



The association between objective measures of residence and worksite neighborhood environment, and self-reported leisure-time physical activities: The Aichi Workers' Cohort Study

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ARTICLE INFO

Keywords:

Geographic information system
Built environment
Residence
Worksite
Neighborhood
Physical activity
Cross-sectional study

ABSTRACT

The possible effects of a neighborhood's built environment on physical activity have not been studied in Asian countries as much as in Western countries. The present study cross-sectionally examined the relationship between geographic information system (GIS) measured residence and worksite neighborhood walkability, and the number of parks/green spaces and sports facilities within a 1 km radius of home and workplace, with self-reported leisure-time habitual (3–4 times per week or more) walking and moderate-to-vigorous intensity habitual exercise among local government workers aged 18 to 64 years living in an urban-suburban area of Aichi, Japan in 2013. A single-level binomial regression model was used to estimate the multivariable odds ratios (ORs) and 95% confidence intervals (95% CIs). Of the 1959 male and 884 female participants, 288 (15%) and 141 (16%) reported habitual walking, respectively, and 18% and 17% reported habitual exercise, respectively. Compared with women who resided in neighborhood with a walkability index of 4–30, those living in an area with that of 35–40 were significantly more likely to engage in leisure-time habitual exercise (multivariable OR: 1.70, 95% CI: 1.08–2.68). Marginally significant positive associations were found between leisure-time habitual exercise and the residential neighborhood's number of parks/green spaces among women, as well as the number of sports facilities among men. In conclusion, a residential neighborhood environment characterized by higher walkability may contribute to the initiation or maintenance of moderate-to-vigorous intensity leisure-time exercise among working women living in an urban-suburban area of Japan.

1. Introduction

Promoting physical activity is a public health priority worldwide, with major implications for the prevention of non-communicable diseases of populations (Kohl et al., 2012). There is growing interest in intervening environmental factors to promote physical activity within communities (Bauman et al., 2012), whereby studies conducted primarily in Western countries have indicated possible positive effects of neighborhood environment on physical activity (Astell-Burt et al., 2014; Kaczynski et al., 2008a, 2008b; Karusisi et al., 2013; Owen et al.,

2007; Sallis et al., 2016; Sugiyama et al., 2014; Sundquist et al., 2011). For example, a multi-country study found that geographic information system (GIS) measures, such as the net residential density and the number of parks, were positively associated with the total amount of moderate-to-vigorous physical activity in adults living in urban cities (Sallis et al., 2016). Given that environment features, and social cultures and norms differ substantially between continents, the findings derived from Western countries are not necessarily applicable to Asian countries. To date, a limited number of studies have been carried out in Asian countries utilizing objectively measured environment

Abbreviations: CIs, confidence intervals; GIS, geographic information system; ORs, odds ratios; NLNI, National Land Numerical Information

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<https://doi.org/10.1016/j.pmedr.2018.07.007>

Received 13 March 2018; Received in revised form 17 July 2018; Accepted 21 July 2018

Available online 24 July 2018

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information (Hanibuchi et al., 2015b; Kondo et al., 2009; Koohsari et al., 2017; Lee et al., 2011; Ying et al., 2015). In addition, the majority of previous studies in Japan have been conducted on the inhabitants of small cities (Kondo et al., 2009; Lee et al., 2011), especially in rural areas (Eshak et al., 2017), which are defined by administrative borders that do not necessarily reflect residential functions.

Thus, we conducted the present study by enrolling workers who resided in areas with geographical and functional variability, including multiple municipalities and a metropolitan area that consisted of functionally-interrelated urban and suburban areas. The study participants were civil servants of a local government aged 18 to 64 years; therefore, their limited socio-economic status variability provided the unique opportunity to study behaviors relating to their neighborhood-specific geographical information. Furthermore, several potential confounding variables, including past medical history and body mass index, were obtained and could be included in the analyses, which is not always the case in studies of geographical characteristics and health. Finally, in previous studies, the features of worksite neighborhood built environments were not weighted as highly as those of residential neighborhood built environments (Adlakha et al., 2015), despite the fact that individuals, especially those of working age, are away from home approximately one-third of the day.

In the present study we examined the association between GIS-measures of residence and worksite neighborhood environmental features and the frequency of self-reported leisure-time physical activities in middle-aged local government workers without a history of major chronic diseases. Analyses were conducted separately for men and women, as the environment may influence lifestyle differently based on gender (Hanibuchi et al., 2015a).

