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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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Abstract

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 behaviour, 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 behaviour during work
- Discuss the role of room function and work characteristics in the association between office design and office workers' sitting behaviour during work

Associations Between Room Function, Office Design, Workplace Spatial Layout and Sitting Patterns During Office Work: A Field Study

Adults with an office job tend to sit a lot during work. The average office worker spends 70–80% (~6 hours) of their worktime 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 min) [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 wellbeing, 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 behaviours. 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 behaviours* posit that supportive (physical) environments are a necessary condition for health behaviours change [11,12]. So, 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?

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, i.e., whether an activity-permissive workstation (e.g., a height-adjustable desks or a pedal machines; [13,14] is present. Some other studies have compared office workers' sitting behaviours before and after the relocation to a completely different office environment [15–17]. Both types of studies generally show a ~20–125 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—e.g., 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 (i.e., 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 (e.g., goal: focused work) versus in meeting rooms (e.g., 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 (e.g., 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—i.e., 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 behaviours has traditionally analysed sitting behaviours on an aggregated level (by analysing *total sitting time*, e.g., per day). By contrast, following recent developments [19,24,25], we analysed 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 behaviours that people engage in and that we can predict, explain, and change, and therefore useful targets for interventions [19]. Second, by modelling the timing of stand-to-sit and sit-to-stand transitions (i.e., 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—e.g., 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 (e.g., work pressure; between-participants), daily work characteristics (e.g., daily task variation; within-participants), and worksite habits (e.g., the use of digital versus paper documents; between-participants). Finally, to replicate previous findings [24] we also analysed 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=500665d3578948838c337617978e4e06). A detailed overview of methods and data analysis is provided in the 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 in total ~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) and an average BMI of 24.0 (*SD* = 3.6). 71% of participants reported a professional job role, 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: Doing desk-based work, minimum age of 18, 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 two 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 maximising 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 ≤ 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 behaviours.

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=39f0dd9237464faa85671a058ee088de).

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 (i.e., 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 non-wear using participants' self-reported sleep and wake times from the daily questionnaire. We identified and excluded activity monitor data during non-work 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 behaviours [20,23] and on observations during worksite visits to the participating organizations. See Table S3, Table S4 and Table S5 (http://links.lww.com/JOM/C353) for all design characteristics that were assessed. See Table 1 and Table 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 (PB) during additional worksite visits. As a reliability check, the first assessment was performed by two researchers (PB and EB). 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 Figure 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 (e.g., meters), and in terms of the least number of turns (for the 'centrality' measures). (4) We calculated 15 spatial layout characteristics (i.e., *metrics;* see Table 3).

Secondary predictors

Work characteristics. Job role (professional vs clerical; see also[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 pressure (6 items), mental load (4 items), job autonomy (4 items), possibilities for contact (2 items), interruptions during work (1 item), and worktime control (3 items) were assessed on a Likert scale ranging from (1) *never* to (4) *always*. For the 1-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 (1 item), organizational focus on stimulating physical activity (1 item), and organizational focus on reducing sitting time (1 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 (1 item) and day-level task variation (1 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), use of paper versus digital documents (from [1] *paper only* to [10] *digital only*).

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 [non-sitting] 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: 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 centimetre), 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 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 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 h, as these were considered to indicate non-wear (i.e., as a time period in which the participant did not wear the activPAL monitor) [30] or extreme values. We removed 0 sitting episodes and 8 standing episodes.

Data merging. For each participant, all sitting episodes and standing episodes that fully (i.e., 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, i.e., 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 (i.e., 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, i.e., 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 (i.e., 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 predictor. Second, we fitted two Cox models with *office design cluster* as 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.

To take into account that our data had a multi-level structure (each participant has multiple stand-to-sit and sit-to-stand transitions, i.e., 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 examination of Schoenfeld residuals[33].

To draw conclusions, we interpreted Hazard Ratios (HRs) and 95% confidence intervals 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 were 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 [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 non-work 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, 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, CI [0.84, 1.26]). However, according to examination of residuals, these results were affected by 8 influential observations. Three of these stemmed from the same participant, who had unusually long sitting episodes (> 65 minutes) in meeting rooms in three 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 8 influential observations, room function significantly predicted the hazard of standing up when sitting (*HR* = 1.59, 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 7 clusters (for details, see Supplementary Text 4 and Table S6 of the supplementary information, http://links.lww.com/JOM/C353). We labelled 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.

