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Associations Between Room Function, Office Design, Workplace Spatial Layout, and Sitting Patterns During Office Work

A Field Study

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Objective: We investigated associations between room function, office design, workplace spatial layout, and office workers' sitting behavior. **Methods:** We analyzed sit-to-stand and stand-to-sit transitions of 48 office workers during one work week (accelerometry), all office locations that those workers visited (end-of-day questionnaire), and physical features of those office locations (coded). **Results:** Office workers sat longer in offices than in meeting rooms; stood longer in large, shared offices; stood longer in offices with two workstations compared to one; stood longer in offices that had additional chairs; and sat longer when waste paper bins were out of arm's reach. **Conclusions:** Office workers' sitting patterns are—to some extent—related to workplace design. However, workplace design may impact sitting mainly through the work tasks and/or opportunities for collegial interactions that room designs afford.

Keywords: sedentary behavior, workplace design, environment, work characteristics, time-to-event analysis

LEARNING OUTCOMES

- Characterize sitting patterns of office workers during work
- Understand the association between office design, workplace spatial layout, and office workers' sitting behavior during work
- Discuss the role of room function and work characteristics in the association between office design and office workers' sitting behavior during work

Adults with an office job tend to sit a lot during work. The average office worker spends 70%–80% (~6 hours) of their work-time sitting,[1,2] which constitutes ~60% of their daily sitting time.[1] Moreover, office workers spent 40%–50% of their sitting time in prolonged, uninterrupted periods of sitting (>30 minutes).[1,3] These high levels of sitting—and especially high levels of uninterrupted sitting—are associated with an increased risk for cardiovascular disease, diabetes, and obesity[4]; may hamper cognitive functioning and productivity[5,6]; and are associated with higher sickness absence.[7] To improve employee health and well-being, office workers need to sit less and stand up more often.

In both science and practice, it is often assumed that the design of the physical work environment influences office workers' sitting behaviors. This assumption is seen in *affordance theory*, which posits that when people perceive an object, they automatically also perceive what they can do with the object.[8,9] For example, when people perceive a chair, they perceive a *seat*—or an object that *affords* sitting.[8] Through this process, the design of the physical environment may invite people to sit down or to stand up.[10] In line with this assumption, *ecological models of health behaviors* posit that supportive (physical) environments are a necessary condition for health behaviors change.[11,12] Therefore, based on prior theory, in principle, it should be possible to design workplace environments that encourage healthy sitting. But what should those workplace environments look like? *How* should they be designed?

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Funding Sources: None declared.
Conflict of Interest: None declared.
Author contributions: P.t.B., D.G.J.B., D.H.J.T., S.A.E.G., and E.B. contributed to the conceptualization of the research and reviewing and editing of the manuscript. P.t.B. and E.B. contributed to the formal analysis, investigation, methodology, visualization, and writing the original draft. P.t.B. contributed to data curation and project administration.
Data availability: Data and R code were used for the analyses in this paper: https://osf.io/8u4ev/?view_only=39f0dd9237464faa85671a058ee088de (blinded for peer review).
Preregistration of research questions, data-processing steps, and analyses: https://osf.io/gnt2m/?view_only=500665d3578948838c337617978e4e06.
Complete overview of the intake questionnaire and the daily questions: https://osf.io/8u4ev/?view_only=39f0dd9237464faa85671a058ee088de (blinded for peer review).
EQUATER Network checklist utilized: Not applicable.
AI statement: No AI was utilized during any stage of the research.
Ethical Considerations & Disclosure(s): The study procedure was approved by the Ethics Committee Social Sciences of the Radboud University (#ETC-SW number 2020-004). All participants provided written informed consent prior to participating.
Supplemental digital contents are available for this article. Direct URL citation appears in the printed text and is provided in the HTML and PDF versions of this article on the journal's Web site (www.joem.org).
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DOI: 10.1097/JOM.0000000000003660

Problematically, designers currently have only few pointers regarding which workplace design characteristics encourage or discourage prolonged sitting versus frequent standing breaks. That is, most prior studies investigated a single-design characteristic only, that is, whether an activity-permissive workstation (eg, a height-adjustable desks or a pedal machines[13,14] is present. Some other studies have compared office workers' sitting behaviors before and after the relocation to a completely different office environment.[15–17] Both types of studies generally show a ~20- to 125-minute decrease in office workers' daily sitting time after the intervention (intervention effects often wear off in the long-term).[14,16] Although these studies are promising, they fail to provide detailed information on which exact (combinations of) design characteristics support sitting less and standing up more often. Thus, existing research provides little guidance on how to design an office environment that is associated with frequent standing breaks.

In the present study, we conducted an extensive exploration of the relation between workplace design features and office workers' sitting patterns. Our general aim was to evaluate whether—and if so, to what extent—workplace design features are linked to office workers' sitting patterns at work. These insights will help to identify which design features are promising candidates for future research and interventions. To study the association between workplace design and sitting patterns, we examined a sample of office workers over the course of a week. Office workers wore an activity tracker to precisely monitor when they stood up and sat down. In addition, at the end of each workday, they reported the rooms they worked in that day. For these rooms, we assessed a large number of design characteristics. We investigated three types of design characteristics: room function, room design, and workplace spatial layout.

First, we examined how the room's function—for example, whether a room is an office or a meeting room—is associated with office workers' sitting patterns. People typically sit down or stand up not for the sake of sitting or standing, but to do something else (ie, to eat dinner, to fetch a coffee).[18,19] In other words, people often sit down or stand up as a means to some goal. At work, people likely sit or stand to achieve work goals and tasks, which are typically different in offices (eg, goal: focused work) versus in meeting rooms (eg, goal: meeting a client). In this study, we compared office workers' tendencies for prolonged sitting and standing in offices versus meeting rooms.

Second, we examined how the specific design of offices and meeting rooms is associated with office workers' sitting patterns. Based on affordance theory, it is plausible that certain design features provide a stronger invitation for people to sit down when standing or to stand up when sitting.[10] For example, a previous qualitative study suggested that, when objects (such as waste bins) are placed out of arm's reach, this could provide triggers for employees to stand up.[20] Another study, in which office workers wore an activity monitor for a week, showed that desk-based workers in private offices engaged in more prolonged sitting than workers in shared offices.[21] This finding suggests that the physical presence of colleagues may also provide a trigger to stand up. In this study, we assessed a large number of office/room design characteristics (eg, number of workstations, presence of trash cans) and their relation to office workers' sitting patterns.

Third, we examined how the location of an office in relation to other offices, meeting rooms, and shared facilities in the building—that is, the spatial layout of the workplace—may shape office workers' sitting patterns. In previous work, researchers calculated the distances from office workers' workstations to other workstations and shared facilities.[22] The researchers found that people walked less when the distance to other workstations and shared facilities was larger. In another study, office workers wore an activity monitor and self-reported how centrally located they felt their workstation was within the office building.[23] Results showed that workers engaged in more frequent breaks from sitting when they perceived that their office was more central. In the present study, we assessed a large number of spatial layout characteristics and their relation to office workers' tendencies for prolonged sitting and standing.

Previous research on sitting behaviors has traditionally analyzed sitting behaviors on an aggregated level (by analyzing *total sitting time*, eg, per day). By contrast, following recent developments,[19,24,25] we analyzed our data on the level of the individual *stand-to-sit transitions* and *sit-to-stand transitions*. This approach has three advantages. First, in contrast to sitting time, stand-to-sit and sit-to-stand transitions are actual behaviors that people engage in and that we can predict, explain, and change, and therefore useful targets for interventions.[19] Second, by modeling the timing of stand-to-sit and sit-to-stand transitions (ie, how long people sit before they stand up and how long they stand before they sit down), we can estimate people's tendency to engage in prolonged, uninterrupted periods of sitting, which are especially unhealthy.[1,26] Finally, our approach allows us to directly link stand-to-sit and sit-to-stand transitions to people's locations, even though people visit different locations throughout the day.

