant component of leisure-time sedentary behavior in adults [8,9]. Therefore, with the increasing engagement of screen time [4,10], there is an urgent need to develop effective strategies to reduce screen time for disease and obesity prevention.

From the ecological perspective, it is crucial to better understand environmental determinants of screen time to develop population-based interventions for a long-term impact [10,11]. However, previous studies examining associations between built environment attributes and screen-based sedentary behavior are limited in several significant ways. Most of these previous studies were cross-sectional design [12-14], reporting from Australia [12,15] and the United States [13,14], as well as more focusing on only TV viewing and objectively-measured walkability [12,13,15]. These previous studies have reported that lowly walkable neighbourhood environment is associated with higher TV viewing time [12,14,15], whereas one study has found no

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associations [13]. However, it remains unclear what specific conditions of built environment people actually live in and how people perceive and realize these specific environmental attributes could influence their time spent in screen time. Thus, in order to strengthen the basis of evidence for developing environmental interventions, further studies examining longitudinal relationship between specific built perceived and objectively-measured neighborhood environment attributes and screen time in adults are needed. In particular, limited studies have focused on Asian countries, it is crucial to further examine how both perceived and objectively-measured environmental attributes are related to changes in screen time in different density, cultural and environmental contexts. These findings would be important to inform policy makers and intervention designers for developing strategies to reduce the increase in screen time through environmental approaches. Therefore, the present study examined cross-sectional and 2-years prospective associations of objective and perceived environmental attributes with screen time in middle-aged Japanese adults.

Materials and methods

Participants

The present study is a prospective cohort study with two waves of data collection: baseline in 2011 and follow-up in 2013. This study used data from a part of the Healthy Built Environment in Japan (HEBEJ) project. At baseline, a total of 3,000 residents aged 40 to 69 years and living in 2 cities in Japan (Nerima City, part of the Tokyo metropolitan area with 716,124 residents and an area of 48 km^2; Kanuma City, a regional city with 102,348 residents and an area of 491 km^2) were randomly selected from the registry of residential addresses based on gender, age group, and residential city. The baseline survey was completed by 1,076 residents (response rate:

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35.9%). Excluding the missing data, the final sample was 1,011 for the cross-sectional analyses. After two years, 533 (52.7 % of the baseline respondents) completed the follow-up survey.

Outcome variable

Participants reported their time spent in the television viewing and leisure-time internet use over a usual week (screen time). Participants were asked, "On how many days did you do the activity during leisure time in the past 7 days?" and "On average, how many minutes did you do the activity during leisure time on the days that you did it?" Using this format, we identified time spent sitting in screen time by multiplying the number of days participants watched television and used internet during leisure time by the average amount of time spent doing so per day. The scale was previously shown to have reasonable reliability and validity [16]. The test–retest reliability of the items was moderate (range 0.6–0.8) and the validity, defined as correlations with 3-day behavioral log data was also moderate (range 0.3–0.6) [17]. For cross-sectional associations, the outcome variable was baseline screen time per day. For prospective associations, the outcome variable was change of screen time per week from baseline to follow-up survey.

Exposure variables

The exposure variables of this study were five environmental attributes – population density, sidewalk availability, access to public transportation, access to destinations, and street connectivity – measured both subjectively and objectively at baseline. These domains were selected on the basis of walkability components and other environmental attributes from previous reviews [18,19]. The perceived measures were

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identified using the Japanese version of the International Physical Activity Questionnaire Environmental Module (IPAQ-E) with a 4-point Likert scale (*strongly agree*, *somewhat agree*, *somewhat disagree*, and *strongly disagree*). The scale has been shown to have good reliability [20]. Five items of IPAQ-E were included: (1) population density ("What is the main type of housing in your neighborhood?" For this question, the five options were detached single-family housing; apartments with 2–3 stories; mix of single-family housing and apartments with 2–3 stories; condos with 4–12 stories; and condos with >13 stories); (2) sidewalk availability ("There are sidewalks on most of the streets in my neighbourhood"); (3) access to public transportation ("It is less than a 10–15 min walk to a transit station from my home"); (4) access to destinations ("There are many places to go within easy walking distance of my home"); (5) street connectivity ("There are many 4-way intersections in my neighbourhood"). Population density was divided into "lower (detached single-family housing)" and "higher (others)". Other four perceived environmental attributes were categorized into "agree" (*strongly agree* and *somewhat agree*) and "disagree" (*somewhat disagree* and *strongly disagree*).

