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BMJ Open

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

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3 **1 Cross-sectional and prospective associations of neighborhood environmental**
4 **2 attributes with screen time**
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Abstract

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

26 **Design:** Prospective cohort study

27 **Setting:** Nerima and Kanuma City of Japan

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

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

36 **Results:** At baseline, mean screen time was 2.3 hour/day. There were cross-sectional
37 associations of objective ($\exp(\beta)$):1.11; 95%CI: 1.01, 1.22) and perceived (1.12; 1.02,
38 1.23) good access to public transport, perceived good access to shop (1.18; 1.04, 1.36),
39 and perceived good street connectivity (1.11; 1.01, 1.23) with higher time spent in
40 screen time at baseline. On average, participants slightly decreased screen time from
41 2.3 to 2.2 hour/day ($p=0.238$) over two years. No objective and perceived
42 environmental attributes were significantly associated with change in screen time.

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

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3 46 Environmental intervention for promoting physical activity may need to consider the
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5 47 potential negative health impact on screen time in Japan.
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10 49 **Key words: screen time, built environment, prospective**
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15 16 17 52 **Strengths and limitations of this study**

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20 53 1. This study used both cross-sectional and prospective design to provide more
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22 54 confirmative evidence on this issue.
23
24 55 2. This study utilized both subjectively and objectively-measured environmental
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26 56 measures, which could better understand what specific conditions of built
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28 57 environment people actually live in and how people perceive and realize these
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30 58 specific environmental attributes could influence their time spent in screen time
31
32
33 59 3. The outcome variable, self-reported screen time, may be subject to recall bias.
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35 60 4. A potential confounder - self-selection of neighborhoods was not examined in this
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37 61 study.
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65 Introduction

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

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

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3 90 associations [13]. However, it remains unclear what specific conditions of built
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5 91 environment people actually live in and how people perceive and realize these
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7 92 specific environmental attributes could influence their time spent in screen time. Thus,
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10 93 in order to strengthen the basis of evidence for developing environmental
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12 94 interventions, further studies examining longitudinal relationship between specific
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14 95 built perceived and objectively-measured neighborhood environment attributes and
15
16 96 screen time in adults are needed. In particular, limited studies have focused on Asian
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18 97 countries, it is crucial to further examine how both perceived and objectively-
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20 98 measured environmental attributes are related to changes in screen time in different
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22 99 density, cultural and environmental contexts. These findings would be important to
23
24 100 inform policy makers and intervention designers for developing strategies to reduce
25
26 101 the increase in screen time through environmental approaches. Therefore, the present
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28 102 study examined cross-sectional and 2-years prospective associations of objective and
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30 103 perceived environmental attributes with screen time in middle-aged Japanese adults.
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36 105 **Materials and methods**

37 38 39 106 **Participants**

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42 107 The present study is a prospective cohort study with two waves of data collection:
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44 108 baseline in 2011 and follow-up in 2013. This study used data from a part of the
45
46 109 Healthy Built Environment in Japan (HEBEJ) project. At baseline, a total of 3,000
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48 110 residents aged 40 to 69 years and living in 2 cities in Japan (Nerima City, part of the
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50 111 Tokyo metropolitan area with 716,124 residents and an area of 48 km²; Kanuma City,
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52 112 a regional city with 102,348 residents and an area of 491 km²) were randomly
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54 113 selected from the registry of residential addresses based on gender, age group, and
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56 114 residential city. The baseline survey was completed by 1,076 residents (response rate:
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3 115 35.9%). Excluding the missing data, the final sample was 1011 for the cross-sectional
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5 116 analyses. After two year, 533 (52.7 % of the baseline respondents) completed the
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7 117 follow-up survey.
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119 **Outcome variable**

120 Participants reported their time spent in the television viewing and leisure-time
121 internet use over a usual week, respectively, which was measured at both baseline and
122 follow-up survey using items with reasonable validity and reliability [16]. The
123 validity and test–retest reliability of the items was both moderate [17]. The outcome
124 variable was calculated by multiplying the number of days participants screen time
125 (the sum of television viewing and leisure-time internet use time) by the average
126 amount of time spent doing so per day. For cross-sectional associations, the outcome
127 variable was baseline screen time per day. For prospective associations, the outcome
128 variable was change of screen time per week from baseline to follow-up survey.
129