Taken together, we evaluated whether—and if so, to what extent—workplace design features are linked to office workers' sitting patterns at work, by studying the association between three types of design features and office workers' stand-to-sit and sit-to-stand transitions. First, we examined the association with room function—for example, whether a room is an office or a meeting room. Second, we examined the association with specific room design characteristics, for offices and meeting rooms separately. Third, we examined the association with workplace spatial layout characteristics.

METHODS

Study Overview

The outcome variables were (*a*) the timing of stand-to-sit transitions (within-participants) and (*b*) the timing of sit-to-stand transitions (within-participants). We assessed these with activity monitors that participants continuously wore on their upper right thigh for the duration of a week.

The primary predictors were *room function* (office vs meeting room; within-participants), *office design characteristics* (within-participants), and *workplace spatial layout characteristics* (within-participants). To assess room function and office design characteristics, we performed worksite visits to the office locations of participating companies and systematically observed each room by scoring a list of office/room design characteristics that was constructed for this study (see Measurements). To assess workplace spatial layout characteristics, we used computer software and floorplans of the worksites to calculate distances and centrality (see Measurements).

To connect the time-stamped activity data to room function, office design characteristics, and workplace spatial layout characteristics, we used a day-reconstruction design.[27] At the end of each workday, participants were asked to report each room where they spent time, along with the start time and end time of their presence in that room. These data were used to link stand-to-sit and sit-to-stand transitions to the respective rooms that they occurred in and hence to the design characteristics and workplace spatial layout characteristics of that room.

To aid the interpretation of our data, we also assessed the following secondary predictors through self-report: general work characteristics (eg, work pressure; between-participants), daily work characteristics (eg, daily task variation; within-participants), and worksite habits (eg, the use of digital vs paper documents; between-participants). Finally, to replicate previous findings,[24] we also analyzed how the timing of stand-to-sit and sit-to-stand transitions varied with time of the day and with activity in the preceding 5 hours.

The study procedure was approved by the ethics committee of the Radboud University (#ECSW-2020-004). We preregistered our research questions, data-processing steps, and analyses on the Open Science Framework (https://osf.io/gnt2m/?view_only=500665d-3578948838c337617978e4e06). A detailed overview of methods and data analysis is provided in Supplementary Text 1 and Supplementary Text 2 of the supplementary information (http://links.lww.com/JOM/C353). Below we present a summary of methods.

Participants

We recruited office workers from a notarial service company and an accountancy and tax advisory company with a total of ~118 eligible employees. Of these, 51 participants signed up to participate in the study, 3 participants dropped out during the measurement week, yielding a final sample of 48 participants. In total, we had 28 female and 20 male participants, with an average age of 39 (SD = 13) years and an average BMI of 24.0 (SD = 3.6) kg/m^2. Seventy-one percent of participants reported a professional job role, and 29% reported a clerical job role.

Study invitations were spread through intranet and work email. Participants could sign up voluntarily via an online survey. Inclusion criteria were as follows: doing desk-based work, minimum age of 18 years, and working at the office location for at least 16 working hours during the measurement week. This threshold was chosen to ensure that participants contributed at least 2 full working days of data, thereby capturing at least some variation in tasks, locations, and sitting patterns, but at the same time allowing employees with part-time contracts to take part, thereby maximizing sample size and representativeness. This consideration is particularly relevant in the Netherlands, where the proportion of employees working part-time is relatively high.

Given the exploratory nature of the study, we aimed to collect as much data as possible within the limits of the organizations (~118 eligible employees) and the study period. Given the many observations for the within-participant predictors, and based on similar previous research,[24] we anticipated adequate power to detect small-to-medium effects for the within-participant predictors. For the between-participants predictors, a sensitivity power analysis (see Supplementary Text 3 and Table S2 in the supplementary information, http://links.lww.com/JOM/C353) indicated that, given our sample size of $N = 48$, we could detect small-to-medium effects (HR ≥ 1.5 and HR $\leq 1/1.5 = 0.67$) with 80% power.

Procedure

After participants signed up for the study, they were invited for an introductory meeting (day 1). In the introductory meeting, the researcher explained the study procedure and participants received the study materials and filled in the questionnaire on individual characteristics and general work characteristics. Next, participants were instructed to apply the activity monitor (activPAL micro3) on their upper-right thigh before the end of that day, using the instructions provided, and to wear it continuously for days 2–8.

On days 2–8, participants received an online invitation via email to fill out the day-reconstruction questionnaire, including questions on sleep and wake times, work start and end times, daily work characteristics, and rooms that they spent time in. Participants were instructed to fill in the questionnaire at the end of their workday, right before leaving the office. On day 9, participants were instructed to remove and return the monitor. In the week after participation, participants received a debriefing as well as a personal report with their own sitting and activity behaviors.

Measures

A complete overview of the intake questionnaire and the daily questions that we used (in Dutch) can be found at the Open Science Framework (OSF; https://osf.io/8u4ev/?view_only=39f-0dd9237464faa85671a058ee088de).

Outcome: Stand-to-Sit and Sit-to-Stand Transitions

The activPAL3 monitor provides time-stamped activity codes: sedentary ("any waking behaviours characterized by an energy expenditure of ≤1.5 metabolic equivalents, while in a sitting, reclining, or lying posture"),[28] standing, or walking. The minimum sitting/upright period time was set at 10 seconds (ie, the device's default setting). In this study, standing and walking were taken together as *standing*, such that each row of our dataset contained either a stand-to-sit or a sit-to-stand transition. We identified and excluded activity monitor data during sleep and nonwear using participants' self-reported sleep and wake times from the daily questionnaire. We identified and excluded activity monitor data during nonwork hours using participants' self-reported work start and end times from the daily questionnaire.

Primary Predictors

Office Design/Room Design

Prior to data collection, we constructed a list of indoor design characteristics for offices and meeting rooms, based on prior research on office ergonomics and sitting behaviors[20,23] and on observations during worksite visits to the participating organizations. See Tables S3, S4, and S5 (http://links.lww.com/JOM/C353) for all design characteristics that were assessed. See Tables 1 and 2 for an overview of characteristics that were used in the data analysis after data reduction.

For all rooms that participants listed in the day reconstruction questionnaires (57 offices and 11 meeting rooms), the indoor design characteristics list was scored by the researcher (P.t.B.) during additional worksite visits. As a reliability check, the first assessment was performed by two researchers (P.t.B. and E.B.). Agreement was reached on all characteristics except three, on which disagreement was resolved through discussion, which was in turn used to further improve the scoring procedure of the subsequent worksite visits.

Workplace Spatial Layout

We calculated a set of workplace spatial layout characteristics for each office, based on worksite floorplans. We used the Spatial Metric Calculator (SMC) software tool,[22] which was developed by the Active Buildings study, funded by the National Institute for Health Research's School for Public Health Research (NIHR SPHR, UK).

We followed a similar procedure as Fisher et al,[22] taking the following steps: (1) We located all offices and shared facilities on the floorplans. As shared facilities, we used meeting rooms, kitchens/coffee points, printers/copiers, stairs, lifts, and bathrooms. (2) We drew a map of all possible walking routes between all offices and shared facilities, consisting of a set of straight lines and points indicating possible turning points (see Fig. 1 for an example). (3) Based on these walking routes, the software tool determined the shortest walking route between each office and other offices, and between offices and each shared facility in terms of distance (eg, meters) and in terms of the least number of turns (for the "centrality" measures). (4) We calculated 15 spatial layout characteristics (ie, *metrics*; see Table 3).

