2017年度 公益財団法人日本台湾交流協会フェローシップ事業成果報告書
（人文社会科学分野）

研究成果報告書

廖崑
国立台湾師範大学
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公益財団法人日本台湾交流協会

日本臺灣交流協會 招聘研究員成果報告書

很感謝日本臺灣交流協會本次提供補助，讓我能有機會前往日本早稻田大學進行為期一個月的研究活動，在這一個月中，與早稻田大學的岡 浩一朗教授、筑波大學柴田 愛准教授以及伊朗籍博士後研究員 Mohammad Javad Koohsari 進行許多的研究會議及討論，成果包括：

1. 撰寫、修正並投稿兩篇關於日本中高齡者環境與健康行為之國際期刊文章 (為本次招聘活動的主要學術成果)：

(1) **Liao Y***, Shibata A, Ishii K, Koohsari M, Oka K. Cross-sectional and prospective associations of neighborhood environmental attributes with screen time. 目前投稿於 **PLoS One [2016 Impact factor: 2.80]** (全文如附件一)

(2) **Liao Y***, Shibata A, Ishii K, Koohsari M, Inoue S, Oka K. Cross-sectional and prospective associations between neighborhood attributes with walking in Japanese middle-to-older-aged adults. 目前投稿於 **Health & Place [2016 Impact factor: 2.54]** (全文如附件二)

2. 地理資訊系統的運用

本次招聘活動的第二個目的為透過與日本當地環境研究專家的交流，將相關研究技術及主題運用於臺灣本土的研究。研究者在多次的會議討論過程中，瞭解到了客觀地理環境的測量工具，如地理資訊系統軟體、Walk score 網站等，皆是未來可應用至臺灣高齡者環境與健康行為之研究工具，期待未來能夠如同日本一樣，透過實證研究找出對於臺灣高齡者健康行為之重要環境因素。有鑑於此，研究者下一階段之研究主題將擬為—促進高齡者從事步行行為之環境策略：地理資訊系統與 Walk score 之運用。

3. 參與日本文化活動

本次招聘活動期間同時也參與了岡浩一朗教授所組之研究室的各項日本文化活動，包括夏季合宿、學術發表會以及文獻選讀分享會等。在參與過程中，研究者與日本的學部生及大學院生進行了許多互動與交流。活動席間，已開始談及並規劃未來能有機會邀請岡浩一朗教授之研究室成員來臺，與國立臺灣師範大學進行學術及文化交流；亦或，在日後將能安排國立臺灣師範大學學生訪日，至日本早稻田進行海外課程與學習。

4. 討論未來高齡者健康促進領域的重要研究方向

在本次招聘活動的最後，研究者也與岡浩一朗教授進一步的討論未來臺日高齡者健康促進領域的重要社會議題—高齡失能預防。因此，未來一年擬將針對高齡者的客觀測量之坐式行為與日常活動功能進行研究 (撰寫中主題： Associations of total amount and patterns of sedentary behavior with physical function among Japanese older adults)，以期找出高齡者日常活動功能之行為影響因子，以提供未來政策及研究參考。

最後，再次感謝日本臺灣交流協會的協助，讓我能有機會在一個月內中好好充實自己及無後顧之憂的進行研究，未來也會持續地增進日本臺灣的學術交流，並著手規劃，且盼望能有機會再度前往日本進行更長時間的學術研究活動。

附件一

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

Yung Liao [1,2§], Ai Shibata [3], Kaori Ishii [2], Mohammad Javad Koohsari [2,4,5], Koichiro Oka [2]

[1] Department of Health Promotion and Health Education, National Taiwan Normal University, 162, Heping East Road Section 1, Taipei, Taiwan. YL: liaoyung@ntnu.edu.tw

[2] Faculty of Sport Sciences, Waseda University, 2-579-15 Mikajima Tokorozawa, Saitama 359-1192, Japan. KI: ishiikaori@aoni.waseda.jp ; KO: koka@waseda.jp

[3] Faculty of Health and Sport Sciences, University of Tsukuba, 3-29-1 Otsuka Bunkyo, Tokyo 112-0012, Japan. AS: ai.o.shibata@gmail.com

[4] Institute for Health and Ageing, Australian Catholic University, Level 6, 215 Spring Street, Melbourne, VIC 3000 Australia. MJK: Javad.Koohsari@bakeridi.edu.au

[5] Behavioural Epidemiology Laboratory, Baker IDI Heart and Diabetes Institute, Level 4, 99 Commercial Rd, Melbourne, Victoria 3004, Australia

[§]Corresponding author:

Y.L., E-mail:liaoyung@ntnu.edu.tw

Tel.: +886-7734-1722;   Fax: +886-2-2363-3026

Abstract

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. 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). 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. 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. 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 on screen time in Japan.