2. Methods

2.1. Subjects and study location

The Aichi Workers' Cohort Study, initiated in 1997, is an ongoing epidemiologic study on non-communicable diseases, including diabetes and cardiovascular disease (Muramatsu et al., 2010; Toyoshima et al., 2009). The subjects are local government workers in a central part of Japan. The area (called Aichi prefecture) includes both urban areas and their rural surrounds. The capital city of the prefecture is Nagoya, which is the fourth-largest metropolitan city by population in Japan. A self-reported questionnaire on leisure-time physical activity and other lifestyles, and medical history was distributed to subjects at their worksite in 2013. Of the total 5630 subjects (3889 men and 1741 women) who responded to the survey, 4592 subjects (3212 men and 1380 women) provided their residential address and were successfully geocoded. The proportion of female workers stands at 30% in the present study, this is slightly lower than the national average of 38% in statistics (Gender Equality Bureau Cabinet Office, 2013). As geocoding accuracy may differ between urban and rural areas (Faure et al., 2017), the present study included only those living in the Nagoya metropolitan area. This area consisted of Nagoya city and the surrounding 30 municipalities (i.e., the urban-suburban area defined by the Urban Employment Area (Kanemoto and Tokuoaka, 2002) and comprised 3077 subjects. Based on the 2010 Japanese Census, the studied area covered approximately 4.8 million people with a density of 3226 people/km². We further excluded 154 subjects with self-reported histories of cancer or cardiovascular disease, and 77 subjects with missing values for the selected confounding variables leaving 2843 subjects (1959 men and 884 women) in the analysis; subjects whose worksites were located in rural areas (non-Urban Employment Area) (17%) were not excluded. The study protocol was approved by the Ethics Review Committee of Nagoya University School of Medicine, Nagoya, Japan and Fujita Health University.

Table 1

Subject characteristics, Aichi Workers' Cohort, 2013.

	Men	Women
Number of subjects	1959	884
Age, mean (standard deviation)	43.9 (10.2)	39.2 (10.6)
Leisure-time habitual walking ^a (%)	15	16
Leisure-time habitual exercise ^a (%)	18	17
Neighborhood		
Walkability, median (range)	33 (9–40)	33 (12–40)
Numbers of parks or green space, median (range)	5 (0–22)	6 (0–21)
Numbers of sports facilities, median (range)	2 (0–33)	2 (0–23)
Worksite		
Walkability, median (range)	23 (5–39)	26 (11–39)
Numbers of parks or green spaces, median (range)	4 (0–18)	3 (0–18)
Numbers of sports facilities, median (range)	7 (0–31)	3 (0–31)
Central headquarter (%)	45.4	25.0
Office workers (vs. professional workers) (%)	58.6	41.6
Educational attainment (≥ 16 years) (%)	86.2	56.6
Married (%)	74.9	54.4
History of hypertension (%)	9.4	2.2
History of diabetes (%)	1.8	0.6
Depression (CES-D ≥ 9) (%)	22.7	31.3
Eating breakfast every day (%)	77.6	71.0
Body mass index (%)		
< 21 (kg/m ²)	24.1	56.7
21– < 25 (kg/m ²)	54.9	35.2
≥ 25 (kg/m ²)	21.0	8.1
Smoking status (%)		
Never	58.7	92.4
Former	24.1	4.8
Current	17.2	2.8
Alcohol drinking habits (%)		
Never	12.9	25.6
Former	1.1	2.0
Current	86.0	72.4
Sleeping hours (%)		
< 6	11.2	17.5
6– < 7	51.9	50.2
≥ 7	36.9	32.2

^a Habitual walking was defined as walking 3–4 times or more per week during leisure-time; habitual exercise was defined as brisk walking, or moderate-or-vigorous physical activity 3–4 or more times per week during leisure-time.

2.2. Definition of the environmental indices

We used three environmental indices: one composite variable of neighborhood walkability, and two physical activity-specific environmental features including availability of parks/green spaces and sports facilities. The details of the walkability index in Japan have been described elsewhere (Hanibuchi et al., 2015b). Briefly, the walkability index consists of population density, road density, access to parks, and access to retail areas. As an objective unit of neighborhood, we employed *chocho-aza*, the smallest administrative unit. All of our data were based on National Land Numerical Information (NLNI), the Japanese population census (Statistics Bureau, 2010), and the retail area data by Zenrin Co. Ltd. as of 2011. The availability of parks/green spaces and sports facilities was measured as the number of respective facilities within 1 km of the individual's residence based on the street network (i.e., the network buffer) using ArcGIS. Data on parks/green spaces were also obtained from NLNI. The locations of public or commercial sports/recreational facilities, such as sports centers, gyms, or fitness facilities (hereafter referred to as sports facilities) were based on point data from the Yellow Pages telephone directory of businesses.

2.3. Definition of leisure-time walking and exercise habits

The participants were asked to estimate their average frequency and duration of four levels of leisure-time physical activities throughout the past year. Namely, the four levels were 1) walk/stroll (walking), 2) brisk walking, 3) moderate-intensity physical activity such as golf,

Table 2
Odds ratios for habitual walking^a according to tertiles of residential neighborhood built environment indices, Aichi Workers' Cohort, 2013.