Objective environmental attributes was measured using Geographic Information Systems (GIS). The following five measures were calculated for each participant within a 800-m radius buffer of their residential address (this buffer area corresponded to a neighborhood setting, which was also used to obtain participant's perceptions): (1) population density (the number of population per square kilometer); (2) sidewalk availability (the length of roads with sidewalks (m) per square km); (3) access to public transportation (the total number of train stations and bus stops per square km); (4) access to destinations (the total number of 30 destination types

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including convenience store, supermarket, hardware shop, fruit store, dry cleaning store, coin laundry, clothing store, post office, library, book store, fast food store, café, bank, restaurant, video shop, video rental shop, pharmacy, drug store, the hairdresser's, park, gym, fitness club, sports facility, kindergarten, elementary school, junior high school, high school, 2-year college, 4-year college, university based on a previous study and IPAQ-E [20,21]; (5) street connectivity (the total number of intersections per square kilometer). These five objectively-measured environmental attributes were dichotomised using the median.

Covariates

The selection of covariates was based on previous studies [22, 23]. Data on respondents' gender (men, women), age (40–49, 50–59, or 60–69 years), current marital status (married, unmarried), educational level (less than 13 years, 13 years or more), employment status (full-time employment, not full-time employment), household income (less than 5 million yen, or 5 million yen or more), body mass index (less than 25kg/m^2, 25kg/m^2 and higher) and residential area (Nerima city and Kanuma city), physical function and moderate-to-vigorous physical activity (MVPA) were included. Physical function was measured by The Japanese version of the Medical Outcomes Study (MOS) Short Form 8-Item Health Survey (SF-8) [24]. Participants were ask "During the past 4 weeks, how much did physical health problems limit your physical activities (such as walking or climbing stairs)?". MVPA was measured by the self-administered, short Japanese version of the International Physical Activity Questionnaire (IPAQ-SV). The test-retest reliability (r = 0.72-0.93) and criterion validity (r = 0.39) of the version of the IPAQ-SV are good and acceptable, respectively [25]. The total number of minutes per week in vigorous-

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intensity physical activity, moderate-intensity physical activity, and walking was computed.

Statistical analyses

For cross-sectional associations, generalized linear modelling (GLM), specifying a gamma distribution and a log link, was utilized to examine cross-sectional associations of perceived and objectively-measured environmental attributes with screen time at baseline because the distribution of outcome variable was skewed. The covariates were adjusted for baseline demographic variables including gender, age, marital status, education attainment, household income, working status and MVPA. For prospective associations, GLM was also used to identify the relationships of perceived and objectively-measured environmental attributes at baseline with follow-up screen time over 2 years, adjusted for socio-demographic variables at baseline, screen time at baseline and employment status change. This approach is equivalent to modelling change in screen time and controls for regression to the mean, which has been used in previous study [15]. Residence area was utilized as the area level unit of all analysis. Results of each model are reported as antilogarithms of the regression coefficients (and their respective 95%CI). The expected proportional increase (for values > 1) or decrease (for values <1) in screen time for "environmental conditions that would support physical activity" environment (reference: "not support" category). For cross-sectional analysis, coefficients less than 1 denote proportionally less time spent in screen time (e.g. Exp (B)=0.95 means 5% less time), whereas coefficients more than 1 denote proportionally more time spent in screen time, relative to the reference category. (e.g. Exp (B)=1.06 means 6% more time). For prospective

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analysis, coefficients less than 1 denote proportionally decreased time spent in screen time, whereas coefficients more than 1 denote proportionally increased time spent in screen time, relative to the reference category. Statistical analyses were conducted using STATA 13 (Stata Corp, College Station, Texas); the level of significance was set at $p < 0.05$.