130 **Exposure variables**

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

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3 140 “disagree” (*somewhat disagree* and *strongly disagree*). Objective environmental
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5 141 attributes was measured using Geographic Information Systems (GIS). The following
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7 142 five measures were calculated for each participant within a 800-m radius buffer of
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9 143 their residential address (this buffer area corresponded to a neighborhood setting,
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11 144 which was also used to obtain participant’s perceptions): (1) population density (the
12
13 145 number of population per square kilometer); (2) sidewalk availability (the length of
14
15 146 roads with sidewalks (m) per square km); (3) access to public transportation (the total
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17 147 number of train stations and bus stops per square km); (4) access to destinations (the
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19 148 total number of 30 destination types including convenience store, supermarket,
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21 149 hardware shop, fruit store, dry cleaning store, coin laundry, clothing store, post office,
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23 150 library, book store, fast food store, café, bank, restaurant, video shop, video rental
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25 151 shop, pharmacy, drug store, the hairdresser’s, park, gym, fitness club, sports facility,
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27 152 kindergarten, elementary school, junior high school, high school, 2-year college, 4-
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29 153 year college, university based on a previous study and International Physical Activity
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31 154 Questionnaire-Environmental Module (IPAQ-E) [20,21]; (5) street connectivity (the
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33 155 total number of intersections per square kilometer). These five objectively-measured
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35 156 environmental attributes were dichotomised using the median.
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158 **Sociodemographic variables**

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45 159 Data on respondents’ gender (men, women), age (40–49, 50–59, or 60–69 years),
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47 160 current marital status (married, unmarried), educational level (less than 13 years, 13
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49 161 years or more), employment status (full-time employment, not full-time employment),
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51 162 household income (less than 5 million yen, or 5 million yen or more), body mass
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53 163 index (less than 25kg/m², 25kg/m² and higher) and residential area (Nerima city and
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55 164 Kanuma city) were included.
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5 166 **Statistical analyses**

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8 167 For cross-sectional associations, generalized linear modelling (GLM), specifying a
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10 168 gamma distribution and a log link, was utilized to examine cross-sectional
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12 169 associations of perceived and objectively-measured environmental attributes with
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14 170 screen time at baseline because the distribution of outcome variable was skewed. The
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16 171 covariates were adjusted for baseline demographic variables including gender, age,
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18 172 marital status, education attainment, household income, working status and MVPA.
19
20 173 For prospective associations, GLM was also used to identify the relationships of
21
22 174 perceived and objectively-measured environmental attributes at baseline with follow-
23
24 175 up screen time over 2 years, adjusted for socio-demographic variables at baseline,
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26 176 screen time at baseline and employment status change. This approach is equivalent to
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28 177 modelling change in screen time and controls for regression to the mean, which has
29
30 178 been used in previous study [15]. Residence area was utilized as the area level unit of
31
32 179 all analysis. Results of each model are reported as antilogarithms of the regression
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34 180 coefficients (and their respective 95%CI). The expected proportional increase (for
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36 181 values > 1) or decrease (for values <1) in screen time for “environmental conditions
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38 182 that would support physical activity” environment (reference: “not support” category).
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40 183 Statistical analyses were conducted using STATA 13 (Stata Corp, College Station,
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42 184 Texas); the level of significance was set at $p < 0.05$.

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49 186 **Results**

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52 187 Basic characteristics of the baseline sample (n=1011) and follow-up sample
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54 188 (n=553) are presented in Table 1. On average, baseline screen time was 2.3 hour/day.
55
56 189 At baseline, cross-sectional associations of objectively-measured ($\exp(\beta)$:1.11; 95%CI:

190 1.01, 1.22) and perceived (exp(β):1.12; 95%CI: 1.02, 1.23) good access to public
 191 transport, perceived good access to shop (exp(β):1.18; 95%CI: 1.04, 1.36), and
 192 perceived good street connectivity (exp(β):1.11; 95%CI: 1.01, 1.23) with higher time
 193 spent in screen time were found. On average, participants slightly decreased screen
 194 time from 2.3 to 2.2 hour/day (p=0.238) over two years. For the prospective
 195 associations, no objectively-measured and perceived environmental attributes were
 196 significantly associated with change in screen time.

197
 198 **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).