	No. of subjects	No. of cases (%)	Age-adjusted OR (95% CI)	P	Multivariable OR1 ^b (95% CI)	P	Multivariable OR2 ^b (95% CI)	P
Men								
Walkability								
9–29	624	95 (15)	1		1		1	
30–34	648	94 (15)	0.97 (0.71–1.32)	0.85	0.98 (0.72–1.33)	0.89	0.98 (0.72–1.33)	0.89
35–40	687	99 (14)	0.94 (0.69–1.28)	0.69	0.94 (0.69–1.29)	0.72	0.94 (0.69–1.28)	0.71
Number of parks or green space within a 1 km network buffer								
0–3	670	101 (15)	1		1		1	
4–7	1042	157 (15)	1.01 (0.75–1.37)	0.93	1.02 (0.75–1.38)	0.91	1.03 (0.76–1.40)	0.86
8–22	247	32 (13)	0.82 (0.60–1.11)	0.19	0.83 (0.61–1.12)	0.23	0.83 (0.61–1.13)	0.24
Number of sports facilities within a 1 km network buffer								
0–1	684	102 (15)	1		1		1	
2–3	196	29 (15)	1.00 (0.74–1.36)	1.00	1.03 (0.75–1.40)	0.87	1.03 (0.75–1.41)	0.85
4–33	1079	159 (15)	1.08 (0.80–1.45)	0.61	1.10 (0.82–1.48)	0.53	1.11 (0.82–1.49)	0.51
Women								
Walkability								
12–30	279	52 (19)	1		1		1	
31–34	276	40 (14)	0.74 (0.47–1.17)	0.20	0.74 (0.47–1.17)	0.20	0.73 (0.46–1.16)	0.18
35–40	329	49 (15)	0.76 (0.50–1.17)	0.21	0.79 (0.51–1.22)	0.28	0.75 (0.48–1.16)	0.19
Number of parks or green space within a 1 km network buffer								
0–3	288	44 (15)	1		1		1	
4–7	201	43 (21)	0.95 (0.59–1.51)	0.82	0.97 (0.60–1.57)	0.90	0.95 (0.59–1.53)	0.83
8–21	395	54 (14)	1.26 (0.81–1.96)	0.30	1.38 (0.88–2.16)	0.16	1.39 (0.89–2.19)	0.15
Number of sports facilities within a 1 km network buffer								
0–1	368	65 (18)	1		1		1	
2–3	196	29 (15)	1.03 (0.65–1.63)	0.91	1.08 (0.67–1.73)	0.75	1.07 (0.67–1.72)	0.77
4–23	320	47 (15)	1.11 (0.73–1.68)	0.64	1.21 (0.79–1.87)	0.39	1.20 (0.78–1.86)	0.41

^a Habitual walking was defined by participation in walking 3–4 times or more per week during leisure-time.

^b Multivariable model 1 is adjusted for age (continuous), educational attainment (< 16, ≥ 16 years), marital status (married, other), location of the office (central, local), office worker (yes, no), body mass index (< 21, 21– < 25, or ≥ 25 kg/m²), smoking status (never, former, or current), alcohol drinking habits (never, former, or current), sleeping hours (< 6, 6– < 7, or ≥ 7), eating breakfast every day (yes, no), depression (yes, no), and history of hypertension or diabetes (yes, no). Multivariable model 2 was further adjusted for respective worksite environmental indices (e.g., in the analysis of residential neighborhood walkability, worksite walkability was adjusted).

“gate ball”, a Japanese game similar to croquet, or gardening; 4) vigorous-intensity physical activity such as tennis, jogging, aerobics dancing or swimming.

The frequency for the four levels of physical activities was self-reported on five scales: almost none, 1–3 times/month, 1–2 times/week, 3–4 times/week, and almost every day. Bout-duration of each physical activity was assessed on six scales: < 30 min, 30–59 min, 1– < 2 h, 2– < 3 h, 3– < 4 h, and > 4 h. Those who responded that they engaged in walking 3–4 or more times per week during leisure-time were defined as having habitual walking regardless of the duration. Habitual exercise was defined as the habit of conducting any one of the following physical activities 3–4 or more times per week during leisure-time regardless of the duration: brisk walking, moderate- and vigorous-intensity physical activity.