Secondary Predictors

Work Characteristics

Job role (professional vs clerical; see also Mullane et al[21]) was assessed by asking participants to self-report their current job title (open question) in the intake questionnaire. We then categorized these responses into "professional" versus "clerical." General work characteristics were assessed through self-report in the intake questionnaire, using selected and adapted subscales of the Questionnaire on the Experience and Evaluation of Work.[29] Work

TABLE 1. List of Office Design Characteristics and the Number of Observed Offices (67 Offices in Total) in each Category

Characteristic	Description	Values
Room size	Calculated from digital floor plans	Continuous (m²) Q25 21.5; Q50 25.0; Q75 19.0
Work spots	Number of desk–chair–PC combinations being used by employees	1 (27) 2 (11) 3 (12) 4 or more (17)
Desk size	"Standard" being approximately 2m²	Standard (50) Large (17)
Small cabinet with desk	Individual cabinet with 2 to 4 drawers, usually under the desk	Present (54) Absent (13)
Trash can	Trash can for normal trash	Within reach (53) Out of reach (14)
Waste paper bin	Trash can for paper trash	Within reach (52) Out of reach (15)
Large cabinets	Usually positioned against the walls	2 or more (40) Less than 2 (27)
Copy machine	Including copy machine, printers, or scanners	Present within reach (3) Present out of reach (4) Absent (60)
Hygiene equipment	Cleaning wipes and hand disinfectant	Present (17) Absent (50)
Air conditioning	Manually or centrally controlled	Present (61) Absent (6)
Paintings	Hanging or standing, for decorative purposes	Present (34) Absent (33)
Framed pictures	Personal pictures of employees, for decorative purposes	Present (22) Absent (45)
Plants	For decorative purposes	Present (30) Absent (37)
Wall color	"Colored" when part of the walls are not white	White (24) Colored (43)
Screen or board	A presentation screen, bulletin board, or whiteboard	Present (17) Absent (50)
Additional chairs and tables	Chairs and tables additional to individual work spots	Additional chairs and tables (24) Additional chairs (15) Absent (28)

pressure (six items), mental load (four items), job autonomy (four items), possibilities for contact (two items), interruptions during work (one item), and work-time control (three items) were assessed on a Likert scale ranging from (1) *never* to (4) *always*. For the one-item measure "interruptions during work," responses were highly unequal over categories (1 "never," 16 "sometimes," 23 "often," and 8 "always"), so we split the scale into two categories (*never/sometimes* vs *often/always*). Task variation (one item), organizational focus on stimulating physical activity (one item), and organizational focus on reducing sitting time (one item) were assessed on a scale from (1) *not at all* to (10) *very much*. See Table S1 (http://links.lww.com/JOM/C353) of the supplementary materials for descriptive statistics and intercorrelations of the general work characteristics. In addition, day-level work pressure (one item) and day-level task variation (one item) were assessed through self-report in the daily questionnaires, on a scale from (1) *not at all* to (10) *very much*.

Worksite Habits

The following worksite habits were assessed through self-report in the intake questionnaire, each with a single item: use of drinking cans (yes/no), use of trays for transporting food and drinks (yes/no), use of towels (paper/reusable), use of cups (mostly reusable/a combination of reusable and disposable), and use of paper versus digital documents (from [1] *paper only* to [10] *digital only*).

TABLE 2. List of Meeting Design Characteristics and the Number of Observed Meeting Rooms (11 Meeting Rooms in Total) in Each Category

Characteristic	Description	Values
Room size	Calculated from digital floor plans	Continuous (m²) Q25 19.5; Q50 25.0; Q75 29.0
Chairs		Continuous (count) Q25 6.5; Q50 8.0; Q75 9.0
Chair variation	Different types of chairs	Yes (4) No (7)
Tables		1 (9) 2 (2)
Large cabinets	Usually positioned against the walls	Absent (3) 1 (5) 2 or more (3)
Hygiene equipment	Cleaning wipes and hand disinfectant	Present (4) Absent (7)
Trash can	Trash can for all types of trash	Present (6) Absent (5)
Plants	For decorative purposes	Present (4) Absent (7)
Screen or board	A presentation screen, bulletin board or whiteboard	Present (6) Absent (5)
Beverages and tableware	Provision of beverages and/or tableware	Present (5) Beverages present (2) Absent (4)

Temporal Dynamics

To assess how the timing of stand-to-sit and sit-to-stand transitions varied throughout the day,[24] we calculated two time-varying predictors from the activity monitor data: (*a*) time of the day (in hours since midnight) and (*b*) active time in the preceding 5 hours (the total time participants spent active [nonsitting] in the 5 hours prior to each stand-to-sit and sit-to-stand transition; in minutes).

Participant Characteristics

For descriptive purposes, individual characteristics were assessed through self-report in the intake questionnaire and included the following: age (in years), gender (male/female/other), education level (highest completed level of education; multiple-choice), tenure (in years), marital status (multiple choice), weight (in kilograms), height (in centimeter), and physical activity during leisure time (from [1] *not at all physically active* to [10] *extremely physically active*). BMI was calculated as weight (kg)/height (m).[2] In addition, for each participant, we calculated the average daily sitting level as the average total sitting time per day (in hours) and the average daily moderate-to-vigorous physical activity (MVPA) level as the average daily time (in minutes) spent walking with MET (metabolic equivalent) values ≥3.

For sensitivity analyses, we also assessed the following characteristics: having a medical condition that hinders sitting or standing (yes/no), degree of medical condition hindering sitting or standing (from [1] *not at all* to [10] *very much*), and whether or not their personal desk was height adjustable (height adjustable into sitting and standing/height adjustable only for sitting/height adjustable by external part for ergonomic sitting/not height adjustable).

Data Analysis

All data and R code that were used for the analyses in this paper have been made publicly available at the Open Science

FIGURE 1. An example of a spatial map drawn in the spatial metric calculator tool. *Note.* The large, colored squares represent offices and shared facilities, with each color indicating an office or a certain type of facility. The small blue squares indicate possible turning points, which are connected by the blue lines to indicate possible walking routes between all offices and shared facilities.

Framework and can be accessed here: https://osf.io/8u4ev/?view_only=39f0dd9237464faa85671a058ee088de.

Data Preparation

Activity Monitor Data

We excluded all sitting and standing episodes that were >8 hours, as these were considered to indicate nonwear (ie, as a time period in which the participant did not wear the activPAL monitor)[30] or extreme values. We removed zero sitting episodes and eight standing episodes.

Data Merging

For each participant, all sitting episodes and standing episodes that fully (ie, both start time and end time) fell between the self-reported start time and end time of the period people spent in a certain room were linked to the characteristics of that room.

Cluster Analysis

We performed an exploratory cluster analysis to cluster rooms on their design characteristics. We performed this analysis for offices only, not for meeting rooms, as we had only 11 meeting rooms in our dataset. We used Gower distance as the distance metric, as this metric is suitable when using both dichotomous and continuous data.[31] We used agglomerative hierarchical clustering with complete linkages. Based on silhouette width plots, elbow plots, and descriptive statistics for clusters, we selected a number of clusters that yielded a meaningful interpretation of different categories of offices with different typical design characteristics.