Key words: screen time, environment, prospective

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 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: 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 “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.

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: 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)

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

* $p < 0.05$

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

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

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).

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)

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 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.

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.

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)

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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附件二

Cross-sectional and prospective associations between neighborhood attributes with walking in Japanese middle-to-older-aged adults

Abstract

Introduction. This study aimed to examine cross-sectional and prospective associations of perceived and objectively-measured neighborhood attributes with purpose-specific walking among Japanese middle-to-older-aged adults.

Methods. This study used cross-sectional and prospective data from the Healthy Built Environment in Japan (HEBEJ) project. Data were collected from adults aged 40 to 69 years living in 2 cities of Japan in 2011 (baseline: n=994; 55.3±8.4 years) and again in 2013 (follow-up: n=544; 54.7 % of baseline sample)**.** Generalized linear modelling was used to examine associations of perceived and objectively-measured built environment attributes (population density, access to destinations, access to public transportation, sidewalk, and street connectivity) with self-reported purpose-specific walking (for commuting, walking during work, for errands, for exercise).

Results. After adjusting for potential confounders, objectively-measured higher population density, better access to public transportation, better street connectivity, and perceived better access to destinations were positively associated with walking for commuting cross-sectionally and prospectively. Better perceived access to destinations was also cross-sectionally and prospectively associated with walking for daily errand.

Conclusion. Specific attributes of neighborhood built environment may be considered for promoting different purposes of walking among middle-to-older aged adults. Further researches identifying neighborhood built environmental attributes that influence walking for variety of purposes in different context of countries are warranted.

Keywords: built environment; purpose-specific walking; middle-to-older aged adults

Background

Regular physical activity is associated with lower rate of all-cause mortality, coronary heart disease, high blood pressure, stroke, type 2 diabetes, colon cancer and breast cancer in adults (World health Organization, 2010). Despite of these health benefits, a half of Japanese middle-to-older aged adults did not engage in sufficient physical activity (Bauman et al., 2009, Japan Ministry of Health Labor and Welfare, 2010)**.** Thus, it is important to develop effective strategies to promote Japanese middle-to-older aged adults to engage in sufficient physical activity because this is a life stage when people begin to experience age-related functional decline and other associated health problems (World Health Organization, 2002).

Moderate-intensity aerobic activity has been emphasized as one of recommended form of physical activity for health promotion and disease prevention (Nelson et al., 2007, Haskell et al., 2007). Walking is a low-cost and safe form of moderate-intensity aerobic physical activity behavior that do not requires specific equipment and could be engaged in daily life easily (Lee and Buchner, 2008). Moreover, walking behavior is easier to be promoted in comparison with other forms of physical activity (Wagner et al., 2001). Compared with other age groups, middle-to-older-aged adults may play different roles in society such as retirement from work and fewer childcare obligations thus may have different patterns of walking behavior (i.e. less work-related walking and more leisure-time walking) (Inoue et al., 2011). Therefore, for developing age-appropriate strategies to promote walking behavior in middle-to-older aged adults, it is critical to better understand the factors associated with purpose-specific walking behaviors.

From ecological model perspectives, walking behavior could be viewed as an interaction of environmental attributes and personal characteristics (Sallis and Owen, 2008). Compared with individual-based interventions, environmental changes are supposed to provide a long-term impact on walking behaviors of larger populations. In particular, neighborhood environment is important for middle-to-older aged adults, because they may spend more time in neighborhoods and are more likely to be influenced by the attributes of the neighborhood environment (World Health Organization, 2002). For example, middle-to-older aged adults who live in a poorly designed neighborhood environment with multiple physical environmental barriers are less likely to go out and therefore their mobility, independence and social contacts could be greatly limited (Cerin et al., 2016). Thus, a deeper understanding of associations of both built and perceived environmental factors with different purposes of walking behavior in middle-to-older aged adults is critical to develop effective environmental approaches to provide a long-term impact on variety purposes of walking behavior (Giles-Corti et al., 2005).

