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Perceived workplace layout design and work-related physical activity and sitting time

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ABSTRACT

The workplace spatial environment has been identified as one of the correlates of workers' active and sedentary behaviours. This study examined the associations of perceived workplace layout design with workers' active and sedentary behaviour in office workers in Japan. Participants in this study (n = 2,265) were recruited from a nationwide online survey conducted in 2019. They completed a questionnaire that assessed work-related physical activity and sedentary time. Self-reported workplace layout measures including local connectivity, overall connectivity, visibility of co-workers, and proximity of co-workers were calculated using the Office Environment and Sitting Scale questionnaire. A two-stage regression model was used for modelling physical activity and sedentary time. After adjusting all covariates, participation in work-related physical activity was positively associated with local and overall connectivity (OR = 1.64, 95% CI 1.28, 2.12, and OR = 1.37 95% CI 1.07, 1.74, respectively) in open-plan offices. However, the visibility and proximity of co-workers were positively associated with any work-related sedentary time in shared and open-plan offices. There was also a positive association between participation in work-related physical activity and local connectivity in shared offices (OR = 1.88, 95% CI 1.30, 2.72). For those participants reporting participation in work-related physical activity, there was a significant positive association between work-related physical activity and local connectivity in open-plan offices (b = 11.28 min/day, 95% CI 2.04, 20.51). Our findings provided evidence on the relevance of workplace layout design to participation and the duration of workers' active and sedentary time in the context of Japan, a country with the world's most extended working hours among adults.

1. Introduction

Physical inactivity is a leading contributor to noncommunicable diseases such as cardiovascular diseases, type II diabetes, and some types of cancer [1]. Sedentary behaviour has also been recognised as an emerging health risk factor, independent of physical activity levels [2]. Office-based workers are one of the 'at risk' populations of having low physical activity and accumulating sitting time [3–5]. For example, a systematic review of 132 studies found that office workers had the lowest device-based sedentary time among occupations [6]. Strategies to improve physical activity and reduce sitting time among office-based workers may contribute to their health and well-being.

The workplace spatial environment has been identified as one of the correlates of workers' active and sedentary behaviours [7,8]. For instance, a study conducted in the USA found that workers in private offices (not shared) spent more time in prolonged sitting behaviour than those working in open-plan offices [9]. Another study conducted in Australia found that the perceived availability of workplaces' shared

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space for informal discussion was associated with lower sitting time among some groups of office workers [10]. Nevertheless, this area of research is limited in two important ways. First, there is a dearth of studies examining associations between the workplace spatial environment and workers' active and sedentary behaviour outside the Western contexts of the USA, Canada, and Australia [7]. For example, a recent systematic review of studies examining office physical attributes and employees' sitting and face-to-face interactions found that no study was conducted in Asia [8]. With regard to perceived workplace layout design based on space syntax, only two previous studies conducted in Australia exist [11,12]. The previous findings from Western countries may not generalise to non-Western countries where workplace norms and culture are different and can influence office environment and behaviour relationships.

Second, the use of space syntax in conceptualising workplace layout design in relation to workers' active and sedentary behaviour has remained limited. Space syntax is a theory and method that originates from architecture and urban design and quantifies spatial layouts using a set of relational measures [13,14]. It is argued that people's perception of and navigation through spatial layouts are influenced by relational factors (more than metric measures), which can be detected in space syntax [15,16]. Space syntax quantifies spatial layouts using a set of estimators based on the graph theory [17]. The axial lines are the longest and fewest lines covering all the spaces within a layout [13]. A justified graph represents how each axial line (node) is connected to its adjunct axial lines (link) [18,19]. Fig. 1 shows (a) a schematic diagram of a hypothetical office layout with its axial lines marked and (b) its justified graph. Since its origination, space syntax has been used in numerous studies analysing the effects of buildings' spatial layouts on various human behaviours [20–22]. While the layout is one of the fundamental design attributes in buildings, only a few studies have examined how space syntax measures of workplace layout are associated with workers' active and sedentary behaviour [11,12,23]. Specifically, only two previous studies conducted in Australia, Duncan et al. [11] and Duncan et al. [12], examined the associations between workplace layout and occupational sitting and breaks using a self-report tool intended to mimic relational factors that are normally derived objectively via space syntax (i.e., overall connectivity, local connectivity, co-worker visibility, and co-worker proximity). They found that local connectivity was associated with more sitting breaks in shared and open-plan offices, and co-worker proximity was negatively associated with the number of sitting breaks in open-plan offices [12]. These studies used self-reported space syntax measures because there are several barriers to obtaining detailed floor plans (i.e., security and privacy issues) to create objective space syntax measures [11]. As a widely used concept in practice, space syntax can provide insightful information on how to (re)design workplace layouts to promote workers' active behaviour.