Primary Analyses

We used multilevel time-to-event analysis[32] to model the timing of stand-to-sit and sit-to-stand transitions.[24] To predict the timing of stand-to-sit transitions, we fitted a shared frailty Cox regression model with event of interest being stand-to-sit transition, and the event time (in minutes) as the timing of the stand-to-sit transition since the previous sit-to-stand transition, that is, how long a participant had been standing before the stand-to-sit transition. As such, the model estimates the *hazard* of a stand-to-sit transition (ie, the momentary likelihood of sitting down while standing at any given minute). To predict the timing of sit-to-stand transitions, we fitted a shared frailty Cox regression model with event of interest being sit-to-stand transitions and the event time (in minutes) as the timing of the sit-to-strand transition since the previous stand-to-sit transition, that is, how long a participant had been sitting before the sit-to-stand transition. As such, the model estimates the *hazard* of a sit-to-stand transition (ie, the momentary likelihood of standing up while sitting at any given minute).

First, we fitted two Cox models (one for the hazard of a stand-to-sit transition and one for the hazard of a sit-to-stand transition) with room function (office vs meeting room) as a predictor. Second, we fitted two Cox models with *office design cluster* as a predictor. Third, we fitted two Cox models for each individual office design characteristic. Fourth, we fitted two Cox models for each workplace spatial layout characteristic.

TABLE 3. List of Workplace Spatial Layout Characteristics With and Descriptive Statistics (Median [Q50] and Interquartile Range [Q25; Q75])

Metric	Description	Q25; Q50; Q75
Average distance to offices (m)	… to all offices on the same floor	11.6; 14.2; 18.9
Average distance to meeting rooms (m)	… to all meeting rooms on the same floor	12.5; 16.6; 23.8
Distance to nearest meeting room (m)	… within the office building	16.6; 25.2; 33.73
Distance to nearest kitchen (m)	… within the office building	15.2; 22.5; 30.5
Average distance to copy machine (m)	… to all copy machines/printers on the same floor	7.4; 11.3; 20.4
Distance to nearest copy machine (m)	… nearest copy machine/printer within the office building	7.2; 10.6; 18.8
Distance to nearest lift (m)	… within the office building	11.7; 12.6; 23.5
Average distance to stairs (m)	… all stairs on the same floor	7.8; 12.9; 15.5
Distance to nearest stairs (m)	… within the office building	7.4; 11.9; 14.4
Average distance to bathroom (m)	… all bathrooms on the same floor	10.3; 14.3; 19.1
Distance to nearest bathroom (m)	… within the office building	10.5; 14.6; 19.0
Average distance to all shared facilities (m)	… all shared facilities on the same floor	9.4; 12.5; 17.8
Average distance to all nearest shared facilities (m)	… average of all nearest distance to each shared facility	14.5; 17.8; 20.5
Centrality (number of turns)	Inverse of the average number of turns needed to reach each point on the spatial graph	0.14; 0.17; 0.19
Centrality (angular deviation)	Inverse of the average angular deviation (°) needed to reach each point on the spatial graph	0.0018; 0.0020; 0.0023

To take into account that our data had a multilevel structure (each participant has multiple stand-to-sit and sit-to-stand transitions; ie, transitions are nested within participants), we added a *frailty term* for participant in all models. This frailty term accounted for the random variability in baseline hazard between individuals (akin to random intercepts in linear mixed-level models). We used sum-to-zero contrasts for the office design cluster predictor, and treatment contrasts for other categorical predictors. To facilitate interpretation, centrality (number of turns) and centrality (angular deviation) were standardized, but descriptive statistics are provided for the unstandardized variable. In all models, we used Efron's method for handling ties.[33] For all models, the proportionality assumption was met, based on the examination of Schoenfeld residuals.[33]

To draw conclusions, we interpreted hazard ratios (HRs) and 95% confidence intervals (95% CIs) for our predictors. For individual office design and workplace spatial layout characteristics, we summarized HRs and 95% CIs in a dot-whisker diagram.

Secondary Analyses

Work Characteristics and Worksite Habits

We explored the association between general and daily work characteristics and worksite habits on the one hand, and stand-to-sit and sit-to-stand transitions on the other hand, with dot–whisker diagrams of HRs and confidence intervals. Continuous work characteristics were standardized to facilitate interpretation. Descriptive statistics are provided for the unstandardized variables. In case of significant associations with any of the work characteristics, we refitted the models of the primary analyses while including the respective work characteristics predictor as covariate, to see whether it would change the pattern of results.

Temporal Dynamics

We also assessed whether the timing of stand-to-sit and sit-to-stand transitions was predicted by time of the day and by activity in the preceding 5 hours. We fitted two shared frailty Cox models (one for stand-to-sit transitions and one for sit-to-stand transitions) for each predictor. For details on calculation, see ten Broeke et al.[24]

Sensitivity Analyses

For each model, we identified influential observations as dfbeta residuals with an absolute value $>2/\sqrt{n}$,[34] and we conducted a sensitivity analysis in which we refitted the model while excluding these influential observations. When refitting the model changed the interpretation of the results, we report this.

RESULTS

Descriptives and Intercorrelations

On average, participants reported 3.5 (SD = 1.1) workdays and 29.5 (SD = 9.8) work hours during the measurement week. Considering both work and nonwork time, participants on average engaged in 10.1 hours of sitting (SD = 1.3) and 50 minutes of moderate-to-vigorous physical activity (SD = 20) per day. Nine participants had a height-adjustable desk, but having a height-adjustable desk was not associated with the timing of stand-to-sit transitions (HR, 1.07; 95% CI, 0.72–1.59) or sit-to-stand transitions (HR, 1.26; 95% CI, 0.70–2.27).

Participants, on average, engaged in 57 stand-to-sit and sit-to-stand transitions per workday, which yielded a total of 6178 stand-to-sit transitions (106 in meeting rooms and 5328 in offices) and 6220 sit-to-stand transitions (100 in meeting rooms and 5275 in offices).

Primary Analyses

Room Function

Room function did not significantly predict the hazard of sitting down when standing (HR, 1.02; 95% CI, 0.83–1.25) or the hazard of standing up when sitting (HR, 1.03; 95% CI, 0.84–1.26). However, according to the examination of residuals, these results were affected by eight influential observations. Three of these stemmed from the same participant, who had unusually long sitting episodes (>65 minutes) in meeting rooms in 3 different days. Three further influential observations stemmed from three participants who sat in the same room at the same time (50–70 minutes), likely reflecting one unusually long meeting. When excluding these eight influential observations, room function significantly predicted the hazard of standing up when sitting (HR, 1.59; 95% CI, 1.28–1.97). In meeting rooms, participants had a 59% higher momentary likelihood to stand up when sitting compared to in offices.

Office Design

Cluster Solution

The clustering algorithm yielded a solution with seven clusters (for details, see Supplementary Text 4 and Table S6 of the supplementary information, http://links.lww.com/JOM/C353). We labeled the clusters based on the characteristics that distinguished them from other clusters. See Table 4 for a summary of the results; see Table S7 (http://links.lww.com/JOM/C353) of the supplementary information for a full overview.

TABLE 4. Summary Description of Office Design Clusters

Cluster	Cluster Name	N (Offices)	Cluster Description
Cluster 1	Small shared offices with screens/boards	7	Relatively small, shared offices, with a presentation screen and/or whiteboard and paintings
Cluster 2	Large desks and large cabinets	10	Private and shared offices with large desks and many large cabinets
Cluster 3	Extra furniture and decorations	13	Private and shared offices with additional chairs (and tables), and various decorations*
Cluster 4	Few large cabinets	12	Relatively small private and shared offices with few large cabinets, and only sometimes additional chairs (and tables)
Cluster 5	Large cabinets and few decorations	20	Private and (mostly) shared offices with many large cabinets, no additional chairs and tables and few decorations*
Cluster 6	Private offices	7	Private offices with many large cabinets, additional chair and tables, and a presentation screen or whiteboard
Cluster 7	Large shared offices with trash cans out of reach and few decorations	3	Relative large, shared offices with trash cans typically out of reach, no additional chairs and tables, and few decorations*

*Decorations refer to paintings, pictures, and plants.