Several previous studies examined the associations of built or perceived environment attributes with walking for different purposes in middle-to-older adults. However, these studies are limited in several important ways. Firstly, they were mostly cross-sectional (Cerin et al., 2013a, Cerin et al., 2013b, Corseuil Giehl et al., 2016, Van Cauwenberg et al., 2013, Inoue et al., 2011), studies using prospective design are still needed to better understand which environmental attributes may support adults to maintain or increase their walking behaviors over a period of time. Secondly, most previous studies focused on either transport-related or recreational purposes (Cerin et al., 2013a, Cerin et al., 2013b, Corseuil Giehl et al., 2016, Van Cauwenberg et al., 2013), it is of value to focus on a comprehensive context of walking behavior (i.e. walking for daily errands or exercise) for designing more tailored interventions. Finally, although perceived and objective measures of the built environment were found to have distinctive effect on walking behaviours as well as a mismatch between these two types of measures (Gebel et al., 2011, Koohsari et al., 2015), most previous studies examined only perceived environmental components (Inoue et al., 2011, Corseuil Giehl et al., 2016, Van Cauwenberg et al., 2013). Addressing these limitations, the current study aims to examine cross-sectional and prospective associations of perceived and objectively-measured neighborhood environment attributes with purpose-specific walking among middle-to-older aged adults.

Methods

2.1 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 community-dwelling 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 postal survey was completed by 1,076 residents (response rate: 35.9%). Excluding the missing data on the outcome and exposure variables of baseline survey, the sample for the cross-sectional analyses consisted of 994 participants. Two years after baseline assessment, the follow-up survey collected data from 611 participants (61.4 %) who completed the follow-up survey. After data cleaning, 544 participants were included for the follow-up analyses. Written informed consent was obtained from all respondents. This survey received prior approval from the Institutional Ethics Committee of Waseda University (2010-238).

2.2 Outcome variables

The outcome variables was purpose-specific walking measured by a valid Japanese version of walking questionnaire, which has been validated (Inoue et al., 2011). The questionnaire instructed participants to report continuous walking done for 5 or more minutes. Respondents were asked about their frequency of walking (days/week) and average walking duration each day (min/day) for 4 specific purposes: (1) walking for errands, (2) walking for exercise, (3) walking for commuting, (4) walking during work. Walking time (min/week) of each purpose was calculated by multiplying the number of days by the average amount of time spent doing so per day.

Exposure variables

The exposure variables of this study were five perceived and five objectively-measured neighborhood environmental attributes, The detailed descriptions of perceived and objective neighborhood environmental measure were reported in a previous study (Liao et al., 2016). These measures were selected on the basis of walkability components and other environmental attributes from previous reviews (Brownson et al., 2009, Saelens et al., 2003). In the present study, the perceived environmental attributes included residential density, access to destinations, access to public transportation, sidewalk availability, and street connectivity, which were identified using the Japanese version of the International Physical Activity Questionnaire Environmental Module (IPAQ-E) with good reliability (Inoue et al., 2009). These five perceived environmental attributes were categorized into "agree" (*strongly agree* and *somewhat agree*) and "disagree" (*somewhat disagree* and *strongly disagree*), except for residential density. Residential density was measured by an item: "what is the main type of housing in your neighborhood?" For this question, the five response options were detached single-family housing, apartments with two to three stories, mix of single-family housing and apartments with two to three stories, apartments with four to 12 stories, and apartments with greater than or equal to 13 stories. Residential density was divided into “lower” (*detached single-family housing*) and “higher” (*other options*).

Objective environmental attributes were measured using geographic information systems software (ESRI, Redlands, CA). The following five measures were calculated for each participant within a 800-m radius (Euclidian) buffer of their geocoded residential address: (1) population density (the number of population per square kilometer); (2) 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, hairdresser, 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 (Brownson et al., 2009, Saelens et al., 2003); (3) access to public transportation (the total number of train stations and bus stops per square km); (4) sidewalk availability (the length of roads with sidewalks (km) per square km); (5) street connectivity (the total number of intersections per square kilometer). A 800-m radius buffer was selected to be consistent with previous studies examining environmental correlates of walking behavior among middle-to-older adults (Nagel et al., 2008, Troped et al., 2014). These five objectively-measured environmental attributes were dichotomized using the median in order to be consistent with the perceived measures.