To address these limitations, this study examined the associations of perceived workplace layout design with workers' active and sedentary behaviour in office workers in Japan. Since these associations may vary based on the type of workplace (e.g., private-enclosed, shared, and open plans) [11,12], the analysis was stratified by workplace type.

2. Methods

2.1. Participants and study design

Participants for this study were recruited from a nationwide online survey conducted in 2019. The data were from the registered individuals of a Japanese internet research service company (My Voice Communication, Inc. Tokyo, Japan). This company's database contains sociodemographic information on approximately one million individuals across Japan who voluntarily took part in this database. An invitation e-mail with a link to participate in the study was sent to 45,659 workers (aged 20–59 years) who were randomly selected from the database by gender and age group (20s, 30s, 40s, and 50s). A total of 3,200 individuals responded to the survey (a response rate of 7.00%): 1,600 participants of each gender and 800 participants of each age group. The analysis was limited to participants (n = 2,265) who reported their occupation type in sitting/desk-based forms of employment because they are more likely to be engaged in work undertaken in office-based settings [12]. Each participant received a cash reward valued at 140 yen and was offered as an incentive to complete the survey. All participants signed an online informed consent form. The study was approved by the Research Ethics Committee, Waseda University, Japan (2012–269, 2013–264).

2.2. Measures

Work-related physical activity and sedentary time. Work-related physical activity was measured using the relevant items in the Global Physical Activity Questionnaire (GPAQ) [24]. In brief, this questionnaire consists of 16 questions that assess self-reported physical activity during work, transport, and leisure in a typical week. This questionnaire has acceptable reliability and validity in Japanese adults [25]. The frequency and duration of moderate- and vigorous-intensity physical activity spent on the work domain were used to calculate the average work-related physical activity per day. The standardised procedures

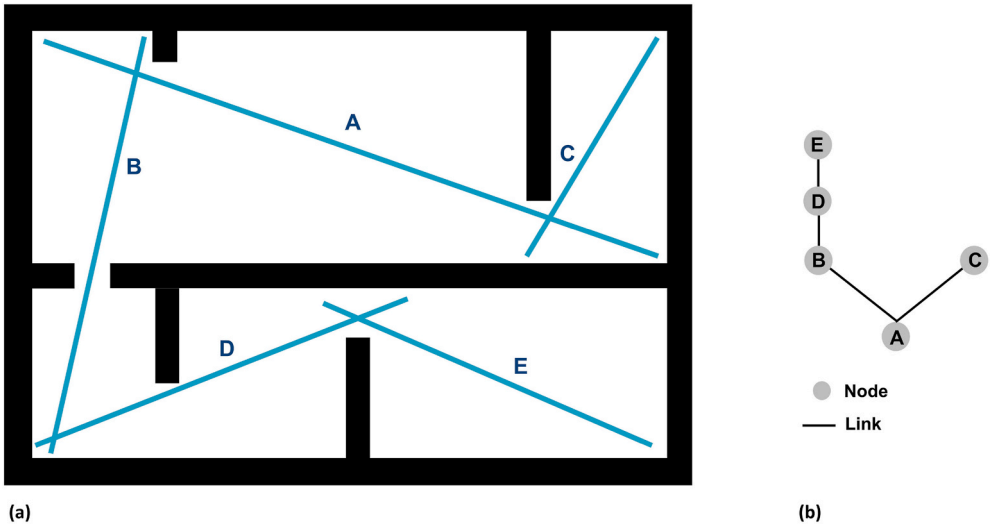

Fig. 1. (a) a schematic diagram of a hypothetical office layout its axial lines (numbers represent axial lines' names) and (b) its justified graph.