Associations Between Office Design Clusters and Stand-to-Sit and Sit-to-Stand Transitions

Cluster significantly predicted the hazard of sitting down when standing (see Fig. 2). Participants sat down significantly sooner (ie, stood shorter) in cluster 1 offices ("small shared offices with screens/boards"; HR, 1.34; 95% CI, 1.05–1.70). Participants sat down later (ie, stood longer) in cluster 7 offices ("large shared offices with trash cans out of reach and few decorations"; HR, 0.74; 95 CI, 0.56–0.99). Cluster did not significantly predict the hazard of standing up when sitting (see Fig. 2).

Office Design Characteristics

We next looked at associations with individual office design characteristics rather than combinations. Figure 3 shows that a few office design characteristics predicted the hazard of sitting down when standing. Participants sat down later (ie, longer standing, HR<1) in offices with two work stations versus with one work station (HR, 0.75; 95% CI, 0.59–0.94) and in offices with additional chairs (HR, 0.80; 95% CI, 0.68–0.95). Participants sat down sooner (ie, shorter standing, HR>1) in offices with framed pictures (HR, 1.20; 95% CI, 1.03–1.39), but in the sensitivity analysis excluding influential observations, this association was insignificant (95% CI, 0.99–1.34).

Figure 3 shows that a few office design characteristics predicted the hazard of standing up when sitting. Participants stood up sooner (ie, shorter sitting) in offices with small cabinets under the desks (HR, 1.23; 95% CI, 1.01–1.50) and in offices that had trash cans (HR, 1.25; 95% CI, 1.02–1.52) and waste paper bins (HR, 1.43; 95% CI, 1.18–1.52) within reach. However, in the sensitivity analysis that excluded influential observations, the associations with small cabinets (95% CI, 0.88–1.33) and with trash cans (95% CI, 0.98–1.48) were nonsignificant.

Meeting Room Design Characteristics

Figure 4 shows that none of the meeting room design characteristics were associated with the hazard of standing up when sitting or the hazard of sitting down when standing.

Workplace Spatial Layout

Figure 5 shows that only the distance to the nearest kitchen significantly predicted the hazard of sitting down when standing: Participants sat down sooner (ie, shorter standing; HR, 1.01; 95% CI, 1.00–1.01) in offices with a larger distance to the nearest kitchen. Workplace spatial layout characteristics did not predict the hazard of standing up when sitting.

Secondary Analyses

Work Characteristics

HRs and 95% CIs for all work characteristics in relation to the hazard of sitting down when standing and the hazard of standing up when sitting are presented in Figure S1 and Table S7 of the supplementary information (http://links.lww.com/JOM/C353). Only work-time control was significantly associated with the hazard of sitting down when standing. Participants who reported more work-time control sat down later (ie, stood longer; HR, 0.89; 95% CI, 0.80–0.99). Work characteristics were not significantly related to the hazard of standing up when sitting.

For each of the primary analyses, we conducted a sensitivity analysis including work-time control as a covariate. When including work-time control, cluster 1 did no longer significantly predict the hazard of sitting down when standing (95% CI, 0.96–1.54). An additional regression analysis indicated that cluster 1 was negatively related to work-time control ($b=-0.69$, $P=0.006$). Therefore, it seems

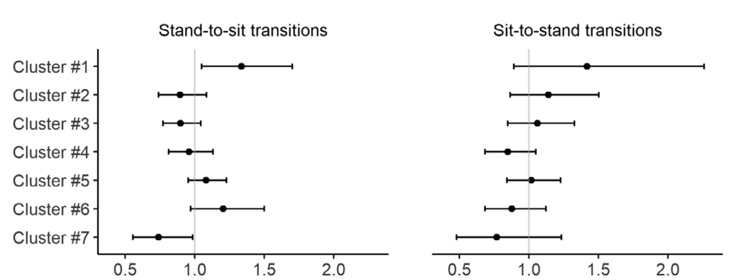

FIGURE 2. Hazard ratio's and 95% confidence intervals for the associations between office design cluster and the hazard of sitting down when standing (stand-to-sit transitions) and the hazard of standing up when sitting (sit-to-stand transitions). When HR>1, this means that participants sat down sooner (left panel) or stood up sooner (right panel). *Note.* Sum-to-zero contrasts were used for office design cluster.

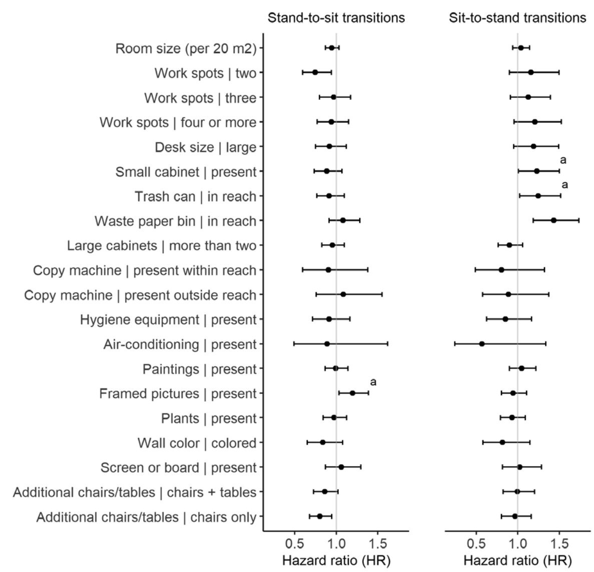

FIGURE 3. Hazard ratios and 95% confidence intervals for the associations between individual office design characteristics and the hazard of sitting down when standing (stand-to-sit transitions) and the hazard of standing up when sitting (sit-to-stand transitions). When HR>1, this means that participants sat down sooner (left panel), or stood up sooner (right panel). *Note.* To improve readability, room size was transformed such that 1 unit depicts 20 m^2.[a] The associations between framed pictures and stand-to-sit transitions, between small cabinets and sit-to-stand transitions, and between trash cans and sit-to-stand transitions were nonsignificant when excluding influential cases.

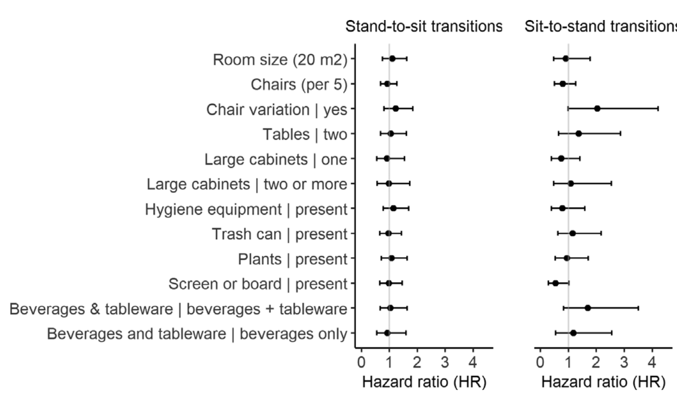

FIGURE 4. Hazard ratios and 95% confidence intervals for the associations between individual meeting room design characteristics and the hazard of sitting down when standing (stand-to-sit transitions) and the hazard of standing up when sitting (sit-to-stand transitions). When HR>1, this means that participants sat down sooner (left panel), or stood up sooner (right panel). *Note.* To improve readability, room size and chairs were transformed such that 1 unit depicts 20 m^2 and five chairs, respectively.

that offices in this cluster were more often visited by participants who reported *lower* work-time control, which explained why participants in these offices sat down sooner. In other words, the association between cluster 1 and sitting down may be considered a spurious association that is due to a third variable, namely, work-time control.