Sociodemographic variables

Baseline participants were asked to report their gender, age, current marital status (married or unmarried), educational level (tertiary education, not tertiary education), working status (working, non-working), annual household income (less than 5 million yen, or 5 million yen or more), and car ownership. Follow-up participants were further asked to report their working status and car ownership again.

2.5 Statistical analyses

For cross-sectional analyses, generalized linear modelling (GLM), specifying a gamma distribution and a log link, was utilized to examine associations of perceived and objectively-measured environmental attributes with purpose-specific walking at baseline because the distribution of the outcome variable was skewed. Models adjusted for baseline sociodemographic variables. For prospective analyses, GLM was also used to identify the relationships of perceived and objectively-measured environmental attributes at baseline with follow-up purpose-specific walking, adjusting for sociodemographic variables at baseline, purpose-specific walking at baseline, employment status change, and car ownership change. This approach is equivalent to modelling change in purpose-specific walking and controls for regression to the mean, which has been used in previous studies (Ding et al., 2012, Liao et al., 2016). Results of each model are reported as antilogarithms of the regression coefficients (and their respective 95%CI). Coefficients less than 1 denote shorter purpose-specific walking for "environmental conditions that would support physical activity" (reference category: "not supporting"). Statistical analyses were conducted using STATA 13 (Stata Corp, College Station, Texas); the level of significance was set at $p < 0.05$.

3. Results

On average, 994 participants spent 54.5 (SD = 113.9) min/week of walking for commuting, 241.1 (SD = 521.2) min/week of walking during work, 45.2 (SD = 93.5) min/week of walking for daily errand; and 66.5 (SD = 132.8) min/week of walking for exercise at baseline (Table 1). For cross-sectional associations (Table 2), walking for commuting was positively associated with perceived residential density (exp(*b*), 95%CI; 1.52, 1.06-2.17), access to destinations (1.52, 1.08-2.15), and access to public transportation (1.59, 1.00-2.53) and all five GIS-measured environmental attributes (population density: 2.41, 1.68-3.48; access to destinations: 1.95, 1.38-2.76; access to public transportation:1.39, 1.00-1.94; sidewalk length: 1.56, 1.12-2.20; street connectivity: 2.37, 1.65-3.40). Furthermore, waking for daily errand was also positively associated with all five perceived environmental factors (residential density: 1.21, 1.01-1.45; access to destinations: 1.42, 1.20-1.69; access to public transportation: 1.32, 1.05-1.67; sidewalks available: 1.20, 1.02-2.41; street well-connected: 1.24, 1.03-1.48) and GIS-measured population density (1.42, 1.19-1.71), access to destinations (1.37, 1.15-1.63), street connectivity (1.37, 1.15-1.62). No significant associations were found between environmental attributes and walking for work and exercise.

At follow-up, participants (N=544) increased their time spent in walking for commuting (59.0 to 61.7 min/week) and walking during work (210.4 to 226.3 min/week), as well decreased their time spent in walking for exercise (70.1 to 63.3 min/week) and walking for daily errand (43.4 to 38.6 min/week). For prospective associations (Table 3), after adjusted for baseline value, perceived better access to destinations (1.62, 1.10-2.37), GIS-measured higher population density (2.14, 1.46-3.16), better access to public transportation (1.78, 1.25-2.54), and better street connectivity (1.52, 1.02-2.27) were associated with increased time spent in walking for commuting. Besides, perceived better access to destination is associated with increased time spent in walking for daily errand (1.43, 1.12-1.82), as well as GIS-measured higher population density (1.37, 1.00-1.88) and better street connectivity (1.40, 1.02-1.92) were related to increased time spent in walking for exercise. On the other hand, perceived sidewalk available and good GIS-measured better access to destinations had 25% (95%CI: 0.57-0.98) and 27% lower (0.55-0.97) time spent in walking during work at follow-up than the counterpart.

4. Discussion

In this cohort of Japanese middle-to-older aged adults, both common and different neighborhood environmental attributes were found to be associated with purpose-specific walking between cross-sectional and prospective analyses. One perceived (good access to destinations) and three objectively-assessed environmental attributes (i.e., higher population density, good access to public transportation, well-connected streets) were associated with walking for commuting both cross-sectionally and prospectively. In addition, the perceptions of better access to destinations were associated with walking for errands both cross-sectionally and prospectively. These results may imply that it is important to promote walking for commuting by improving the access to public transportation, and increasing street connectivity, as well as increasing awareness of access to destinations could promote both walking for commuting and daily errand. For developing age-appropriate strategies to promote different purposes of walking behavior in middle-to-older aged adults, these remarkable findings could contribute to the evidence on the both cross-sectional and prospective associations of perceived and objectively-derived environmental attributes with purpose-specific walking in a non-Western country.