provided by the World Health Organization were followed to clean data [26]. Previous studies suggest that there may be different correlates for initiation versus maintenance of physical activity [27]. Thus, two work-related physical activity variables were estimated: (1) any participation in work-related physical activity versus no participation; and (2) duration (minutes/day) among those who reported participation. Work-related sedentary behaviour was assessed using a Japanese self-report questionnaire with a 1-week recall period [28]. This questionnaire assesses six domain-specific sitting behaviours, including driving or riding by car; using public transport; at work; watching television, videos, and DVDs; using a computer, cell phone, or tablet PC outside of working hours; and in leisure time (excluding watching television, videos, and DVDs separately for workdays and non-workdays. In our study, participants were asked to report their daily average sedentary behaviours over the past seven days separately for workdays and non-workdays (weekends) in the work-related domain. This questionnaire has moderate to high test-retest reliability (intraclass correlation coefficient [ICC] = 0.83) for the work domain with a 1-week recall period [28]. There were also significant ($P < 0.001$) correlations between total self-reported and accelerometer-based sedentary time, comparing this questionnaire with accelerometer-based sedentary time [28]. The average daily value of work-related sedentary time was calculated by weighting the number of workdays and non-workdays.

Workplace layout measures. Workplace layout measures including local connectivity, overall connectivity, visibility of co-workers, and proximity of co-workers were calculated using the Office Environment and Sitting Scale (OFFESS) questionnaire developed by Duncan et al. [11]. This questionnaire has demonstrated good test-retest reliability [11]. Workplace design configuration measures were assessed by asking participants about their agreement level (1 = strongly agree to 4 = strongly disagree) with 17 question items (Table 1). The means of relevant items were calculated as workplace design configuration characteristics. A subsample of workers (n = 200) from the 3,200 workers who responded to the survey reported the workplace design configuration characteristics twice within two weeks to examine the test-retest reliability. In our sample, the Cronbach's alpha of local connectivity, overall connectivity, visibility of co-workers, and proximity of co-workers were 0.78, 0.92, 0.88, and 0.78, respectively.

Workplace type. A single item from the OFFESS questionnaire was used to assess workplace type [11]: "Now please think about the area where most desks or workstations are located. Which of the following best describes the location of the majority of desks/workstations in your building? (1) In an office separated from other offices by floor to ceiling walls, door, not shared with anyone else; (2) In an office separated from other offices by floor to ceiling walls, door, shared by 2–4 people; (3) In a single area containing many desks/workstations separated by high partitions (greater than 1.5 m in height); (4) In a single area containing many desks/workstations separated by low partitions (less than 1.5 m in height), and (5) In a single area containing many desks/workstations separated by no partitions." Similar to the previous two studies [11,12], workplace type was categorised into private enclosed offices (response 1), shared offices (responses 2 and 3), and open-plan offices (responses 4 and 5).

Sociodemographic characteristics. Participants self-reported their age, gender (female or male), marital status (single or couple), highest education (tertiary or below tertiary), workplace scale (≤29, 30–99, ≥100 employees, or not applicable), and gross annual individual income (<¥4,000,000 or ≥ ¥4,000,000).

2.3. Statistical analysis

Descriptive statistics, including frequencies and percentages, means, and standard deviations, were estimated for all variables. Pearson's correlation coefficient was used to test the correlations between workplace layout measures. One-way analysis of variance (ANOVA) was used to compare workplace layout measures between different workplace types.

Table 1
Workplace layout measures included in this study.

	Question Items [11]
Local connectivity	Please think about the layout of your building, including the location of offices, kitchens, and other common rooms in relation to each other: 1. There are many alternative routes to move around my office (I don't have to go the same way every time). 2. Clearly defined pathways for travel between workstations frequently intersect with each other. 3. I can take many different travel routes through the office to reach the same destination when travelling. 4. Hallways and passageways in my building frequently intersect each other. 5. I can access kitchen or coffee rooms directly from hallways/passageways.
Overall connectivity	This question relates to how easily you can move around your building. Please think about passageways including areas between desks/workstations that people can easily walk through to get from one place to another: 1. To travel from my workstation/desk to the closest meeting room/area requires many changes in direction. 2. Walking from my own workstation/desk to most others in the building requires many changes in direction. 3. To travel from the main entry of my building/floor to my workstation/desk requires many changes in direction. 4. Walking in my building requires frequent changes in direction one after another. 5. To travel from my workstation/desk to the closest toilet requires many changes in direction. 6. My office building has many rooms that are difficult to find.
Visibility of co-workers	Please think about how frequently you see people standing around, walking and talking in your building: 1. From my workstation/desk I can see several colleagues sitting or standing at their workstations/desks (do not include offices with the door closed) 2. I frequently "bump in to" other people when walking in my building 3. I frequently see people/other employees walking around inside the building 4. I frequently see people/other employees standing and talking inside the building
Proximity of co-workers	Please only think about those people employed in the same organization as you. If you work in a building that has employees from several different organisations please do not consider these employees in your answers: 1. From my workstation/desk I can hear other people talking quietly at their workstation/desk. 2. There many other workstations/desks located in my building within a short walk of my workstation/desk.