When including work-time control, the distance to nearest kitchen also did no longer significantly predict the hazard of sitting down when standing (95% CI, 0.9996–1.01). An additional correlation analysis indicated that the distance to the nearest kitchen was *positively* related to work-time control ($r=0.15$, $P<0.001$). Rather than a third variable problem, this suggests that the relatively small association between distance to nearest kitchen and sitting down may not have been robust against a slight reduction in statistical power by adding an additional covariate (ie, work-time control).

Worksite Habits

HRs and 95% CIs for all worksite habits in relation to the hazard of sitting down when standing and the hazard of standing up when sitting are presented in Figure S2 (http://links.lww.com/JOM/C353). Only the use of digital versus paper documents was related to the hazard of sitting down when standing: Participants who reported using a mix of digital and paper documents sat down sooner (ie, stood shorter) compared to participants who reported using only digital documents (HR, 1.30; 95% CI, 1.04–1.64). Worksite habits were not significantly related to the hazard of standing up when sitting.

Temporal Dynamics

Time of the Day

In contrast to ten Broeke et al,[20] time of the day did not significantly predict the hazard of sitting down when standing (HR, 1.00; 95% CI, 0.99–1.01). In line with ten Broeke et al,[20] time of the day significantly predicted the hazard of standing up when sitting (HR, 1.01; 95% CI, 1.001–1.02). Later on the workday, participants stood up sooner (ie, sat shorter) compared to earlier on the workday.

Activity in the Preceding 5 Hours

In contrast to ten Broeke et al,[20] activity in the preceding 5 hours did not significantly predict the hazard of sitting down when standing (HR, 1.00; 95% CI, 0.998–1.001). In line with ten Broeke et al,[24] activity in the preceding 5 hours significantly predicted the hazard of standing up when sitting (HR, 1.001; 95% CI, 1.000–1.002). After more-than-usual activity in the preceding 5 hours, participants stood up sooner (ie, sat shorter).

DISCUSSION

In this study, we explored the relation between office/room design, workplace spatial layout, and office workers' sitting patterns. In short, we found that office workers' sitting patterns were associated with (*a*) room function, (*b*) typical combinations (ie, clusters) of office design characteristics, and (*c*) a few individual design characteristics, including the number of workstations in a room, the presence of additional chairs, and the presence of a waste paper bin within arm's reach.

Room Function

We found that participants had a stronger tendency for prolonged sitting in offices than in meeting rooms. This is consistent with findings from a previous study that tracked office workers' locations within the office building and showed that they mainly engaged in prolonged sitting at their desk location.[35] Together, these findings may reflect the different goals and tasks that people pursue in these rooms. In offices, people probably engage in prolonged sitting to engage in focused computer work. In meeting rooms, people may stand up to greet a client, to draw on a whiteboard, or to hand over materials to other meeting attendees. In general, this is consistent with the idea that people often sit or stand to achieve another, more meaningful goal.[18,19]

Office Design Characteristics

We found that participants had a stronger tendency for prolonged standing in large, shared offices with trash cans out of reach and with few decorations (cluster 7). In addition, participants had a weaker tendency for prolonged standing in small, shared offices with screens or bulletin boards (cluster 1), but this association was alternatively explained by work-time control (explained later in this discussion). Interestingly, these combinations of design characteristics were differently associated with sitting patterns from those of individual design characteristics. For instance, room size, the presence of a screen or bulletin board, the presence of decorations, and having trashcans present within arm's reach were in themselves not associated with the timing of stand-to-sit transitions. In other words, the way design characteristics are put together may have a different impact on office workers' sitting patterns than individual design characteristics in that office. This is in line with the classic idea from Gestalt theory: "the whole is more than the sum of its parts."[36]

Still, we also identified some individual office design characteristics that were associated with prolonged sitting and standing by themselves. First, we found that office workers had a stronger tendency for prolonged standing in shared offices compared to private offices. It may be that shared offices offer greater opportunities for face-to-face interaction with colleagues. In line with this explanation, previous research showed that office workers engaged in more and longer face-to-face interactions when their workstation was located closer to coworkers.[37] Speculatively, in shared offices, employees may remain standing while interacting with colleagues, whereas in private offices, there are no such invitations for face-to-face interaction.

Second, office workers in our study had a stronger tendency for prolonged standing in offices with additional chairs. This finding is somewhat counterintuitive. Based on affordance theory,[9] having multiple chairs available would provide a stronger invitation for sitting down. Potentially, workers of the participating organizations used offices with additional chairs for specific work-related purposes, such as meeting colleagues or clients, which in turn could have explained the association with prolonged standing. These speculations should, however, be tested in future research before drawing conclusions.

Third, participants had a stronger tendency for prolonged sitting when waste paper bins were positioned out of reach. This finding does not support the idea that the intention of throwing away waste provides a trigger for standing up.[20] Although this finding is hard to explain, it is worth noting that office workers may combine several tasks, such as waste disposal and getting a drink, involving a single sit-to-stand transition but potentially a longer standing break. This speculation is in line with our finding that in offices in cluster 7 (ie, large, shared offices, with trash cans out of reach and few decorations), participants stood longer.

Workplace Spatial Layout

We did not find robust evidence that the workplace spatial layout was associated with tendencies for prolonged sitting or standing.

Work-Time Control

Importantly, the association between cluster 1 offices and prolonged standing was alternative explained by a third variable: office workers' experienced work-time control. Specifically, offices in cluster 1 were more often visited by people experiencing low work-time control. Low work-time control, in turn, was associated with sitting down sooner (shorter standing). Therefore, employees may have shown shorter standing episodes in these offices because they felt less liberty about when, how, and how long they take breaks during the workday (ie, low work-time control[38]), rather than the design of the offices.

Temporal Dynamics

With regard to time of day, we found that office workers had a stronger tendency for prolonged sitting earlier in the workday. Later in the workday, they stood up sooner. This finding replicates previous work in a different population (employees from the United Kingdom).[24] This pattern is somewhat counterintuitive, as employees typically feel more mental fatigue later in the day.[39,40] If one assumes that mental fatigue is associated with longer sitting episodes, one would expect longer sitting in afternoons. However, our findings are in line with modern accounts of fatigue that perceive fatigue as a signal to switch to another task.[41,42] When employees feel fatigued later in the workday, they may have a stronger tendency to switch to different work tasks that involve standing up (eg, print some documents) and/or to take breaks that involve standing up (eg, walk to the coffee machine).

Overall Interpretation of Findings

Taken together, our findings are consistent with the idea that specific design features may—at least to some extent—shape people's prolonged sitting and standing at work.[9,11,12] Taking this idea one step further, our findings seem to suggest two general principles regarding the potential impact of workplace design on sitting:

First, office designs as a whole may differently affect office workers' sitting than the individual design features in it.