For the cross-sectional associations, perceived and objectively-measured environmental attributes were only found to be associated with walking for commuting and daily errand, but not in walking during work and walking for exercise. Consistent with previous studies (Koohsari et al., 2014, Sugiyama et al., 2012, Brownson et al., 2009, Saelens et al., 2003), both actual and perceived higher-density neighborhood with better access to utilitarian destinations (e.g., local shops, services, and public transit), availability of sidewalks and well-connected streets can facilitate utilitarian walking such as walking for commuting or daily errand. On the other hand, the possible explanations that no perceived or objectively-measured environmental factors were found to be cross-sectionally associated with walking during work or walking for exercise could be most work-related walking may not occur in neighborhoods, as well as for the components of walkability examined in the present study might be more relevant to transport-related walking than leisure-time walking.

Some environmental attributes were found to be associated with purpose-specific walking in cross-sectional analyses but not in prospective analyses, namely perceived residential density, perceived access to public transportation, perceived street connectivity, and objectively-measured street connectivity. On the contrary, objectively-measured higher population density and better street connectivity were associated prospectively with increased time spent in walking for exercise, although no cross-sectional associations were found. Furthermore, objectively-measured better access to destinations, and perceived sidewalk presence were negatively related to work-related walking. Although the possible reasons for these inconsistency between cross-sectional and prospective analyses remain unclear, these findings may support a previous study (Sugiyama et al., 2015) and imply that some perceived and objective-measured environmental correlates of walking identified in the cross-sectional studies may not certainly support adults to maintain or increase walking behaviors over a period of time. Thus, it is suggested that further studies using both cross-sectional and prospective design examining the associations between environment and purpose-specific walking to confirm the present results are warranted.

This study has some limitations. First, we used self-reported purpose-specific walking, which may be subject to recall bias. However, purpose-specific walking is considered reasonably to be collected by self-report (Hajna et al., 2015). Second, a potential confounder - self-selection (people's preference to live in walking-friendly neighborhoods) was not examined in this study. Finally, all streets including those inaccessible for pedestrians were included in this study, and only one buffer size was employed to aggregate each street layout measure. Future studies can use 'pedestrian network' and a variety of buffer sizes in calculating the street network measures.

5. Conclusion

Specific attributes of neighborhood built environment may be considered for promoting different specific purposes of walking among middle-to-older aged adults. Further research identifying neighborhood built environmental attributes that influence walking for variety of purposes in different context of countries are warranted.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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Table 1 Characteristics of baseline and follow-up respondents

	Sample for cross-sectional analyses (n=994)	Sample for Prospective analyses (n=544)
Baseline		
Gender, % men	552 (52.5%)	291 (53.5%)
Age, mean (SD)	55.3 (8.4)	54.5 (8.3)
Marital status, % married	846 (85.1%)	471 (86.6%)
Educational attainment, % with tertiary education	532 (53.5%)	316 (58.1%)
Household income, % ¥5,000,000 p.a. +	506 (50.9%)	306 (56.3%)
Work status, % non-working	252 (25.4%)	126 (23.2%)
Walking for commuting (min/wk), mean (SD)	54.5 (113.9)	61.6 (121.9)
Walking during work (min/wk), mean (SD)	241.1 (521.2)	226.3 (505.9)
Walking for daily errand (min/wk), mean (SD)	45.2 (93.5)	38.6 (65.2)
Walking for exercise (min/wk), mean (SD)	66.5 (132.8)	63.3 (124.5)
Follow-up		
Change in working status	-	
Keep working	-	395 (72.6)
Start working	-	14 (2.6)
Stop working	-	23 (4.2)
Keep no working	-	112 (20.6)
Change in car ownership	-	2.2 (1.7)
No owning car		44 (8.1)
Stop owning car		26 (4.8)
Start owning car		18 (3.3)
Keep owning car		456 (83.8)

Abbreviations: p.a.: per annum.