2.4. Statistical analysis

To assess the fit of our data to a two-level cross-classified multilevel model, intra-class correlation coefficients (ICCs) were calculated by setting municipalities (city/ward/town/village) of residence and the worksite at level-2 as a random effect in the unconditional model. As the total variation in either habitual walking or habitual exercise accounted for by municipalities was small (all ICCs < 0.001), a single-level binomial regression model for residences and worksites was used to examine the age- and multivariable-adjusted associations between environmental indices and habitual walking and exercise. Subjects were grouped into sex-specific tertiles using the subsequently described cutoff values for each environmental index with the lowest tertile as the

reference. Residence neighborhood walkability index: 4–29 (reference), 30–34, or 35–40 for men, and 4–30 (reference), 31–34, or 35–40 for women; the number of parks/green spaces within a 1 kilometer network buffer of the respondents' home: 0–3 (reference), 4–7, or 8–22 for men, and 0–3 (reference), 4–7, or 8–21 for women; the number of sports facilities within a 1 kilometer network buffer of the respondents' home: 0–1 (reference), 2–3, or 4–33 for men, and 0–1 (reference), 2–3, or 4–23 for women. The respective cutoff values for the worksite environmental indices were as follows, walkability: 4–22 (reference), 23–27, or 28–39 for men, and 12–22 (reference), 23–28, or 29–39 for women; the number of parks/green spaces: 0–3 (reference), 4, or 5–8 for men, and 0–2 (reference), 3, or 4–7 for women; the number of sports facilities: 0–3 (reference), 4–6, or 7–10 for men, and 0–1 (reference), 2–6, or 7–8 for women.

We constructed three models, the first was a continuous age-adjusted model. Multivariable model 1 also adjusted for educational attainment (< 12, ≥ 12 years), marital status (yes, no), office work (yes, no), location of the office (central headquarters, local branch), body mass index (< 21, 21– < 25, or ≥ 25 kg/m²), smoking status (never, former, or current), alcohol drinking habits (never, former, or current), sleeping hours (< 6, 6– < 7, or ≥ 7 h), and history of hypertension or diabetes (yes, no). Model 2 also adjusted for the respective worksite environmental indices (e.g., in the analysis of residential neighborhood walkability, worksite walkability was mutually adjusted). Additional analyses were done by redefining habitual walkers or exercisers to include only subjects who conducted walking or exercise at least 30 min per bout, respectively. P value < 0.05 and < 0.10 (two-tailed) were considered to be statistically significant and marginally significant,

Table 3
Odds ratios for habitual exercise^a according to tertiles of residential neighborhood built environment indices, Aichi Workers' Cohort, 2013.

	No. of subjects	No. of cases (%)	Age-adjusted OR (95% CI)	P	Multivariable OR1 ^b (95% CI)	P	Multivariable OR2 ^b (95% CI)	P
Men								
Walkability								
9–29	624	104 (17)	1		1		1	
30–34	648	121 (19)	1.15 (0.86–1.53)	0.35	1.12 (0.84–1.50)	0.43	1.12 (0.84–1.50)	0.43
35–40	687	126 (18)	1.12 (0.84–1.49)	0.43	1.11 (0.83–1.48)	0.49	1.10 (0.83–1.47)	0.50
Number of parks or green spaces within a 1 km network buffer								
0–3	670	125 (19)	1		1		1	
4–7	1042	181 (17)	1.28 (0.96–1.71)	0.10	1.25 (0.93–1.68)	0.13	1.25 (0.93–1.68)	0.13
8–22	247	45 (18)	1.23 (0.93–1.63)	0.14	1.25 (0.94–1.66)	0.12	1.24 (0.93–1.65)	0.14
Number of sports facilities within a 1 km network buffer								
0–1	684	126 (18)	1		1		1	
2–3	196	38 (19)	0.90 (0.67–1.21)	0.48	0.88 (0.65–1.18)	0.39	0.88 (0.65–1.18)	0.38
4–33	1079	187 (17)	1.28 (0.98–1.67)	0.07	1.30 (0.99–1.70)	0.06	1.29 (0.98–1.69)	0.07
Women								
Walkability								
12–30	279	36 (13)	1		1		1	
31–34	276	49 (18)	1.47 (0.92–2.35)	0.11	1.48 (0.92–2.39)	0.11	1.47 (0.91–2.37)	0.12
35–40	329	64 (19)	1.63 (1.04–2.54)	0.03	1.69 (1.07–2.67)	0.02	1.70 (1.08–2.68)	0.02
Number of parks or green spaces within a 1 km network buffer								
0–3	288	54 (19)	1		1		1	
4–7	201	26 (13)	1.18 (0.74–1.87)	0.49	1.24 (0.77–1.99)	0.37	1.27 (0.79–2.04)	0.33
8–21	395	69 (17)	1.45 (0.94–2.26)	0.10	1.47 (0.93–2.31)	0.10	1.48 (0.94–2.33)	0.09
Number of sports facilities within a 1 km network buffer								
0–1	368	50 (14)	1		1		1	
2–3	196	42 (21)	1.30 (0.84–2.02)	0.24	1.28 (0.81–2.01)	0.29	1.26 (0.80–1.98)	0.32
4–23	320	57 (18)	1.10 (0.73–1.68)	0.65	1.08 (0.70–1.67)	0.72	1.05 (0.68–1.62)	0.83

^a Habitual exercise was defined by participation in brisk walking, moderate-or-vigorous physical activity 3–4 or more times per week during leisure-time.