Since work-related physical activity and sedentary time are semi-continuous variables with a lower bound of zero, it is necessary to use regression-type models to handle this type of variable to assess the associations between workplace layout measures and outcomes. We used a two-stage regression model (i.e., hurdle model) to model physical activity and sedentary time [29,30]. First, multivariate logistic regressions were used to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) for the association between each workplace layout measure and daily participation in any work-related physical activity or any work-related sedentary time adjusting covariates. Second, among those reporting participation, covariate-adjusted multivariate linear regressions estimated the linear associations (b = unstandardised regression coefficients and 95% CI) between each workplace layout measure and duration of daily work-related physical activity and work-related sedentary time. The same covariates were included in both models. Furthermore, each workplace layout measure was examined separately in each model to examine their total effects. A complete-case analysis was chosen because the percentage of missing data for our variables of interest was low (5%) [31]. Analyses were conducted using Stata 15.0 (Stata Corp., College Station, TX, USA), and the level of significance was set at $p < 0.05$.

3. Results

Table 2 shows the characteristics of the study participants. Our sample consisted of mostly female (51.7%), single (55.6%), tertiary or higher educated (86.0%), those working in a large workplace (58.5%), and those with a gross annual individual income of less than four million yen (51.5%), with a mean age of 40.5 ± 10.7 years. Table 3 shows the participants' workplace layout measures and how they differ by workplace type.

Table 4 shows the results of the associations between workplace layout measures and participation in work-related physical activity and work-related sedentary time. After adjusting all covariates, participation in work-related physical activity was positively associated with local and overall connectivity (OR = 1.64, 95% CI 1.28, 2.12, and OR = 1.37 95% CI 1.07, 1.74, respectively) in open-plan offices. There was also a positive association between participation in work-related physical activity and local connectivity in shared offices (OR = 1.88, 95% CI 1.30, 2.72). No significant associations were observed between participation in work-related physical activity and the visibility and proximity of co-workers for any of the workplace types. However, the visibility and proximity of co-workers were positively associated with any work-related sedentary time in shared and open-plan offices. No significant associations were observed between any work-related sedentary time and local and overall connectivity for any of the workplace types.

Table 5 presents the results of the associations between workplace layout measures and work-related physical activity, and work-related sedentary time. For those participants reporting participation in work-related physical activity, there was a significant positive association between work-related physical activity and local connectivity in open-plan offices (b = 11.28 min/day, 95% CI 2.04, 20.51). There were no significant associations between the duration of work-related physical activity and workplace layout measures in private-enclosed and shared offices. After adjusting all covariates, there was a significant negative association between work-related sedentary time and overall connectivity in private-enclosed offices (b = −17.80 min/day, 95% CI -35.37, −0.22). No significant associations were observed between the duration of work-related sedentary time and workplace layout measures in shared and open-plan offices.

4. Discussion

This study is one of only a few empirical studies to assess associations between office layout measures and workers' active and sedentary behaviour. We found that these associations differ by workplace type among a sample of office workers in Japan. For example, none of the perceived office layout measures was significantly associated with participation in or duration of work-related physical activity in private-enclosed offices. Despite the potential differences in workplace culture, our findings in Japanese workers are similar to two previous studies conducted in Australia [11,12]. For instance, Duncan et al. [12] found that co-worker's proximity was negatively associated with the number of sedentary breaks in open-plan offices (not in private-closed or shared offices). This is also notable given that our study included the same measure of perceived workplace layout used by Duncan et al. [11,12]. We also found that different perceived office layouts may be differentially associated with workplace physical activity and sedentary behaviour. To the authors' knowledge, no previous studies have assessed the effects of perceived space syntax measures of office layouts in relation to workers' physical activity. Like others [11,12], our findings highlight the importance of workplace type in interpreting workplace layout's role on workers' physical activity and sedentary behaviour while also emphasising the potential for (re)designing office layouts that can impact these behaviours. The fact that some of our findings in Japanese workers were consistent with findings involving workers in other countries [11,12] might suggest that certain office design and layout correlates of physical activity and sitting time may be regarded as universal independent of a localities workplace norms or culture. Nevertheless, future research should examine the relationships between these same variables in different countries or populations to ascertain their generalizability.