Results

Basic characteristics of the baseline sample (n=1011, mean age: 55.8±4.3 years) and follow-up sample (n=553, mean age: 54.6±8.3 years) are presented in Table 1. On average, participants' screen time was not statistically different over 2 years (2.3 hours/day at baseline and 2.2 hours/day at follow-up; p=0.24). Table 2 shows that at baseline, after adjusted for potential confounders (model 2), cross-sectional associations of objectively-measured (exp(β):1.11; 95%CI: 1.01, 1.22) and perceived (exp(β):1.12; 95%CI: 1.02, 1.23) good access to public transport, perceived good access to shop (exp(β):1.18; 95%CI: 1.04, 1.36), and perceived good street connectivity (exp(β):1.11; 95%CI: 1.01, 1.23) with higher time spent in screen time were found. As Table 3 shows, for the prospective associations, no objectively-measured and perceived environmental attributes were significantly associated with change in screen time.

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Table 1. Characteristics of baseline and follow-up respondents

	Sample for cross-sectional analyses (n=1011)	Sample for Prospective analyses (n=533)
Baseline		
Gender, % men	512(51.2)	276(51.8)
Age, mean (SD)	55.8(4.3)	54.6(8.3)
Marital status, % married	844(84.3)	454(85.2)
Educational attainment, % with tertiary education	536(53.6)	308(57.8)
Household income, %		
<¥5,000,000 p.a.	492(49.2)	244(45.8)
¥5,000,000 p.a. +	494(49.4)	283(53.1)
Refusing answer or missing	15(1.5)	6(1.1)
Work status, % non-working	743(74.2)	406(76.2)
BMI, mean (SD)	23(3.2)	22.9(3.3)
MVPA (hr/week), mean (SD)	9.3(13.4)	9.2(12.4)
Screen time (hr/day), mean (SD)	2.3(1.9)	2.3(1.9)
Follow-up		
Change in working status	-	
Keep working	-	388(72.8)
Start working	-	17(3.2)
Stop working	-	18(3.4)
No working	-	110(20.6)
Screen time (hr/day), mean (SD)	-	2.2(1.7)

Abbreviation: MVPA, moderate-to-vigorous physical activity; BMI, body mass index.

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Table 2: Proportional change (95%CI) in screen time according to objective and perceived environmental attributes at baseline (N=1011)

	Model 1			Model 2		
	Exp(B)	95%CI	p-value	Exp(B)	95%CI	p-value
Perceived						
Residential density (High)	1.02	0.91-1.14	0.69	1.02	0.93-1.13	0.66
Access to destination (Good)	1.10	0.99-1.22	0.06	1.12	1.02-1.23	0.02*
Access to public transportation (Good)	1.20	1.03-1.39	0.01*	1.18	1.04-1.36	0.01*
Sidewalk (Yes)	1.04	0.94-1.15	0.43	1.06	0.97-1.17	0.20
Street connectivity (Good)	1.10	0.99-1.23	0.08	1.11	1.01-1.23*	0.04*
GIS						
Residential density (High)	0.96	0.87-1.06	0.45	0.96	0.87-1.06	0.44
Access to destination (Good)	1.07	0.96-1.18	0.21	1.05	0.96-1.16	0.29
Access to public transportation (Good)	1.13	1.03-1.25	0.01*	1.11	1.01-1.22	0.03*
Sidewalk (Yes)	0.99	0.89-1.10	0.88	0.99	0.91-1.10	0.98
Street connectivity (Good)	0.97	0.88-1.08	0.60	1.00	0.91-1.11	0.95

* $p < 0.05$

Generalized linear model (specifying a gamma distribution and using a log link)

Model 1: Unadjusted model; Model 2: Adjusted for gender, age, marital status, education attainment, household income, employment status, car ownership status, BMI, physical function and MVPA at baseline

Results of each model are reported as antilogarithms of the regression coefficients (and their respective 95%CI). Coefficients less than 1 denote proportionally less time spent in screen time, whereas coefficients more than 1 denote proportionally more time spent in screen time, relative to the reference category.

Abbreviation: MVPA, moderate-to-vigorous physical activity; BMI, body mass index.