Second, the workplace design may shape office workers' sitting patterns mainly in an indirect way, rather than a direct way. That is, from our data, we learned that office workers' tendencies for prolonged sitting and standing were mainly shaped by room function (office versus meeting rooms) and opportunities for face-to-face interaction (private vs shared offices). In other words, rather than a direct effect of design, the workplace design may shape

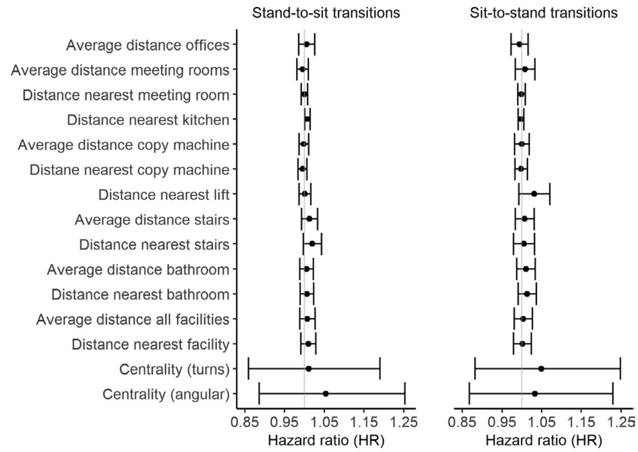

FIGURE 5. Hazard ratios and 95% confidence intervals for the associations between workplace spatial layout characteristics (in meters) and the hazard of sitting down when standing (stand-to-sit transitions) and the hazard of standing up when sitting (sit-to-stand transitions). This means that participants sat down sooner (left panel) or stood up sooner (right panel).

sitting patterns indirectly through the specific work tasks and/or for face-to-face interactions that a room was designed for. This principle is in line with the idea that people's tendencies for prolonged sitting and standing are mainly determined by their ongoing (work) tasks and goals.[18,19] Therefore, to understand sitting behaviors at work and the potential impact of workplace design, it is crucial to consider employees' ongoing work tasks and goals.

Strengths and Limitations

A key strength of this study is that it moved beyond the common practice of zooming in on a single design feature (eg, activity-permissive workstations) when attempting to understand sitting behaviors. We examined a large number of office design characteristics and workplace spatial layout characteristics in relation to people's sitting patterns at work. Consequently, this study painted a broad picture of how office design is related to sitting. We achieved this big-picture perspective by combining and analyzing several rich sources of data (ie, accelerometery-based measures of sitting behaviors, self-reported location data, observations of the physical environment, intake questionnaires). Moreover, our broad assessment of both workplace design and work characteristics enabled us to disentangle the potential impact of the environment versus the impact of the nature and context of work.

We note four limitations. First, participants in this study signed up voluntarily and were compensated for their participation with a personal report on their sitting patterns. Thus, our participants may have been relatively interested in learning about, and potentially improving, their own sitting behaviors. Although our sample's physical activity levels were largely in line with the general Dutch population,[43] our sample may not be representative of the larger population of desk-based workers.

Second, the list of office design characteristics that was constructed for this study was tailored to the organizations that participated in the study. Therefore, our data are constrained by the variation in office design characteristics that naturally occurred at these specific worksites. We note that the workplace design of these organizations could be characterized as traditional (eg, workstations were not shared between employees; all offices, whether private or shared, we enclosed). Thus, the associations between workplace design and office workers' sitting patterns may differ in other types of office environments, such as open plan office environments[23] or environments designed for activity-based working.[44]

Third, we captured sitting behavior of, on average, 3.5 workdays per participant, with some participants only working for 2 days during the measurement week. The minimum of 16 work hours at the office allowed employees with a part-time contract to be included, thereby increasing sample size and representativeness. However, this limited time frame may not fully capture the variability in exposure to different office design features. Future research with more extensive measurement periods is necessary to provide a full picture of how workplace design shapes sitting patterns over time.

Fourth, we relied on a single modeling approach for analyzing sit-to-stand and stand-to-sit transitions, namely, shared frailty Cox models. We note that other approaches for recurrent-event data could also have been considered, such as Andersen-Gill for or Prentice-Williams-Peterson models, each with their own strengths. However, shared frailty Cox models were particularly appropriate for the present study because they explicitly account for unobserved between-person heterogeneity in baseline hazard—and important feature of stand-to-sit and sit-to-stand transitions—and have provided useful insights into sitting patterns in previous work.[24,25] Nevertheless, future research could compare alternative modeling approaches to further evaluate the robustness of our findings.

Implications for Interventions and Future Research

Our study identified several features of physical office environments that are associated with an increased risk for unhealthy sitting behaviors. Specifically, future research and interventions should focus on offices—and in particular, private offices—rather than meeting rooms. Intervention strategies that aim to encourage standing during meetings[45] may be a start, but not a sufficient solution to the problem of prolonged sitting at work. Moreover, interventions seem most needed during mornings, when prolonged sitting is most prevalent.

Our data further suggest that that it may be more fruitful to focus on combinations of design features that together make up an office design, rather than individual design features, as these may have different effects on sitting behaviors. Moreover, future research and interventions should consider the work tasks and/or face-to-face interactions that office designs may invite. In particular, future studies could examine sitting patterns in different variations of an activity-based work setup: a shared workplace with a variety of rooms and areas that are designed for specific tasks (eg, a phone room, quiet focus areas) instead of each worker having a permanent personal workstation.[44]

Finally, future research needs to address the impact of work tasks and work characteristics on office workers' sitting patterns. Although these characteristics may play a key role in determining people's sitting behaviors, research on this topic is still in its infancy. For example, which types of work tasks (eg, reading, writing, communication via email, phone calls) are associated with prolonged sitting? And, how does the scheduling of work tasks across the day impact employees' tendencies for prolonged sitting and standing? Answers to such questions should provide starting points for the design of activity-based work environments, as well as for the development of interventions that aim to increase the frequency of sit-to-stand transitions.

CONCLUSION

To improve office workers' health, well-being and productivity, we need workplace environments that discourage prolonged sitting and encourage frequent standing breaks. Based on our findings, designers and practitioners should focus intervention initiatives on offices, and especially private offices, rather than meeting rooms. More generally, we emphasize that workplace design may mainly impact office workers' sitting patterns because different room designs may afford certain work tasks and/or face-to-face interactions. Accordingly, we highlight that the work that employees do—and the way they do it—may play an important, but understudied, role in office workers' sitting patterns. Understanding the role of work schedules and tasks, in interaction with workplace environments, may be key to developing effective interventions for healthier sitting.