All office layout measures were positively associated with the likelihood of undertaking any workplace physical activity for all office types, but only local connectivity and overall connectivity were significant for shared and open-plan office types. Perceived local and overall connectivity items reflect space syntax measures of connectivity and integration, respectively [11]. While connectivity and integration are related, they refer to unique characteristics of spatial layouts [13]. The former refers to how easily someone can access available routes within a building. The latter indicates how topologically close a specific space is to other spaces in a building. We found that local connectivity was associated with higher odds of any work-related physical activity in shared and open-plan offices and higher duration of work-related physical activity in open-plan offices. In open-plan offices, overall connectivity was also associated with higher odds of any work-related physical activity but did not translate into more minutes of work-related physical activity. We were unable to compare these findings with others since no study was found examining associations between perceived space syntax measures of office layout and physical activity. However, these findings are consistent with several previous studies showing the correlations between space syntax connectivity and integration measures of spatial layout and movement in buildings [32,33] and neighbourhoods [34,35].

Our findings also showed that overall connectivity was associated with lower work-related sedentary time in private-enclosed offices. In a previous study conducted in Australia, Duncan et al. [12] also found that local connectivity was associated with the number of breaks in sitting time in shared and open-plan offices. Co-workers' visibility and proximity were unfavourably associated with any work-related sedentary time in shared and open-plan offices. To our knowledge, no study has examined office layout measures in relation to work-related sedentary time. There may be a disincentive to move around the office in shared and open-plan offices because of the disruption to work or the potential to be judged. It may be possible that seeing others (shared and open-plan offices) sittings acts as a cue also to sit more (social norm) – not wanting to be seen moving around too much or being perceived as wasting time or not working in the context of Japanese workplaces.

This study has some limitations. Our self-reported measures of physical activity and sedentary behaviour may be subject to recall bias. People's perceptions of their surrounding physical environment may not always be matched with the actual environment. Previous studies have shown that both perceived and objective physical environmental measures are essential because they can have distinctive effects on health

Table 2
Characteristics of study participants (N = 2,265).

Variable	Mean (SD) or N (%)
Age (years)	40.5 (10.7)
Gender	
Female	1171 (51.7)
Male	1094 (48.3)
Marital status	
Single	1259 (55.6)
Couple	1006 (44.4)
Highest education	
Tertiary	1947 (86.0)
Below tertiary	318 (14.0)
Workplace scale	
Small (≤ 29 employees)	544 (24.0)
Medium (30–99 employees)	323 (14.3)
Large (≥ 100 employees)	1326 (58.5)
Not applicable	72 (3.2)
Gross annual individual income	
< ¥4,000,000	1167 (51.5)
≥ ¥4,000,000	1098 (48.5)

Table 3
Participants' workplace layout measures.

	Overall (n = 2,265)		Private-enclosed office (n = 435)		Shared office (n = 477)		Open-plan office (n = 1,353)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Local connectivity	2.3	0.6	2.16[a]	0.71	2.24[b]	0.63	2.33[a,b]	0.63
Overall connectivity	2.0	0.7	1.97[a]	0.77	2.08[a]	0.65	2.02	0.67
Visibility of co-workers	2.8	0.8	2.44[a,b]	0.94	2.64[a,c]	0.67	2.91[b,c]	0.73
Proximity of co-workers	2.7	0.8	2.38[a,b]	0.96	2.64[a,c]	0.79	2.86[b,c]	0.77

Estimates with the same letter superscript ([a, b, c]) are significantly different between groups at $p < 0.05$, based on one-way ANOVA: Tukey.

Table 4
Associations between workplace layout measures and participation in work-related physical activity and work-related sedentary time.