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 Figure 2). Participants sat down significantly sooner (i.e., 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 (i.e., 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 Figure 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 (i.e., 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, CI [0.68, 0.95]. Participants sat down sooner (i.e., shorter standing, HR > 1) in offices with framed pictures (HR = 1.20, CI [1.03, 1.39]), but in the sensitivity analysis excluding influential observations this association was insignificant (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 (i.e., 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, CI [1.02, 1.52]) and waste paper bins (HR = 1.43, CI [1.18, 1.52]) within reach. However, in the sensitivity analysis that excluded influential observations, the associations with small cabinets (CI [0.88, 1.33]) and with trash cans (CI [0.98, 1.48]) were non-significant.

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 (i.e., 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

Hazard ratios 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 worktime control was significantly associated with the hazard of sitting down when standing. Participants who reported more worktime control sat down later (i.e., 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 worktime control as covariate. When including worktime control, Cluster #1 did no longer significantly predict the hazard of sitting down when standing (95% [0.96, 1.54]). An additional regression analysis indicated that Cluster #1 was negatively related to worktime control (b = -0.69, p = .006). So, it seems that offices in this cluster were more often visited by participants who reported *lower* worktime 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 worktime control.

When including worktime control, the distance to nearest kitchen also did no longer significantly predict the hazard of sitting down when standing (CI [0.9996, 1.01]. An additional correlation analysis indicated that the distance to the nearest kitchen was *positively* related to worktime control (r = 0.15, p < .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 (i.e., worktime control).

Worksite habits

Hazard ratios 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 (i.e., 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., (2020), 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., (2020), time of the day significantly predicted the hazard of standing up when sitting, HR = 1.01, CI [1.001, 1.02]. Later on the workday, participants stood up sooner (i.e., sat shorter) compared to earlier on the workday.

Activity in the preceding 5 hours. In contrast to ten Broeke et al., (2020), 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, CI [1.000, 1.002]. After more-than-usual activity in the preceding 5 hours, participants stood up sooner (i.e., 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, i.e., 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 worktime control (explained later in this discussion). Interestingly, these combinations of design characteristics were differently associated with sitting patterns than 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 itself 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 co-workers [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 (i.e., 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.

Worktime control

Importantly, the association between Cluster #1 offices and prolonged standing was alternative explained by a third variable: office workers' experienced worktime control. Specifically, offices in Cluster #1 were more often visited by people experiencing low worktime control. Low worktime control, in turn, was associated with sitting down sooner (shorter standing). So, employees may have showed shorter standing episodes in these offices because they felt less liberty about when, how, and how long they take breaks during the workday (i.e., low worktime 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 UK; [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. Yet, 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 (e.g., print some documents), and/or to take breaks that involve standing up (e.g., 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 versus shared offices). In other words, rather than a direct effect of design, the workplace design may shape 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]. So, to understand sitting behaviours 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 (e.g.,, activity-permissive workstations) when attempting to understand sitting behaviours. 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 analysing several rich sources of data (i.e., accelerometery-based measures of sitting behaviours; 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 behaviours. 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. So, our data is 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 (e.g., 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 behaviour 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 timeframe 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 modelling 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 modelling 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 increased risk for unhealthy sitting behaviours. 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 behaviours. 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 set-up: a shared workplace with a variety of rooms and areas that are designed for specific tasks (e.g., 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. Though these characteristics may play a key role in determining people's sitting behaviours, research on this topic is still in its infancy. For example, which types of work tasks (e.g., 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, wellbeing 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 under-studied, 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 T, Mcisaac T, Douillette K, et al. Sedentary behaviour and health in adults: an overview of systematic reviews. *Appl Physiol Nutr Metab*. 2020;45: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. *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 Auckl NZ*. 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, editors. *Sedentary Behaviour Epidemiology*. Cham: Springer International Publishing. p. 381–403.