^b Multivariable model 1 is adjusted for age (continuous), educational attainment (< 16, ≥ 16 years), marital status (married, other), location of the office (central, local), office worker (yes, no), body mass index (< 21, 21– < 25, or ≥ 25 kg/m²), smoking status (never, former, or current), alcohol drinking habits (never, former, or current), sleeping hours (< 6, 6– < 7, or ≥ 7), eating breakfast every day (yes, no), depression (yes, no), and history of hypertension or diabetes (yes, no). Multivariable model 2 is further adjusted for respective worksite environmental indices (e.g., in the analysis of residential neighborhood walkability, worksite walkability was adjusted).

respectively, in the current study.

3. Results

The mean (standard deviation) age of subjects was 43.9 (10.2) and 39.2 (10.6) years for men and women, respectively. The proportion of habitual walking was 15% in men and 16% in women, while the values for habitual exercise were 18% and 17%, respectively (Table 1). There were subjects (4.4% of men and 4.3% of women) who were classified as both habitual walkers and habitual exercisers: The actual compositions of habitual exercise were brisk walking (62%), moderate-intensity (17%) and vigorous-intensity physical activity (28%) in men, and 69%, 11% and 27% in women, separately (data not shown in table).

No association was found between residential neighborhood environmental features and habitual walking (Table 2). Compared to women who resided in neighborhoods with walkability scores < 30, those living in neighborhoods with a walkability index of 35–40 were significantly more likely to engage in habitual exercise (multivariable OR: 1.70, 95% CI: 1.08–2.68). Men living in neighborhoods with four or more sports facilities tended to have exercise habits we defined as habitual compared with those living in neighborhoods with zero to three sports facilities (OR: 1.29, 95% CI: 0.98–1.69). Similarly, women living in neighborhoods with eight or more parks/green spaces were more likely to have exercise habits than those living in neighborhoods with zero to three parks/green spaces (OR: 1.48, 95% CI: 0.94–2.33) (Table 3). Worksite neighborhood environment features were not associated with either habitual walking (Table 4) or exercise (Table 5) during leisure-time.

4. Discussion

We found that neighborhood walkability was positively related to having a habit of exercise in middle-aged working women in an urban-suburban area of Japan. This is the first report to examine walkability in a sample of workers whose residential location is more geographically dispersed than those in community-based samples. The present study is also unique in terms of the urban-suburban setting, as epidemiologic studies are often conducted in rural settings in Japan (Eshak et al., 2017; Soma et al., 2017). One previous study in Japan did not find any significant associations between residential neighborhood GIS-measured walkability and leisure-time physical activity (walking and exercise combined) in women, but identified a marginal relationship in men (Hanibuchi et al., 2015b). However, this previous study did report a positive association between perceived walkability and leisure-time physical activity in women, consistent with the present study findings. Nevertheless, the reasons accounting for the discrepancies in the associations that were found when GIS walkability was applied are unknown. Such discrepancies may be due to the nation-wide community-based sample used in the earlier study, compared to the sample of workers in urban-suburban settings used in the present study. Specifically, the discrepancies in the findings could be related to the smaller confounding effect associated with socio-economic status in the present study (Murakami et al., 2011). Also, geocoding accuracy is reportedly favorable in urban versus rural areas for capturing environment characteristics (Faure et al., 2017). Moreover, we also distinguished exercise from walking in the present study. Our finding that there was a positive association between walkability and habitual exercise in women was in

Table 4
Odds ratios for habitual walking^a according to tertiles of worksite neighborhood built environment indices, Aichi Workers' Cohort, 2013.