211
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213 Table 3: Proportional change (95%CI) in screen time over 2 years according to objective and perceived
 214 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 |

215 * p < 0.05

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

217 Covariates: gender, age, marital status, education attainment, household income, BMI, leisure-time

218 sitting for transport and MVPA at baseline, change in employment status and car ownership

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

220 95%CI). The expected proportional increase (for values > 1) or decrease (for values <1) in screen time

221 for “environmental conditions that would support physical activity” (reference: “not support” category)

222

223 Discussion

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

238
239 Contrary to expectations, adults who live in neighborhood environment with GIS-
240 measured good access to public transportation, and perceived good access to
241 destinations, good access to public transportation, good street connectivity was
242 positively associated with higher levels of screen time, which have been found to be
243 positively related to higher levels of physical activity [18,23]. The present results
244 were also inconsistent with previous studies which have reported the inverse
245 associations between high walkable environment and screen-based sedentary time
246 from Western countries [12,14,15]. Only one Belgium study reported similar result
247 with the present study that high walkable environment is positively associated with

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3 248 total sitting time [22]. The possible speculation for these results could be that physical
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5 249 activity-supportive neighborhood environment (e.g. there are so many shops, train
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7 250 stations, and bus stops within 1.6km radius of their house) could reduce the time spent
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10 251 in commute and daily errand, and thus adults may have more leisure-time to engage in
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12 252 screen time. Although there is limited evidence in existing literature to draw the
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14 253 conclusion and possible mechanism regarding the inverse associations between
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16 254 environment and screen time, the present study may have several important
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18 255 implications. First of all, the perceptions of environmental attributes should be
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20 256 considered to be predictors of screen time for future studies. Moreover, further
21
22 257 evidence in Asian countries using specific environmental measures are needed due to
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24 258 the difference in residential density, culture and built environment between Western
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26 259 countries and Asian country. Finally, examining the relationships among
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28 260 environmental factors, physical activity and sedentary behavior concurrently would be
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30 261 the priority to better understand the potential positive or negative health effects of
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32 262 environment on both physical activity and sedentary behavior for the policy initiatives.
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36 264 Another novel finding is that no prospective associations of screen time over 2 years
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38 265 with objective and perceived environmental attributes. The possible explanation for
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40 266 this result could be that the follow-up duration of this study was only two years and
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42 267 screen time is a highly domestic behaviour for adults during leisure time, which may
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44 268 maintain for years unless the adjustment of home environment or the change in
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46 269 employment status. Therefore, the present study might provide a preliminary
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48 270 understanding on built environmental determinants of screen time for developing
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50 271 effective population-based interventions [10,11]. Therefore, to further confirm the
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52 272 prospective associations, studies with a longer follow-up time are needed in the future.
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5 274 This study has several limitations. First, the outcome variable - self-reported screen
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7 275 time may be subject to recall bias. Thus, future studies should consider measuring
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9 276 screen time using objectively measurement to provide more confirmative evidence.
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11 277 Second, a potential confounder - self-selection of neighborhoods was not examined in
12
13 278 this study. Despite such limitations, the strengths of this study were the both cross-
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15 279 sectional and prospective design and the utilization of five both subjectively and
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17 280 objectively-measured environmental components, which could provide more
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19 281 confirmative evidence on this issue.
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25 283 **Conclusion**

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28 284 Activity-supportive neighborhood environmental attributes appear to be related to
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30 285 higher level of screen time cross-sectionally. Pattern of screen time might be
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32 286 maintained rather changed over time under the same neighborhood environments.
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34 287 Environmental intervention for promoting physical activity may need to consider the
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36 288 potential negative health impact of screen time in Japan.
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3 291 **Declarations**
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6 292 **Ethics approval and consent to participate**
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9 293 Written informed consent was obtained from all respondents. This survey received prior approval from
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11 294 the Institutional Ethics Committee of Waseda University.

12
13 295 **Consent for publication**
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15 296 Our manuscript did not include any details, images, or videos relating to individual participants. All
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17 297 participants agreed with that their self-reported data will be used for publication.

18
19 298 **Availability of data and material**
20

21 299 This study used data from a part of the Healthy Built Environment in Japan (HEBEJ) project. Data and
22
23 300 material is available in Lab of Behavioral Sciences (Oka Koichiro), College of Sport Sciences at
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25 301 Waseda University (Address: 2-579-15 Mikajima Tokorozawa, Saitama 359-1192, Japan)

26
27 302 **Contributorship statement**
28

- 29 303 1. Study concept and design: Oka, Shibata, Ishii.
30 304 2. Acquisition, analysis, or interpretation of data: Liao, Shibata
31 305 3. Drafting of the manuscript: Liao, Shibata, Koohsari.
32
33 306 4. Critical revision of the manuscript for important intellectual content: Oka, Shibata, Ishii, Koohsari
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35 307 5. Statistical analysis: Liao, Shibata.
36
37 308 6. Administrative, technical, or material support: Ishii, Koohsari
38
39 309 7. Study supervision: Oka, Shibata.