12. Sallis JF, Owen N, Fisher EB. Ecological models of health behavior. In: Glanz K, Rimer BK, Viswanath K, editors. *Health Behavior: Theory, Research, and Practice*. John Wiley & Sons; 2015.

13. Chu AHY, Ng SHX, 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*. 2016;66:408–411.

16. Gorman E, Ashe M, Dunstan D, 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*. 2022;0:1–14.
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*. 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, Nederland: 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 J, Benson L, M Cole P, Ram N. Multilevel Survival Analysis: Studying the Timing of Children's Recurring Behaviors. *Dev Psychol*. . Epub ahead of print September 23, 2018. DOI: 10.1037/dev0000619.

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. 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. *A source book of Gestalt psychology*. London, England: Kegan

Paul, Trench, Trubner & Company; 1938. p. 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 MLM, Geurts SAE, Kompier MAJ, 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.

Figure legends

Fig. 1

An Example of a Spatial Map Drawn in the Spatial Metric Calculator Tool

Note. The large, coloured squares represent offices and shared facilities, each colour 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.

Fig. 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.

Fig. 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 non-significant when excluding influential cases

Fig. 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 5 chairs, respectively.

Fig. 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).

Figure 1

Figure 2

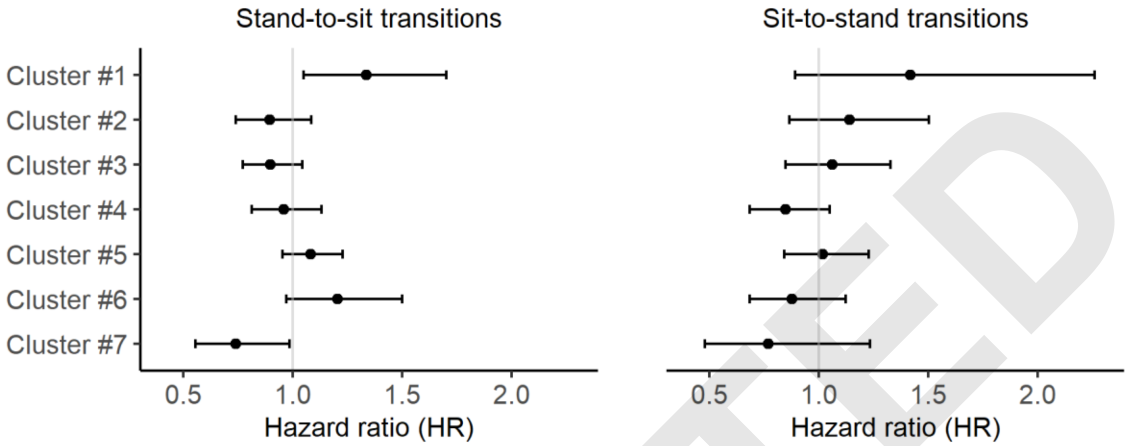
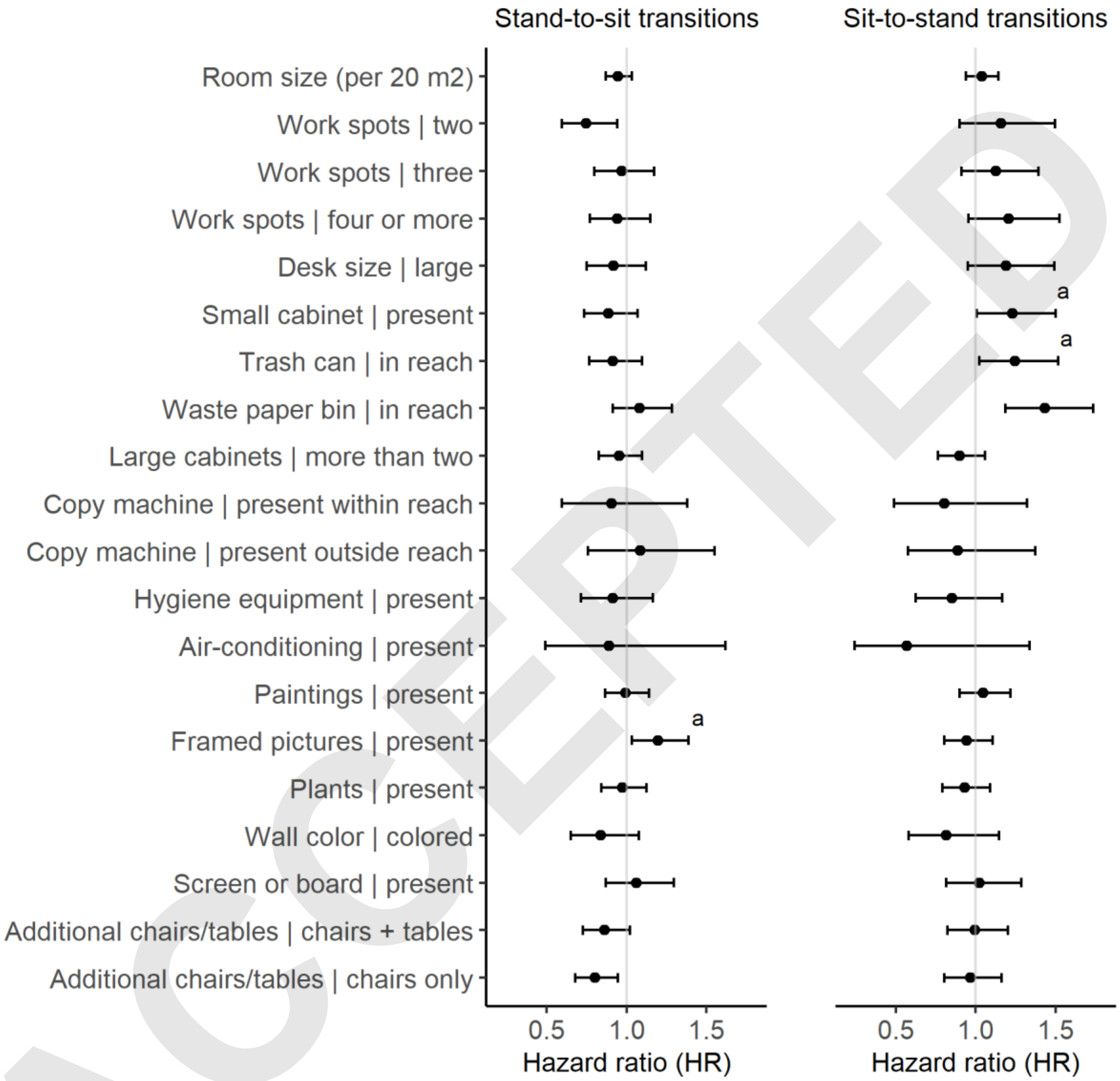
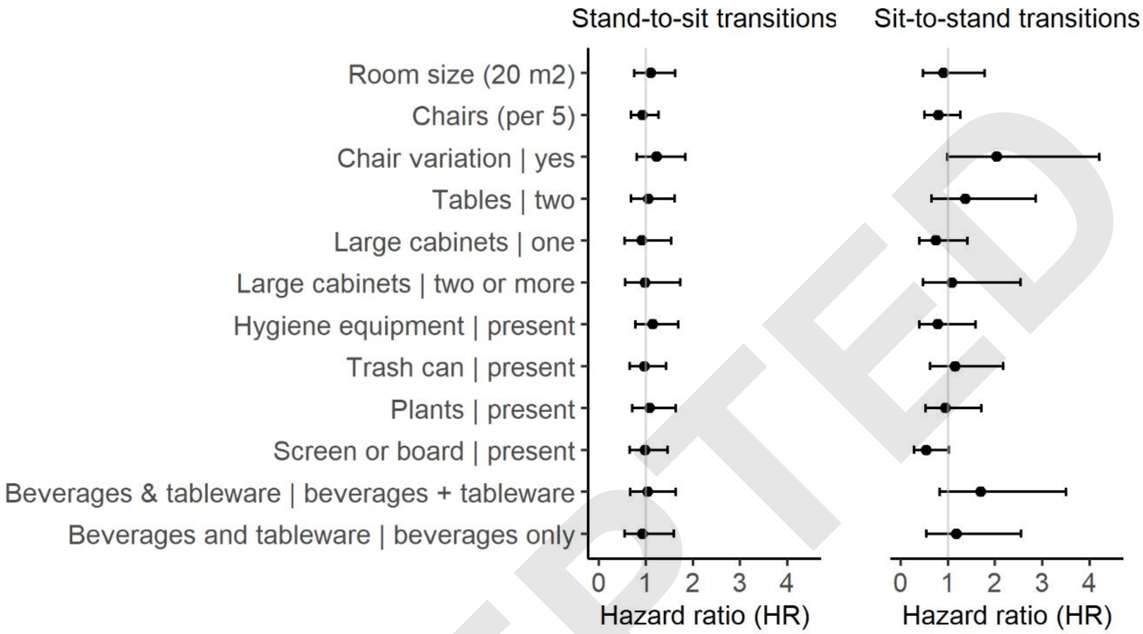