	No. of subjects	No. of cases (%)	Age-adjusted OR (95% CI)	P	Multivariable OR1 ^b (95% CI)	P	Multivariable OR2 ^b (95% CI)	P
Men								
Walkability								
5–22	221	32 (14)	1		1		1	
23–27	1096	173 (16)	1.12 (0.74–1.68)	0.60	1.17 (0.69–1.99)	0.55	1.17 (0.69–1.99)	0.56
28–39	642	85 (13)	0.91 (0.59–1.41)	0.67	0.89 (0.57–1.40)	0.62	0.89 (0.57–1.40)	0.62
Number of parks or green spaces within a 1 km network buffer								
0–3	670	101 (15)	1		1		1	
4	1042	157 (15)	0.84 (0.55–1.30)	0.44	0.84 (0.54–1.30)	0.44	0.98 (0.73–1.32)	0.89
5–8	247	32 (13)	1.01 (0.77–1.32)	0.97	0.98 (0.73–1.32)	0.89	0.85 (0.55–1.31)	0.45
Number of sports facilities within a 1 km network buffer								
0–3	684	102 (15)	1		1		1	
4–6	196	29 (15)	0.99 (0.76–1.30)	0.94	0.96 (0.71–1.31)	0.80	1.00 (0.63–1.57)	0.99
7–10	1079	159 (15)	0.99 (0.63–1.54)	0.95	1.00 (0.63–1.57)	0.99	0.96 (0.70–1.31)	0.79
Women								
Walkability								
13–22	197	29 (15)	1		1		1	
23–28	381	52 (14)	0.89 (0.55–1.47)	0.65	1.30 (0.72–2.35)	0.38	1.26 (0.70–2.28)	0.44
29–39	306	60 (20)	1.38 (0.85–2.25)	0.20	1.44 (0.87–2.39)	0.15	1.47 (0.88–2.43)	0.14
Number of parks or green spaces within a 1 km network buffer								
0–2	288	44 (15)	1		1		1	
3	201	43 (21)	1.47 (0.91–2.37)	0.11	1.47 (0.90–2.41)	0.12	1.48 (0.90–2.42)	0.12
4–7	395	54 (14)	0.87 (0.56–1.34)	0.53	0.87 (0.54–1.42)	0.58	0.88 (0.54–1.43)	0.60
Number of sports facilities within a 1 km network buffer								
0–1	368	65 (18)	1		1		1	
2–6	196	29 (15)	0.81 (0.54–1.22)	0.31	0.90 (0.51–1.59)	0.70	0.89 (0.51–1.54)	0.67
7–8	320	47 (15)	0.82 (0.51–1.32)	0.41	0.90 (0.52–1.56)	0.72	0.89 (0.50–1.56)	0.67

^a Habitual walking was defined by participation in walking 3–4 times or more per week during leisure-time.

^b Multivariable model 1 is adjusted for age (continuous), educational attainment (< 16, ≥ 16 years), marital status (married, other), office worker (yes, no), body mass index (< 21, 21– < 25, or ≥ 25 kg/m²), smoking status (never, former, or current), alcohol drinking habits (never, former, or current), sleeping hours (< 6, 6– < 7, or ≥ 7), eating breakfast every day (yes, no), depression (yes, no), and history of hypertension or diabetes (yes, no). Multivariable model 2 is further adjusted for respective residence environmental indices (e.g., in the analysis of worksite neighborhood walkability, residence walkability was adjusted).

line with findings from Western countries where objectively measured walkability were associated with objectively measured moderate-to-vigorous physical activity (Sallis et al., 2009; Sundquist et al., 2011; Van Dyck et al., 2010). An additional analysis taking exercise duration (i.e., 30 min or more per bout) (Ministry of Health, Labour and Welfare, 2013) into consideration revealed that high walkability was still significantly associated with habitual exercise in women (OR: 1.67, 95% CI: 1.00–2.78). Several features of walkability have emerged to be related to physical activity in previous reports. One multi-country study of urban cities in America, Europe, Oceania, and Hong Kong reported that GIS-measured net residential density and the number of parks were linked to moderate-to-vigorous physical activity in adults (Sallis et al., 2016). The present findings showed a significant association only for women, thus we can speculate that residential neighborhood walkability may be an important determinant of initiating or maintaining exercise in middle-aged Japanese women working for a local government. Although it remains unclear whether the participants exercised indoors or outside, we do know they engaged in exercise. According to a nation-wide survey (Sasakawa Sports Foundation, 2012), the variation of venues for leisure-time physical activity among working men were wider than their female counterpart. Venues for exercise among women were more likely to be limited to road, park, gym, dance studio and training room, home or courtyard. Therefore walkability might be related to the ease of accessing places for exercise by walking or using transportation more in women. Indeed, one study in an urban Japanese city reported that a greater land use diversity was positively related to cycling time for transportation, in women only (Kondo et al., 2009). Furthermore, GIS-measured neighborhood land use diversity was positively associated with leisure-time walking, only in women, in a

different urban Japanese city (Lee et al., 2011).

Although we did not observe any association in the present study, the potential effect of parks or open spaces on physical activity has been widely studied (Floyd et al., 2008; Joseph and Maddock, 2016) especially among adolescent or older adults in the United States (Bancroft et al., 2015). Most of the existing studies focused on park-based physical activity, and examined it according to features, proximity, and perceived accessibility of park (Brown et al., 2014; Brownson et al., 2009; Costigan et al., 2017; Evenson et al., 2016; Kaczynski et al., 2014; Koohsari et al., 2013; Schipperijna et al., 2013; Troped et al., 2010). Therefore, the association between objectively measured density of parks and green spaces within home neighborhood and physical activity remains to be elucidated.

The number of parks in multiple-countries study (Sallis et al., 2016) or sports facilities in Sweden (Eriksson et al., 2012) within 1-km buffer of residence was associated with daily amount of moderate-to-vigorous physical activity in adults. The percentage of green space within 1-km (or 1-mile) buffer of residence was associated with moderate-to-vigorous physical activity performed that is at least once a week in Australia (Astell-Burt et al., 2014), meeting physical activity recommendations for older adults aged 50–75 years (Li et al., 2008), and self-reported moderate-to-vigorous physical activity in the United States (Coutts et al., 2013). However, no relationship was found in Dutch or Danish people (Maas et al., 2008; Schipperijna et al., 2013).