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48
49 314 **Conflict of Interest Statement**
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51 315 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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1 **Cross-sectional and prospective associations of neighborhood environmental**
2 **attributes with screen time in Japanese middle-aged and older adults**

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22

Abstract

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

26 **Design:** Prospective cohort study

27 **Setting:** Nerima and Kanuma City of Japan

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

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

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

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

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3 46 Environmental intervention for promoting physical activity may need to consider the
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5 47 potential negative health impact on screen time in Japan.
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9 49 **Key words: screen time, built environment, prospective**
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16 52 **Strengths and limitations of this study**
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19 53 1. This study used both cross-sectional and prospective design to provide more
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21 54 confirmative evidence on this issue.
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23 55 2. This study utilized both subjectively and objectively-measured environmental
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25 56 measures, which could better understand what specific conditions of built
26
27 57 environment people actually live in and how people perceive and realize these
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29 58 specific environmental attributes could influence their time spent in screen time
30
31 59 3. The outcome variable, self-reported screen time, may be subject to recall bias.
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33 60 4. Potential confounders such as self-selection of neighborhoods and home
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35 61 environment were not examined in this study
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37 62 5. The final sample may not be representative of the populations of Nerima City and
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39 63 Kanuma City.
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67 **Introduction**

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

82
83 From the ecological perspective, it is crucial to better understand environmental
84 determinants of screen time to develop population-based interventions for a long-term
85 impact [10,11]. However, previous studies examining associations between built
86 environment attributes and screen-based sedentary behavior are limited in several
87 significant ways. Most of these previous studies were cross-sectional design [12-14],
88 reporting from Australia [12,15] and the United States [13,14], as well as more
89 focusing on only TV viewing and objectively-measured walkability [12,13,15]. These
90 previous studies have reported that lowly walkable neighbourhood environment is
91 associated with higher TV viewing time [12,14,15], whereas one study has found no

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3 92 associations [13]. However, it remains unclear what specific conditions of built
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5 93 environment people actually live in and how people perceive and realize these
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7 94 specific environmental attributes could influence their time spent in screen time. Thus,
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9 95 in order to strengthen the basis of evidence for developing environmental
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11 96 interventions, further studies examining longitudinal relationship between specific
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13 97 built perceived and objectively-measured neighborhood environment attributes and
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15 98 screen time in adults are needed. In particular, limited studies have focused on Asian
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17 99 countries, it is crucial to further examine how both perceived and objectively-
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20 100 measured environmental attributes are related to changes in screen time in different
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22 101 density, cultural and environmental contexts. These findings would be important to
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24 102 inform policy makers and intervention designers for developing strategies to reduce
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26 103 the increase in screen time through environmental approaches. Therefore, the present
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28 104 study examined cross-sectional and 2-years prospective associations of objective and
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31 105 perceived environmental attributes with screen time in middle-aged Japanese adults.
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35 107 **Materials and methods**

36 37 38 108 **Participants**

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41 109 The present study is a prospective cohort study with two waves of data collection:
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43 110 baseline in 2011 and follow-up in 2013. This study used data from a part of the
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45 111 Healthy Built Environment in Japan (HEBEJ) project. At baseline, a total of 3,000
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47 112 residents aged 40 to 69 years and living in 2 cities in Japan (Nerima City, part of the
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49 113 Tokyo metropolitan area with 716,124 residents and an area of 48 km²; Kanuma City,
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51 114 a regional city with 102,348 residents and an area of 491 km²) were randomly
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54 115 selected from the registry of residential addresses based on gender, age group, and
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56 116 residential city. The baseline survey was completed by 1,076 residents (response rate:
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3 117 35.9%). Excluding the missing data, the final sample was 1,011 for the cross-sectional
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5 118 analyses. After two years, 533 (52.7 % of the baseline respondents) completed the
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7 119 follow-up survey.
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121 **Outcome variable**