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255 Table 3: Proportional change (95%CI) in screen time over 2 years according to objective and perceived

256 environmental attributes, after adjusted for baseline leisure-time sitting for transport (N=533)

	Model 1			Model 2		
	Exp (B)	95%CI	p-value	Exp (B)	95%CI	p-value
Perceived						
Residential density (High)	1.06	1.16-1.25	0.37	1.11	0.97-1.27	0.14
Access to destination (Good)	0.96	0.84-1.10	0.54	1.00	0.88-1.14	0.97
Access to public transportation (Good)	1.06	0.87-1.29	0.54	1.08	0.89-1.30	0.46
Sidewalk (Yes)	0.96	0.84-1.09	0.50	0.99	0.87-1.12	0.84
Street connectivity (Good)	1.03	0.89-1.19	0.72	1.06	0.92-1.22	0.39
GIS						
Residential density (High)	1.01	0.88-1.14	0.94	1.05	0.92-1.20	0.47
Access to destination (Good)	1.06	0.93-1.20	0.41	1.07	0.94-1.23	0.29
Access to public transportation (Good)	1.02	0.90-1.16	0.78	1.02	0.90-1.16	0.74
Sidewalk (Yes)	1.10	0.97-1.24	0.16	1.11	0.98-1.26	0.10
Street connectivity (Good)	1.04	0.91-1.18	0.58	1.08	0.94-1.24	0.26

257 * $p < 0.05$

258 Generalized linear model (specifying a gamma distribution and using a log link)

259 Model 1: Unadjusted model; Model 2: Adjusted for gender, age, marital status, education attainment,

260 household income, BMI, physical function and MVPA at baseline, change in employment status and

261 car ownership.

262 Results of each model are reported as antilogarithms of the regression coefficients (and their respective

263 95%CI). Coefficients less than 1 denote proportionally decreased time spent in screen time, whereas

264 coefficients more than 1 denote proportionally increased time spent in screen time, relative to the

265 reference category.

266 Abbreviation: MVPA, moderate-to-vigorous physical activity; BMI, body mass index.

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Discussion

To our knowledge, this is the first study to examine both cross-sectional and prospective associations between neighborhood environments and screen time using both perceived and objective measures of specific neighborhood environmental attributes among middle-aged Japanese adults in an Asian country. The results of this study support previous finding on built environment attributes of neighborhoods that are related to physical activity also may play an important role in influencing sedentary behavior independently [12,14,15,26] and further extend the results for revealing both perceived (good access to public transport, access to shop, and street connectivity) and objectively-measured (good access to public transport) physical activity-supportive environmental attributes are related to higher levels of screen time cross-sectionally. These findings would be important to inform policy makers and intervention designers that when designing environmental approach to promote physical activity, it would be crucial to consider its negative impact on screen time, at least in Japan.

Contrary to expectations, adults who live in neighborhood environment with GIS-measured good access to public transportation, and perceived good access to destinations, good access to public transportation, good street connectivity was positively associated with higher levels of screen time, which have been found to be positively related to higher levels of physical activity [18,27]. The present results were also inconsistent with previous studies which have reported the inverse associations between high walkable environment and screen-based sedentary time from Western countries [12,14,15]. Only one Belgium study reported similar result with the present study that high walkable environment is positively associated with

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total sitting time [26]. The possible speculation for these results could be that physical activity-supportive neighborhood environment (e.g. there are so many shops, train stations, and bus stops within 1.6km radius of their house) could reduce the time spent in commute and daily errand, and thus adults may have more leisure-time to engage in screen time. Although there is limited evidence in existing literature to draw the conclusion and possible mechanism regarding the inverse associations between environment and screen time, the present study may have several important implications. First of all, the perceptions of environmental attributes should be considered to be predictors of screen time for future studies. The present results indicate that perceived environmental attributes might be better predictors of screen time than objective ones. It is possible how middle-to-older-aged adults perceive and understand their neighbourhood environment might be more important for their decision on spending time in screen time in their home. Moreover, further evidence in Asian countries using specific environmental measures are needed due to the difference in residential density, culture and built environment between Western countries and Asian country. Finally, examining the relationships among environmental factors, physical activity and sedentary behavior concurrently would be the priority to better understand the potential positive or negative health effects of environment on both physical activity and sedentary behavior for the policy initiatives.