Stand-to-sit transitions
Sit-to-stand transitions
Cluster #1
Cluster #2
Cluster #3
Cluster #4
Cluster #5
Cluster #6
Cluster #7
0.5
1.0
1.5
2.0
Hazard ratio (HR)
0.5
1.0
1.5
2.0
Hazard ratio (HR)

Figure 3



Stand-to-sit transitions
Sit-to-stand transitions
Room size (per 20 m2)
Work spots | two
Work spots | three
Work spots | four or more
Desk size | large
Small cabinet | present
Trash can | in reach
Waste paper bin | in reach
Large cabinets | more than two
Copy machine | present within reach
Copy machine | present outside reach
Hygiene equipment | present
Air-conditioning | present
Paintings | present
Framed pictures | present
Plants | present
Wall color | colored
Screen or board | present
Additional chairs/tables | chairs + tables
Additional chairs/tables | chairs only
a
a
a
0.5
1.0
1.5
Hazard ratio (HR)
0.5
1.0
1.5
Hazard ratio (HR)

Figure 4



Stand-to-sit transitions
Sit-to-stand transitions
Room size (20 m2)
Chairs (per 5)
Chair variation | yes
Tables | two
Large cabinets | one
Large cabinets | two or more
Hygiene equipment | present
Trash can | present
Plants | present
Screen or board | present
Beverages & tableware | beverages + tableware
Beverages and tableware | beverages only
0 1 2 3 4
Hazard ratio (HR)
0 1 2 3 4
Hazard ratio (HR)