122 Participants reported their time spent in the television viewing and leisure-time
123 internet use over a usual week (screen time). Participants were asked, “On how many
124 days did you do the activity during leisure time in the past 7 days?” and “On average,
125 how many minutes did you do the activity during leisure time on the days that you did
126 it?” Using this format, we identified time spent sitting in screen time by multiplying
127 the number of days participants watched television and used internet during leisure
128 time by the average amount of time spent doing so per day. The scale was previously
129 shown to have reasonable reliability and validity [16]. The test–retest reliability of the
130 items was moderate (range 0.6–0.8) and the validity, defined as correlations with 3-
131 day behavioral log data was also moderate (range 0.3–0.6) [17]. For cross-sectional
132 associations, the outcome variable was baseline screen time per day. For prospective
133 associations, the outcome variable was change of screen time per week from baseline
134 to follow-up survey.
135

136

136 **Exposure variables**

137 The exposure variables of this study were five environmental attributes – population
138 density, sidewalk availability, access to public transportation, access to destinations,
139 and street connectivity – measured both subjectively and objectively at baseline.

140 These domains were selected on the basis of walkability components and other
141 environmental attributes from previous reviews [18,19]. The perceived measures were

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3 142 identified using the Japanese version of the International Physical Activity
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5 143 Questionnaire Environmental Module (IPAQ-E) with a 4-point Likert scale (*strongly*
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7 144 *agree, somewhat agree, somewhat disagree, and strongly disagree*). The scale has
8
9 145 been shown to have good reliability [20]. Five items of IPAQ-E were included: (1)
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11 146 population density (“What is the main type of housing in your neighborhood?” For
12
13 147 this question, the five options were detached single-family housing; apartments with
14
15 148 2–3 stories; mix of single-family housing and apartments with 2–3 stories; condos
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17 149 with 4–12 stories; and condos with >13 stories); (2) sidewalk availability (“There are
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19 150 sidewalks on most of the streets in my neighbourhood”); (3) access to public
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21 151 transportation (“It is less than a 10–15 min walk to a transit station from my home”);
22
23 152 (4) access to destinations (“There are many places to go within easy walking distance
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25 153 of my home”); (5) street connectivity (“There are many 4-way intersections in my
26
27 154 neighbourhood”). Population density was divided into “lower (detached single-family
28
29 155 housing)” and “higher (others)”. Other four perceived environmental attributes were
30
31 156 categorized into “agree” (*strongly agree* and *somewhat agree*) and “disagree”
32
33 157 (*somewhat disagree* and *strongly disagree*).
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39 159 Objective environmental attributes was measured using Geographic Information
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41 160 Systems (GIS). The following five measures were calculated for each participant
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43 161 within a 800-m radius buffer of their residential address (this buffer area
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45 162 corresponded to a neighborhood setting, which was also used to obtain participant’s
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47 163 perceptions): (1) population density (the number of population per square kilometer);
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49 164 (2) sidewalk availability (the length of roads with sidewalks (m) per square km); (3)
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51 165 access to public transportation (the total number of train stations and bus stops per
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53 166 square km); (4) access to destinations (the total number of 30 destination types
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3 167 including convenience store, supermarket, hardware shop, fruit store, dry cleaning
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5 168 store, coin laundry, clothing store, post office, library, book store, fast food store, café,
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7 169 bank, restaurant, video shop, video rental shop, pharmacy, drug store, the
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9 170 hairdresser's, park, gym, fitness club, sports facility, kindergarten, elementary school,
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11 171 junior high school, high school, 2-year college, 4-year college, university based on a
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13 172 previous study and IPAQ-E [20,21]; (5) street connectivity (the total number of
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15 173 intersections per square kilometer). These five objectively-measured environmental
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17 174 attributes were dichotomised using the median.
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22 176 **Covariates**

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25 177 The selection of covariates was based on previous studies [22, 23]. Data on
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27 178 respondents' gender (men, women), age (40–49, 50–59, or 60–69 years), current
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29 179 marital status (married, unmarried), educational level (less than 13 years, 13 years or
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31 180 more), employment status (full-time employment, not full-time employment),
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33 181 household income (less than 5 million yen, or 5 million yen or more), body mass
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35 182 index (less than 25kg/m², 25kg/m² and higher) and residential area (Nerima city and
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37 183 Kanuma city), physical function and moderate-to-vigorous physical activity (MVPA)
38
39 184 were included. Physical function was measured by The Japanese version of the
40
41 185 Medical Outcomes Study (MOS) Short Form 8-Item Health Survey (SF-8) [24].
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43 186 Participants were ask “During the past 4 weeks, how much did physical health
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45 187 problems limit your physical activities (such as walking or climbing stairs)?”. MVPA
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47 188 was measured by the self-administered, short Japanese version of the International
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49 189 Physical Activity Questionnaire (IPAQ-SV). The test-retest reliability ($r = 0.72-0.93$)
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51 190 and criterion validity ($r = 0.39$) of the version of the IPAQ-SV are good and
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53 191 acceptable, respectively [25]. The total number of minutes per week in vigorous-
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3 192 intensity physical activity, moderate-intensity physical activity, and walking was
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10 11 196 **Statistical analyses**