Table 2: Proportional change (95%CI) in walking for purposes according to objective and perceived environmental attributes (N=994)

	Purpose-specific walking							
	For commuting		During work		For errands		For exercise	
	Exp(b)	95%CI	Exp(b)	95%CI	Exp(b)	95%CI	Exp(b)	95%CI
Perceived attributes								
Higher residential density (reference: lower)	1.52	1.06-2.17*	1.14	0.91-1.45	1.21	1.01-1.45*	1.01	0.83-1.22
Better access to destinations (reference: disagree)	1.52	1.08-2.15*	1.00	0.81-1.24	1.42	1.20-1.69**	1.12	0.94-1.35
Better access to public transportation (reference: disagree)	1.59	1.00-2.53*	0.92	0.69-1.23	1.32	1.05-1.67*	1.27	0.99-1.61
Sidewalks available (reference: disagree)	1.35	0.99-1.84	0.96	0.79-1.18	1.20	1.02-1.41*	1.06	0.89-1.25
Streets well connected (reference: disagree)	1.11	0.77-1.60	0.86	0.69-1.08	1.24	1.03-1.48*	1.20	0.99-1.45
Objectively-assessed attributes								
Higher population density (reference: lower)	2.41	1.68-3.48**	1.04	0.83-1.30	1.42	1.19-1.71**	1.00	0.83-1.20
Better access to destinations (reference: poorer access)	1.95	1.38-2.76**	0.90	0.73-1.12	1.37	1.15-1.63**	1.09	0.91-1.31
Better access to public transportation (reference: poorer access)	1.39	1.00-1.94*	0.87	0.70-1.08	1.13	0.96-1.33	0.99	0.83-1.18
Longer sidewalk length (reference: shorter)	1.56	1.12-2.20*	0.94	0.76-1.17	1.09	0.92-1.29	1.10	0.92-1.31
Better street connectivity (reference: less connected)	2.37	1.65-3.40**	0.91	0.73-1.14	1.37	1.15-1.62*	0.92	0.77-1.11

* $p < 0.05$ ** $p < 0.001$

Generalized linear model (specifying a gamma distribution and using a log link)
Covariates: gender, age, marital status, education attainment, household income, working status, and car ownership status at baseline

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 walking for purposes for “better” environment (reference: “poor” category)

Table 3: Proportional change (95%CI) in walking for purposes over 2 years according to objective and perceived environmental attributes (N=544)

	Purpose-specific walking							
	For commuting		During work		For errands		For exercise	
	Exp(b)	95%CI	Exp(b)	95%CI	Exp(b)	95%CI	Exp(b)	95%CI
Perceived attributes								
Higher residential density (reference: lower)	1.34	0.89-2.02	1.16	0.85-1.59	1.01	0.78-1.30	1.09	0.79-1.50
Better access to destinations (reference: disagree)	1.62	1.10-2.37*	0.85	0.64-1.12	1.43	1.12-1.82*	1.05	0.77-1.41
Better access to public transportation (reference: disagree)	1.29	0.77-2.15	1.23	0.83-1.82	1.27	0.90-1.77	0.89	0.58-1.36
Sidewalks available (reference: disagree)	0.87	0.61-1.24	0.75	0.57-0.99*	1.16	0.92-1.45	0.91	0.69-1.20
Streets well connected (reference: disagree)	1.24	0.83-1.85	0.96	0.71-1.29	1.18	0.91-1.53	1.16	0.84-1.60
Objectively-assessed attributes								
Higher population density (reference: lower)	2.14	1.46-3.16**	1.03	0.76-1.38	1.23	0.96-1.58	1.37	1.00-1.88*
Better access to destinations (reference: poorer access)	1.16	0.78-1.72	0.73	0.55-0.97*	1.29	0.96-1.56	1.08	0.80-1.47
Better access to public transportation (reference: poorer access)	1.78	1.25-2.54*	0.87	0.66-1.15	1.16	0.92-1.47	0.96	0.72-1.28
Longer sidewalk length (reference: shorter)	1.37	0.94-1.99	0.79	0.60-1.05	1.20	0.94-1.52	1.05	0.79-1.41
Better street connectivity (reference: less connected)	1.52	1.02-2.27*	0.95	0.71-1.28	1.15	0.90-1.48	1.40	1.02-1.92*

* $p < 0.05$ ** $p < 0.001$

Generalized linear model (specifying a gamma distribution and using a log link)
Covariates: gender, age, marital status, education attainment, household income, walking for each purposes at baseline, change in working 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 walking for purposes for “better” environment (reference: “poor” category)