Figure 5

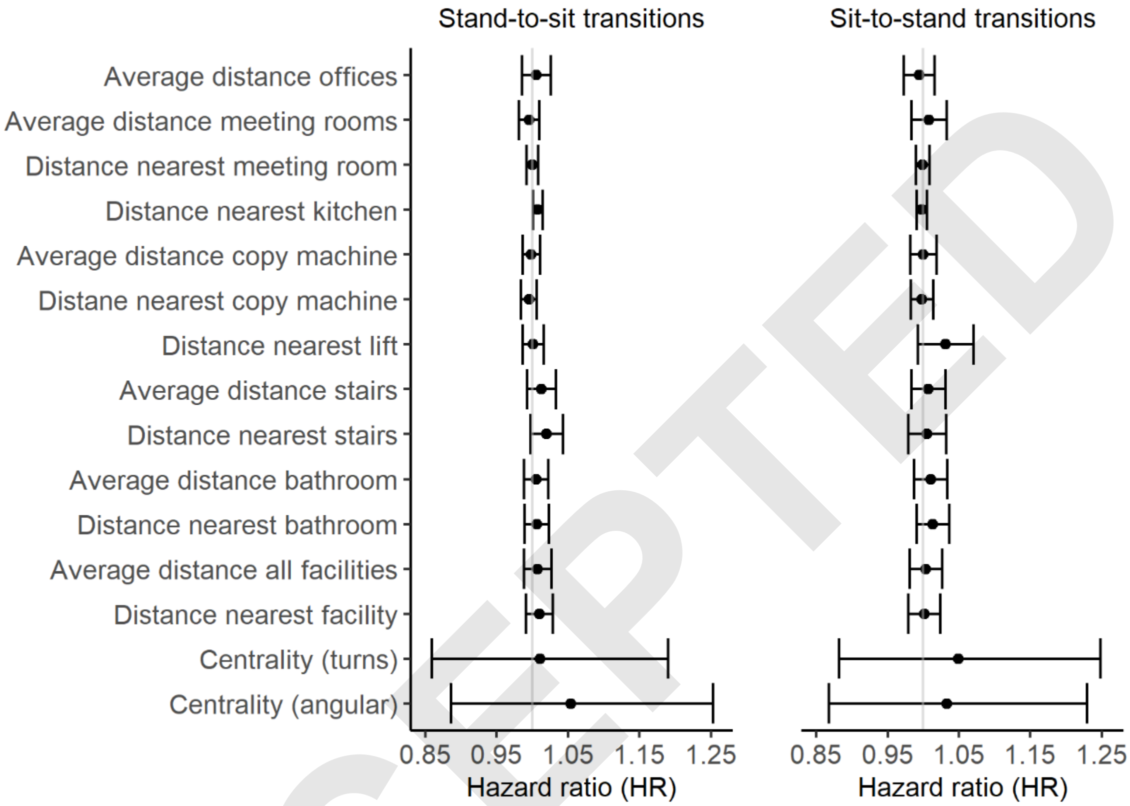

Stand-to-sit transitions
Sit-to-stand transitions
Average distance offices
Average distance meeting rooms
Distance nearest meeting room
Distance nearest kitchen
Average distance copy machine
Distane nearest copy machine
Distance nearest lift
Average distance stairs
Distance nearest stairs
Average distance bathroom
Distance nearest bathroom
Average distance all facilities
Distance nearest facility
Centrality (turns)
Centrality (angular)
0.85 0.95 1.05 1.15 1.25
Hazard ratio (HR)
0.85 0.95 1.05 1.15 1.25
Hazard ratio (HR)

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 (m^2) Q25 21.5; Q50 25.0; Q75 19.0
Work spots	Number of desk – chair – pc combinations being used by employees	one (27) two (11) three (12) four or more (17)
Desk size	'standard' being approximately $2m^2$	standard (50) large (17)
Small cabinet with desk	Individual cabinet with two to four 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	two or more (40) less than two (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 colour	'Colored' when part of the walls are not white	white (24) coloured (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)

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 (m^2) 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		one (9) two (2)
Large cabinets	Usually positioned against the walls	absent (3) one (5) two 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)

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 (meter)	… to all offices on the same floor	11.6; 14.2; 18.9
Average distance to meeting rooms (meter)	… to all meeting rooms on the same floor	12.5; 16.6; 23.8
Distance to nearest meeting room (meter)	… within the office building	16.6; 25.2; 33.73
Distance to nearest kitchen (meter)	… within the office building	15.2; 22.5; 30.5
Average distance to copy machine (meter)	… to all copy machines / printers on the same floor	7.4; 11.3; 20.4
Distance to nearest copy machine (meter)	… nearest copy machine / printer within the office building	7.2; 10.6; 18.8
Distance to nearest lift (meter)	… within the office building	11.7; 12.6; 23.5
Average distance to stairs (meter)	… all stairs on the same floor	7.8; 12.9; 15.5
Distance to nearest stairs (meter)	… within the office building	7.4; 11.9; 14.4
Average distance to bathroom (meter)	… all bathrooms on the same floor	10.3; 14.3; 19.1
Distance to nearest bathroom (meter)	… within the office building	10.5; 14.6; 19.0
Average distance to all shared facilities (meter)	… all shared facilities on the same floor	9.4; 12.5; 17.8
Average distance to all nearest shared facilities (meter)	… 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

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 refers to paintings, pictures, and plants

Supplementary Information for

Associations Between Room Function, Office Design, Workplace Spatial Layout and Sitting Patterns During Office Work: A Field Study

This Supplementary Information includes:

Supplementary text 1: Detailed 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 full 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, the primary researcher (PB) performed several 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 metrics of distance and centrality (see Measurements).

To connect the time-stamped activity monitor data to room function, office design characteristics and workplace spatial layout characteristics, we used a day-reconstruction design (Kahneman et al., 2004): At the end of each day during the measurement week, participants were asked to report each office, meeting room, and/or canteen that 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 office or room that it occurred in, and hence to the correct office design characteristics and workplace spatial layout characteristics of that room.