REFERENCES

1. Bailey DP. Sedentary behaviour in the workplace: prevalence, health implications and interventions. Br Med Bull 2021;137:42–50.
2. Prince SA, Elliott CG, Scott K, Visintini S, Reed JL. Device-measured physical activity, sedentary behaviour and cardiometabolic health and fitness across occupational groups: a systematic review and meta-analysis. Int J Behav Nutr Phys Act 2019;16:30.
3. Ryan CG, Dall PM, Granat MH, Grant PM. Sitting patterns at work: objective measurement of adherence to current recommendations. Ergonomics 2011;54:531–538.
4. Saunders TJ, Mcisaac T, Douillette K, et al . Sedentary behaviour and health in adults: an overview of systematic reviews. Appl Physiol Nutr Metab 2020;45(10 (Suppl. 2)):S197–S217.
5. Chandrasekaran B, Pesola AJ, Rao CR, Arumugam A. Does breaking up prolonged sitting improve cognitive functions in sedentary adults? A mapping review and hypothesis formulation on the potential physiological mechanisms. BMC Musculoskelet Disord 2021;22:274.
6. Giurgiu M, Nissen R, Müller G, Ebner-Priemer UW, Reichert M, Clark B. Drivers of productivity: being physically active increases yet sedentary bouts and lack of sleep decrease work ability. Scand J Med Sci Sports 2021;31:1921–1931.
7. Drake E, Ekblom MM, Ekblom O, Kallings LV, Blom V. Cardiorespiratory fitness and device-measured sedentary behaviour are associated with sickness absence in office workers. Int J Environ Res Public Health 2020;17:628.
8. Gibson J. The Theory of Affordances. In: The Ecological Approach to Visual Perception. Boston: Houghton Mifflin; 1977.
9. Rietveld E. Situating the embodied mind in a landscape of standing affordances for living without chairs: materializing a philosophical worldview. Sports Med 2016;46:927–932.
10. Withagen R, de Poel HJ, Araújo D, Pepping G-J. Affordances can invite behavior: reconsidering the relationship between affordances and agency. New Ideas Psychol 2012;30:250–258.
11. Hadgraft NT, Dunstan DW, Owen N. Models for understanding sedentary behaviour. In: Leitzmann MF, Jochem C, Schmid D, eds. Sedentary Behaviour Epidemiology. Cham: Springer International Publishing:381–403.
12. Sallis JF, Owen N, Fisher EB. Ecological models of health behavior. In: Glanz K, Rimer BK, Viswanath K, eds. Health Behavior: Theory, Research, and Practice. Hoboken, NJ: John Wiley & Sons; 2015.
13. Chu AH, Ng SH, Tan CS, Win AM, Koh D, Müller-Riemenschneider F. A systematic review and meta-analysis of workplace intervention strategies to reduce sedentary time in white-collar workers. Obes Rev 2016;17:467–481.
14. Zhu X, Yoshikawa A, Qiu L, Lu Z, Lee C, Ory M. Healthy workplaces, active employees: a systematic literature review on impacts of workplace environments on employees' physical activity and sedentary behavior. Build Environ 2020;168:106455.
15. Engelen L, Dhillon HM, Chau JY, Hespe D, Bauman AE. Do active design buildings change health behaviour and workplace perceptions? Occup Med (Lond) 2016;66:408–411.
16. Gorman E, Ashe MC, Dunstan DW, et al . Does an 'activity-permissive' workplace change office workers' sitting and activity time? PLoS One 2013;8:e76723.
17. Jancey JM, McGann S, Creagh R, Blackford KD, Howat P, Tye M. Workplace building design and office-based workers' activity: a study of a natural experiment. Aust N Z J Public Health 2016;40:78–82.
18. Gardner B, Flint S, Rebar AL, et al . Is sitting invisible? Exploring how people mentally represent sitting. Int J Behav Nutr Phys Act 2019;16:85.
19. ten Broeke P, Gardner B, Beckers DGJ, Geurts SAE, Bijleveld E. Why do people sit? A framework for targeted behavior change. Health Psychol Rev 2023;17:641–654.
20. Löffler D, Sperlich B, Wan J, Knött J, Vogel A, Hurtienne J. Office ergonomics driven by contextual design. Ergon Des Q Hum Factors Appl 2015;23:31–35.
21. Mullane SL, Toledo MJL, Rydell SA, et al . Social ecological correlates of workplace sedentary behavior. Int J Behav Nutr Phys Act 2017;14:117.
22. Fisher A, Ucci M, Smith L, et al . Associations between the objectively measured office environment and workplace step count and sitting time: cross-sectional analyses from the active buildings study. Int J Environ Res Public Health 2018;15:1135.
23. Duncan MJ, Short C, Rashid M, Cutumisu N, Vandelanotte C, Plotnikoff RC. Identifying correlates of breaks in occupational sitting: a cross-sectional study. Build Res Inf 2015;43:646–658.
24. ten Broeke P, Olthof M, Beckers DGJ, et al . Temporal dynamics of sitting behavior at work. Proc Natl Acad Sci U S A 2020;117:14883–14889.
25. ten Broeke P, van Bakel BMA, Bakker EA, et al . Sitting patterns in cardiovascular disease patients compared With healthy controls and impact of cardiac rehabilitation. Scand J Med Sci Sports 2022;32:1639–1649.
26. Biddle SJH, Bennie J. Editorial for special issue: advances in sedentary behavior research and translation. AIMS Public Health 2017;4:33–37.
27. Kahneman D, Krueger AB, Schkade DA, Schwarz N, Stone AA. A survey method for characterizing daily life experience: the day reconstruction method. Science 2004;306:1776–1780.
28. Tremblay MS, Aubert S, Barnes JD, et al . Sedentary Behavior Research Network (SBRN)—Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act 2017;14:75.
29. van Veldhoven M, Meijman T. Het meten van psychosociale arbeidsbelasting met een vragenlijst. Amsterdam, the Netherlands: NIA; 1994.
30. Edwardson CL, Winkler EAH, Bodicoat DH, et al . Considerations when using the activPAL monitor in field-based research with adult populations. J Sport Health Sci 2017;6:162–178.
31. Pavoine S, Vallet J, Dufour A-B, Gachet S, Daniel H. On the challenge of treating various types of variables: application for improving the measurement of functional diversity. Oikos 2009;118:391–402.
32. Lougheed JP, Benson L, Cole PM, Ram N. Multilevel survival analysis: studying the timing of children's recurring behaviors. Dev Psychol 2019;55:53–65.
33. Singer JD, Willet JB. Applied Longitudinal Data Analysis. Oxford: Oxford University Press; 2003.
34. Belsley DA, Kuh E, Welsch RE. Regression Diagnostics: Identifying Influential Data and Sources of Collinearity. Hoboken, NJ: John Wiley & Sons; 2005.
35. Spinney R, Smith L, Ucci M, et al . Indoor tracking to understand physical activity and sedentary behaviour: exploratory study in UK Office buildings. PLoS One 2015;10:e0127688.
36. Wertheimer M. Gestalt theory. In: A source book of Gestalt psychology. London, England: Kegan Paul, Trench, Trubner & Company; 1938:1–11.
37. Sugiyama T, Hadgraft N, Clark BK, et al . Office spatial design attributes, sitting, and face-to-face interactions: systematic review and research agenda. Build Environ 2021;187:107426.
38. Härmä M. Workhours in relation to work stress, recovery and health. Scand J Work Environ Health 2006;32:502–514.
39. Dora J, van Hooff M, Geurts S, Kompier M, Bijleveld E. Fatigue, boredom and objectively measured smartphone use at work. R Soc Open Sci 2021;8:201915.
40. van Hooff ML, Geurts SA, Kompier MA, Taris TW. "How fatigued do you currently feel?" Convergent and discriminant validity of a single-item fatigue measure. J Occup Health 2007;49:224–234.
41. Dora J, van Hooff MLM, Geurts SAE, Kompier MAJ, Bijleveld E. The effect of opportunity costs on mental fatigue in labor/leisure trade-offs. J Exp Psychol Gen 2022;151:695–710.
42. Kurzban R, Duckworth A, Kable JW, Myers J. An opportunity cost model of subjective effort and task performance. Behav Brain Sci 2013;36:661–679.
43. RIVM. LSM-A Bewegen en Ongevallen/Leefstijlmonitor. RIVM. Available from: https://www.sportenbewegenincijfers.nl/kernindicatoren/zitgedrag#node-zitgedrag. 2021. Accessed November 8, 2022.
44. Foley B, Engelen L, Gale J, Bauman A, Mackey M. Sedentary behavior and musculoskeletal discomfort are reduced when office workers trial an activity-based work environment. J Occup Environ Med 2016;58:924–931.
45. Stray V, Sjøberg DIK, Dybå T. The daily stand-up meeting: a grounded theory study. J Syst Softw 2016;114:101–124.