Another novel finding is that no prospective associations of screen time over 2 years with objective and perceived environmental attributes. The possible explanation for this result could be that the follow-up duration of this study was only two years and screen time is a highly domestic behaviour for adults during leisure time, which may maintain for years unless the adjustment of home environment or the change in

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employment status. Therefore, the present study might provide a preliminary understanding on built environmental determinants of screen time for developing effective population-based interventions [10,11]. Therefore, to further confirm the prospective associations, studies with a longer follow-up time are needed in the future.

This study has several limitations. First, the outcome variable - self-reported screen time may be subject to recall bias. Thus, future studies should consider measuring screen time using objectively measurement to provide more confirmative evidence. Second, the use of the IPAQ-SV may have overestimated time spent in MVPA. Third, potential confounders such as self-selection of neighborhoods and home environment were not examined in this study. Finally, the participants who responded the follow-up survey were more likely to have higher educational levels (58.1% vs. 47.4%, p =0.002) and have higher income (53.4% vs. 43.9%, p =0.01) than those who did not. Thus, the final sample may not be representative of the populations of Nerima City and Kanuma City. Despite such limitations, the strengths of this study were the both cross-sectional and prospective design and the utilization of five both subjectively and objectively-measured environmental components, which could provide more confirmative evidence on this issue.

Conclusion

Activity-supportive neighborhood environmental attributes appear to be related to higher level of screen time cross-sectionally. Pattern of screen time might be maintained rather changed over time under the same neighborhood environments. Environmental intervention for promoting physical activity may need to consider the potential negative health impact of screen time in Japan.

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Declarations

Ethics approval and consent to participate

Written informed consent was obtained from all respondents. This survey received prior approval from the Institutional Ethics Committee of Waseda University (2010-238).

Consent for publication

Our manuscript did not include any details, images, or videos relating to individual participants. All participants agreed with that their self-reported data will be used for publication.

Availability of data and material

This study used data from a part of the Healthy Built Environment in Japan (HEBEJ) project. Data and material is available in Lab of Behavioral Sciences (Oka Koichiro), College of Sport Sciences at Waseda University (Address: 2-579-15 Mikajima Tokorozawa, Saitama 359-1192, Japan)

Contributorship statement

1. Study concept and design: Oka, Shibata, Ishii.
2. Acquisition, analysis, or interpretation of data: Liao, Shibata
3. Drafting of the manuscript: Liao, Shibata, Koohsari.
4. Critical revision of the manuscript for important intellectual content: Oka, Shibata, Ishii, Koohsari
5. Statistical analysis: Liao, Shibata.
6. Administrative, technical, or material support: Ishii, Koohsari
7. Study supervision: Oka, Shibata.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Page 1, Line 1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Page 2, Line 2, Line 36 to Page 3, Line 47
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported Page 5, Line 92-103
Objectives	3	State specific objectives, including any prespecified hypotheses Page 5, Line 103-105
Methods		
Study design	4	Present key elements of study design early in the paper Page 5, Line 109-110
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection Page 5, Line 111 to Page 6, Line 119
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Page 5, Line 111 to Page 6, Line 119 *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable Page 6, Line 121 to Page 9, Line 193
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group Page 6, Line 121 to Page 9, Line 193
Bias	9	Describe any efforts to address potential sources of bias Page 5, Line 114-116
Study size	10	Explain how the study size was arrived at Page 5, Line 116 to Page 6, line 118
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why Page 8, Line 178-183
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding

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	Page 9, Line 196 to Page 10, Line 221
	(*b*) Describe any methods used to examine subgroups and interactions
	(*c*) Explain how missing data were addressed
	(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
	(*e*) Describe any sensitivity analyses

Continued on next page

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Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed Page 10, Line 224-225
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders Page 10, Line 224-227
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time Page 10, Line 225-227
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included Page 10, Line 227-234
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses No other analyses were done
Discussion		
Key results	18	Summarise key results with reference to study objectives Page 14, Line 269-282
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Page 17, Line 323-328
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Page 14, Line 284 to Page 16, Line321
Generalisability	21	Discuss the generalisability (external validity) of the study results Page 16, Line 328-332
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based Page 17, Line 362-365

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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