We observed a marginally significant association between habitual exercise and the number of sports facilities in men, and the number of parks/green spaces in women. The weak associations found in the present study may be due to the relatively high socioeconomic background of the civil servants who might be less dependent on spatial

Table 5
Odds ratios for habitual exercise^a according to tertiles of worksite workplace built environment indices, Aichi Workers' Cohort, 2013.

	No. of subjects	No. of cases (%)	Age-adjusted OR (95% CI)	P	Multivariable OR1 ^b (95% CI)	P	Multivariable OR2 ^b (95% CI)	P
Men								
Walkability								
5–22	221	49 (22)	1		1		1	
23–27	1096	176 (16)	0.67 (0.47–0.96)	0.03	0.75 (0.47–1.22)	0.25	0.75 (0.47–1.22)	0.25
28–39	642	126 (20)	0.85 (0.59–1.24)	0.40	0.84 (0.57–1.22)	0.36	0.84 (0.57–1.22)	0.35
Number of parks or green spaces within a 1 km network buffer								
0–3	670	125 (19)	1		1		1	
4	1042	181 (17)	0.91 (0.71–1.18)	0.48	0.96 (0.73–1.26)	0.75	0.95 (0.72–1.25)	0.72
5–8	247	45 (18)	0.97 (0.66–1.41)	0.87	0.97 (0.66–1.42)	0.87	0.95 (0.65–1.40)	0.81
Number of sports facilities within a 1 km network buffer								
0–3	684	126 (18)	1		1		1	
4–6	196	38 (19)	1.07 (0.71–1.60)	0.75	1.12 (0.75–1.69)	0.58	1.11 (0.74–1.67)	0.63
7–10	1079	187 (17)	0.93 (0.72–1.19)	0.55	0.99 (0.75–1.32)	0.97	0.99 (0.75–1.32)	0.96
Women								
Walkability								
13–22	197	35 (18)	1		1		1	
23–28	381	63 (17)	0.88 (0.55–1.39)	0.57	0.66 (0.37–1.20)	0.18	0.69 (0.38–1.26)	0.22
29–39	306	51 (17)	0.89 (0.55–1.43)	0.62	0.81 (0.49–1.32)	0.39	0.78 (0.47–1.28)	0.33
Number of parks or green spaces within a 1 km network buffer								
0–2	288	54 (19)	1		1		1	
3	201	26 (13)	0.59 (0.35–0.98)	0.04	0.65 (0.38–1.11)	0.12	0.65 (0.38–1.11)	0.11
4–7	395	69 (17)	0.89 (0.60–1.32)	0.55	0.75 (0.48–1.17)	0.21	0.75 (0.48–1.17)	0.21
Number of sports facilities within a 1 km network buffer								
0–1	368	50 (14)	1		1		1	
2–6	196	42 (21)	1.78 (1.13–2.80)	0.01	1.12 (0.75–1.69)	0.58	1.54 (0.91–2.59)	0.11
7–8	320	57 (18)	1.41 (0.93–2.13)	0.11	0.99 (0.75–1.32)	0.97	1.26 (0.72–2.19)	0.42

^a Habitual exercise was defined by participation in brisk walking, or moderate-or-vigorous physical activity 3–4 times or more per week during leisure-time.

^b Multivariable model 1 is adjusted for age (continuous), educational attainment (< 16, ≥ 16 years), marital status (married, other), office worker (yes, no), body mass index (< 21, 21– < 25, or ≥ 25 kg/m²), smoking status (never, former, or current), alcohol drinking habits (never, former, or current), sleeping hours (< 6, 6– < 7, or ≥ 7), eating breakfast every day (yes, no), depression (yes, no), and history of hypertension or diabetes (yes, no). Multivariable model 2 is further adjusted for respective residence environmental indices (e.g., in the analysis of worksite neighborhood walkability, residence walkability was adjusted).

accessibility to perform particular sports or exercise activities (Karusisi et al., 2013). Alternatively, the average level of car ownership in the area of the present study was 1.30 cars per household, 21% more compared to the national average of 1.07 (Wikipedia contributors, 2017), which warrants further studies accounting for driving status (Karusisi et al., 2013). Also, Japan has one of the largest number of bicycles per capita in the world (Steele, 2018), and the estimated ownership rate in Central Japan where Aichi prefecture is located (1.39 bikes per household) is even higher than the national average of 1.35 (Japan Bicycle Promotion Institute, 2014).