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13 197 For cross-sectional associations, generalized linear modelling (GLM), specifying a
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15 198 gamma distribution and a log link, was utilized to examine cross-sectional
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17 199 associations of perceived and objectively-measured environmental attributes with
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19 200 screen time at baseline because the distribution of outcome variable was skewed. The
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21 201 covariates were adjusted for baseline demographic variables including gender, age,
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23 202 marital status, education attainment, household income, working status and MVPA.

24
25 203 For prospective associations, GLM was also used to identify the relationships of
26
27 204 perceived and objectively-measured environmental attributes at baseline with follow-
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29 205 up screen time over 2 years, adjusted for socio-demographic variables at baseline,
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31 206 screen time at baseline and employment status change. This approach is equivalent to
32
33 207 modelling change in screen time and controls for regression to the mean, which has
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35 208 been used in previous study [15]. Residence area was utilized as the area level unit of
36
37 209 all analysis. Results of each model are reported as antilogarithms of the regression
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39 210 coefficients (and their respective 95%CI). The expected proportional increase (for
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41 211 values > 1) or decrease (for values <1) in screen time for “environmental conditions
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43 212 that would support physical activity” environment (reference: “not support” category).

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45 213 For cross-sectional analysis, coefficients less than 1 denote proportionally less time
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47 214 spent in screen time (e.g. Exp (B)=0.95 means 5% less time), whereas coefficients
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49 215 more than 1 denote proportionally more time spent in screen time, relative to the
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51 216 reference category. (e.g. Exp (B)=1.06 means 6% more time). For prospective

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3 217 analysis, coefficients less than 1 denote proportionally decreased time spent in screen
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5 218 time, whereas coefficients more than 1 denote proportionally increased time spent in
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7 219 screen time, relative to the reference category. Statistical analyses were conducted
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9 220 using STATA 13 (Stata Corp, College Station, Texas); the level of significance was
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11 221 set at $p < 0.05$.

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14 15 16 223 **Results**

17
18 224 Basic characteristics of the baseline sample ($n=1011$, mean age: 55.8 ± 4.3 years)
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20 225 and follow-up sample ($n=553$, mean age: 54.6 ± 8.3 years) are presented in Table 1. On
21
22 226 average, participants' screen time was not statistically different over 2 years (2.3
23
24 227 hours/day at baseline and 2.2 hours/day at follow-up; $p=0.24$). Table 2 shows that at
25
26 228 baseline, after adjusted for potential confounders (model 2), cross-sectional
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28 229 associations of objectively-measured ($\exp(\beta):1.11$; 95%CI: 1.01, 1.22) and perceived
29
30 230 ($\exp(\beta):1.12$; 95%CI: 1.02, 1.23) good access to public transport, perceived good
31
32 231 access to shop ($\exp(\beta):1.18$; 95%CI: 1.04, 1.36), and perceived good street
33
34 232 connectivity ($\exp(\beta):1.11$; 95%CI: 1.01, 1.23) with higher time spent in screen time
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36 233 were found. As Table 3 shows, for the prospective associations, no objectively-
37
38 234 measured and perceived environmental attributes were significantly associated with
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40 235 change in screen time.

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238 **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) |

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

240

241 Table 2: Proportional change (95%CI) in screen time according to objective and perceived
 242 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 |

243 * p < 0.05

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

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

248 Results of each model are reported as antilogarithms of the regression coefficients (and their respective
 249 95%CI). Coefficients less than 1 denote proportionally less time spent in screen time, whereas
 250 coefficients more than 1 denote proportionally more time spent in screen time, relative to the reference
 251 category.