	Any work-related physical activity (n = 2,261)			Any work-related sedentary time (n = 2,017)		
	Private-enclosed office (n = 433)	Shared office (n = 477)	Open-plan office (n = 1,351)	Private-enclosed office (n = 384)	Shared office (n = 419)	Open-plan office (n = 1,214)
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Local connectivity	1.40 (0.91, 2.17)	1.88 (1.30, 2.72)	1.64 (1.28, 2.12)	0.63 (0.35, 1.12)	0.98 (0.54, 1.81)	1.33 (0.90, 1.98)
Overall connectivity	1.29 (0.85, 1.96)	1.37 (0.96, 1.95)	1.37 (1.07, 1.74)	0.75 (0.43, 1.33)	1.00 (0.54, 1.86)	0.72 (0.49, 1.06)
Visibility of co-workers	1.32 (0.93, 1.87)	1.40 (0.99, 1.97)	1.11 (0.90, 1.38)	1.20 (0.74, 1.94)	1.94 (1.09, 3.47)	1.53 (1.09, 2.13)
Proximity of co-workers	1.18 (0.85, 1.63)	1.19 (0.90, 1.58)	1.09 (0.89, 1.33)	1.05 (0.67, 1.66)	1.73 (1.05, 2.83)	1.63 (1.20, 2.22)

Note: OR = odds ratio, CI = confidence interval, All models adjusted for age, gender, marital status, educational attainment, workplace scale, and income.

Table 5
Associations between workplace layout measures and duration of work-related physical activity and work-related sedentary time (min/day).

	Work-related physical activity minutes (n = 371)			Work-related sedentary time (n = 1,893)		
	Private-enclosed office (n = 59)	Shared office (n = 110)	Open-plan office (n = 202)	Private-enclosed office (n = 355)	Shared office (n = 393)	Open-plan office (n = 1,145)
	b (95% CI)	*b* (95% CI)	*b* (95% CI)	*b* (95% CI)	*b* (95% CI)	*b* (95% CI)
Local connectivity	5.51 (−13.72, 24.75)	−28.95 (−64.67, 6.76)	11.28 (2.04, 20.51)	−12.92 (−31.09, 5.25)	−0.95 (−18.22, 16.32)	−4.59 (−13.25, 4.07)
Overall connectivity	16.94 (−1.15, 35.04)	13.34 (−22.29, 48.97)	0.35 (−8.78, 9.48)	−17.80 (−35.37, −0.22)	−7.26 (−24.34, 9.81)	−7.20 (−15.65, 1.26)
Visibility of co-workers	5.00 (−11.93, 21.93)	−34.07 (−69.36, 1.22)	1.39 (−6.75, 9.53)	−5.20 (−19.56, 9.17)	−0.29 (−16.34, 15.75)	2.42 (−5.09, 9.93)
Proximity of co-workers	9.44 (−5.83, 24.71)	−26.36 (−54.80, 2.09)	−0.14 (−7.63, 7.36)	−5.75 (−19.12, 7.62)	5.20 (−8.26, 18.66)	2.87 (−4.14, 9.87)

Note: *b* = unstandardised regression coefficients, CI = confidence interval, All models adjusted for age, gender, marital status, educational attainment, workplace scale, and income.

behaviours [36,37]. Therefore, future field experiments can test objective measures of space syntax to quantify workplace layouts in relation to employees' activity. Such field experiments are needed to future support our study findings and those of others [11,12] that have relied on self-report space syntax measures. In addition, further studies are needed to test the cultural appropriateness of the OFFESS questionnaire for its use in non-Western countries. However, we found associations with this tool in the expected direction and supported by two previous studies conducted in Western countries [11,12], which also used the same tool. Therefore, this tool has predictive validity in the context of Japan, but maybe it could be improved by making the items more culturally relevant. Although the participants were recruited nationally, they may not accurately represent the office workers' population in Japan; because participants were recruited from a database developed by a Japanese internet research service company. We have no available data to compare the sample with the total population of office workers in Japan. Nevertheless, our study was intended to demonstrate whether workplace layout was associated with physical activity and sedentary behaviour in the work domain. Data on the length of time people worked at their workplace were not available in this study. Workers who spend more time in their workplaces may be more familiar with the layout and more likely to know others (social environment), influencing their behaviour.

5. Conclusions

Workplace layout design may influence active and sedentary behaviours among the office workers group, an at-risk group for being physically inactive. Our findings provided empirical evidence on the relevance of workplace layout design to participation and the duration of workers' active and sedentary time in the context of Japan, a country with the world's most extended working hours among adults. Further studies are necessary to extend these findings in other regions and among other workgroups.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. In particular, none of the authors has a financial interest in the Space Syntax Limited company.

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