Our findings indicate gender differences in the associations (Annerstedt et al., 2012). Reportedly, intensive physical activities are likely to be performed at gym, health club and home in adults (Azevedo et al., 2007), which may partly explain the marginally significant association for the number of sports facilities with exercise habits in men in this study. Also, marginally significant association between park and exercise in women in the present study would partly be supported by a previous study that reported parks and parkland in living environment was more strongly associated with exercise among women than men (Kaczynski et al., 2008b).

The lack of association found between walkability and leisure-time walking habits is in agreement with one previous Australian study (Owen et al., 2007), but contrary to most of results found in Western countries (Sallis et al., 2009; Sundquist et al., 2011; Van Dyck et al., 2010). It may partly be related to our non-inclusion of walking from home to work, which could be influenced by geographical characteristics of the residential as well as work neighborhood. Further study should be conducted on this issue. As some features of walkability, like GIS-measured land use diversity, street connectivity, proximity of

parkland, have also been associated with walking for leisure (Lee et al., 2011) or the number of walking steps (Ying et al., 2015) in Asian studies, further investigation is still needed to explore whether factors other than walkability index would be related to leisure-time walking in Asian context.

The fact that walking for leisure was not associated with the availability of parks/green spaces in the present study was partly supported by one previous study where GIS-measured accessibility to public open space was not associated with recreational walking (Sugiyama et al., 2014), but contrary to the finding that people living in a neighborhood with more green space were more likely to walk (Astell-Burt et al., 2014). Thus, it may not be the number of parks or green spaces nearby, but their qualities such as size (Christian et al., 2017; Giles-Corti et al., 2005a), aesthetics (Sugiyama et al., 2014), walking infrastructure (Kaczynski et al., 2008a), or even the neighborhood pedestrian environments used to get there (Koohsari et al., 2013; Sugiyama et al., 2014) that may actually be the determinants for walking. Further studies, including qualitative evaluations, are needed to obtain more specific and detailed information about exercise promoting neighborhoods.

We did not find an association between the environmental features of the worksite neighborhood and leisure-time walking or exercise, which is inconsistent with a previous study conducted in a metropolitan city in the United States (Barrington et al., 2015). That study found that a physical activity supportive worksite neighborhood built environment was associated with 10 min or more walking per day, but not with moderate-to-vigorous physical activity during leisure-time. The lack of association in the current study might be due to the fact that approximately 40% of the subjects worked at the central headquarter office.

This may have reduced variability in the environmental features of the worksite neighborhood. Moreover, failure to find an association may be due to lack of time for exercise in the typical workday. Future studies should consider the amount of time spent at work and worksite policies that support physical activity (Dodson et al., 2016; Lillehoj et al., 2016).

The strengths of the current study include the use of GIS-measures of both residence and worksite environmental characteristics, the urban-suburban setting, and the utilization of workers with the same employer, which could minimize the confounding of socioeconomic status. In addition, we assessed walking and moderate-to-vigorous physical activity for leisure separately.

There are some limitations that warrant consideration. First, although validation of questionnaire has been proved to be good (Inoue et al., 2008), we lack detailed information regarding type and location of physical activities. Also, physical activity was self-reported only once without considering seasonal variation (Shephard, 2003), both of which would be related to non-differential misclassification that could attenuate or mask the true relationship (Giles-Corti et al., 2005b). Also, this makes it difficult to make causal inferences, even though the cross-sectional design of the present study precludes determination of any causality; utilization of interventional studies would be ideal. In addition, environmental context such as safety was not considered in the current study. Although there are geographic variations in the crime rate, it is generally low in Japan (Police Policy Research Center, 2012), and was reported to be a weak factor to characterize physical environmental (Humpel et al., 2002). Finally, the present study subjects were exclusively civil servants, thus the generalizability of the present findings to other populations may be limited.

5. Conclusion

Residential neighborhood walkability was associated with habitual exercise that consists of brisk walking or moderate-to-vigorous-intensity physical activity in working women living in urban-suburban areas of Japan, independent of individual characteristics. Further studies are needed to examine whether walkability is causally related to exercise habits.

Conflict of interest

The authors declare no conflicts of interest.

Acknowledgements

The authors thank the participants and the healthcare personnel of the local government office. This work was supported in part by MEXT/JSPS KAKENHI (Grant Numbers 13470087 and 17390185 to H.T., 17790384, 22390133, 23659346, 26293153, and 18H03057 to H.Y., 16590499, 18590594, 20590641, 23590787, and 15K08802 to K.T., and 25893088 and 16K19278 to Y. L.), Health and Labor Sciences research grants for Comprehensive Research on Cardiovascular and Life-Style Related Diseases: H26-Junkankitou [Seisaku]-Ippan-001 and H29-Junkankitou [Seishuu]-Ippan-003 from the Ministry of Health, Labour and Welfare, and research grants from the Japan Atherosclerosis Prevention Fund (to H.Y.), the Aichi Health Promotion Foundation (to H.Y.), and the Uehara Memorial Foundation (to H.Y.).

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