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

253

254

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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269 Discussion

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

284
285 Contrary to expectations, adults who live in neighborhood environment with GIS-
286 measured good access to public transportation, and perceived good access to
287 destinations, good access to public transportation, good street connectivity was
288 positively associated with higher levels of screen time, which have been found to be
289 positively related to higher levels of physical activity [18,27]. The present results
290 were also inconsistent with previous studies which have reported the inverse
291 associations between high walkable environment and screen-based sedentary time
292 from Western countries [12,14,15]. Only one Belgium study reported similar result
293 with the present study that high walkable environment is positively associated with

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3 294 total sitting time [26]. The possible speculation for these results could be that physical
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5 295 activity-supportive neighborhood environment (e.g. there are so many shops, train
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7 296 stations, and bus stops within 1.6km radius of their house) could reduce the time spent
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9 297 in commute and daily errand, and thus adults may have more leisure-time to engage in
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11 298 screen time. Although there is limited evidence in existing literature to draw the
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13 299 conclusion and possible mechanism regarding the inverse associations between
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15 300 environment and screen time, the present study may have several important
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17 301 implications. First of all, the perceptions of environmental attributes should be
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19 302 considered to be predictors of screen time for future studies. The present results
20
21 303 indicate that perceived environmental attributes might be better predictors of screen
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23 304 time than objective ones. It is possible how middle-to-older-aged adults perceive and
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25 305 understand their neighbourhood environment might be more important for their
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27 306 decision on spending time in screen time in their home. Moreover, further evidence in
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29 307 Asian countries using specific environmental measures are needed due to the
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31 308 difference in residential density, culture and built environment between Western
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33 309 countries and Asian country. Finally, examining the relationships among
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35 310 environmental factors, physical activity and sedentary behavior concurrently would be
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37 311 the priority to better understand the potential positive or negative health effects of
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39 312 environment on both physical activity and sedentary behavior for the policy initiatives.
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46 314 Another novel finding is that no prospective associations of screen time over 2 years
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48 315 with objective and perceived environmental attributes. The possible explanation for
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50 316 this result could be that the follow-up duration of this study was only two years and
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52 317 screen time is a highly domestic behaviour for adults during leisure time, which may
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54 318 maintain for years unless the adjustment of home environment or the change in

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3 319 employment status. Therefore, the present study might provide a preliminary
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5 320 understanding on built environmental determinants of screen time for developing
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7 321 effective population-based interventions [10,11]. Therefore, to further confirm the
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9 322 prospective associations, studies with a longer follow-up time are needed in the future.

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13 324 This study has several limitations. First, the outcome variable - self-reported screen
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15 325 time may be subject to recall bias. Thus, future studies should consider measuring
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17 326 screen time using objectively measurement to provide more confirmative evidence.

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20 327 Second, the use of the IPAQ-SV may have overestimated time spent in MVPA. Third,
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22 328 potential confounders such as self-selection of neighborhoods and home environment
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24 329 were not examined in this study. Finally, the participants who responded the follow-
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26 330 up survey were more likely to have higher educational levels (58.1% vs. 47.4%, p
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28 331 =0.002) and have higher income (53.4% vs. 43.9%, p =0.01) than those who did not.

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31 332 Thus, the final sample may not be representative of the populations of Nerima City
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33 333 and Kanuma City. Despite such limitations, the strengths of this study were the both
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35 334 cross-sectional and prospective design and the utilization of five both subjectively and
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37 335 objectively-measured environmental components, which could provide more
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39 336 confirmative evidence on this issue.

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42 43 338 **Conclusion**

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47 339 Activity-supportive neighborhood environmental attributes appear to be related to
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49 340 higher level of screen time cross-sectionally. Pattern of screen time might be
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51 341 maintained rather changed over time under the same neighborhood environments.

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53 342 Environmental intervention for promoting physical activity may need to consider the
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55 343 potential negative health impact of screen time in Japan.

344 **Declarations**

345 **Ethics approval and consent to participate**

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

348 **Consent for publication**

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

351 **Availability of data and material**

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

355 **Contributorship statement**

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

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367 **Conflict of Interest Statement**

368 The authors declare that there are no conflicts of interest.

369 **Acknowledgements**

370 Not applicable.

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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) <i>Cohort study</i> —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 <i>Case-control study</i> —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 <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants (b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount) |
| Outcome data | 15* | <i>Cohort study</i> —Report numbers of outcome events or summary measures over time Page 10, Line 225-227 |
| | | <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure |
| | | <i>Cross-sectional study</i> —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

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|------------------|----|--|
| 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, Line 321 |
| 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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