To aid the interpretation of our data, we also assessed the following contextual information as secondary predictors through self-report: general work characteristics (e.g., work pressure; between-participants), daily work characteristics (e.g., daily task variation; within-participants), and worksite habits, (e.g., the use of digital versus paper documents; between-participants). Finally, to replicate previous findings of ten Broeke et al., (2020) we also analyzed how the timing of stand-to-sit and sit-to-stand transitions varied with time of the day and activity in the preceding 5 hours (i.e., temporal dynamics).

We preregistered our research questions, data-processing steps, and analyses at the Open Science Framework (https://osf.io/gnt2m/?view_only=500665d3578948838c337617978e4e06).

Participants

We recruited 48 office workers from a notarial service company (company A) with two office locations (*N* = 11 at location A1; *N* = 3 at location A2), and a accountancy and tax advisory company (company B) with two office locations (*N* = 25 at location B1, *N* = 14 at location B2). In total we had 28 female and 20 male participants, with an average age of 39 (*SD* = 13), an average BMI of 24.0 (*SD* = 3.6). 28% of participants had a high educational level (university education), 71% had a medium educational level (vocational education, general secondary education or pre-university education), and 2% had a low educational level (prevocational secondary education). 71% of participants reported a professional job role, 29% reported a clerical job role. Median tenure (in years) was 7 years.

Study invitations were spread through intranet and work email. Participants could sign up voluntarily via an online survey. Inclusion criteria were: Doing desk-based work, minimum age of 18, 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 two 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 parttime contracts to take part, thereby maximizing sample size and representativeness.

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 (ten Broeke et al., 2020) we anticipated adequate power to detect small to medium effects for the within-participant predictors. For the between-participants predictors, we conducted a post-hoc sensitivity analysis (see Supplementary text 3) to explore the magnitude of the effect sizes that we could detect with a power of $1 - \beta = .80$ given our sample size of $N = 48$. Results indicated that we could detect minimal HR ~ 1.5 for positive associations, and minimal HR ~ 1/1.5 = 0.67 for negative associations, which can be considered medium effects for continuous between-participant predictors, and small-to-medium effects for comparing two groups (Azuero, 2016).

Procedure

Because of the Covid-19 pandemic and related lockdown measures, data collection was conducted in two batches. Batch 1 ($N = 28$) was collected in the spring of 2020, and batch 2 ($N =$

20) in the fall of 2021[1]. During both data-collection periods no lockdown-related measures were in place. During Batch 2 only social distancing and hygiene measures (no hand-shaking, etc.) were in place.

After participants signed up for the study, they were invited for an introductory meeting on day 1 of their preferred participation week. In the introductory meeting, the researcher explained the study procedure and participants received the study materials and filled in the intake 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 at the end of each day (on a self-selected time) to fill out the day-reconstruction questionnaire, including questions on sleep and wake times (every day), work start and end times, daily work characteristics, and rooms that they spent time in (workdays only). 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 the monitor and to hand it in at the reception at their office location, where it was collected by the primary researcher. In the week after participation, participants received a debriefing explaining

[1] Shared frailty Cox regression models with batch (2020 vs 2021) as predictor, indicated no significant difference in the hazard of a stand-to-sit transitions and the hazard of a sit-to-stand transition between participants who participated in 2020 and participants who participated in 2021.

the goal of the study, as well as a personal report including a schematic overview of their personal activity-monitor data and information on how to sit less and stand up more often.

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; URL to the OSF project).

Outcome: Stand-to-sit and sit-to-stand transitions

The activPAL3 monitor provides time-stamped activity codes for activity: sedentary ("any waking behavior characterized by an energy expenditure of ≤ 1.5 metabolic equivalents, while in a sitting, reclining, or lying posture"; Tremblay et al., 2017), standing, walking. The minimum sitting/upright period time was set at 10 seconds (default). In this study, standing and walking were taken together as *standing*, such that the data reflected each stand-to-sit and sit-to-stand transition. We identified and excluded activity monitor data during sleep and non-wear using participants' self-reported sleep and wake times from the daily questionnaire. We identified and excluded activity monitor data during non-work hours using participants' self-reported work start and end times from the daily questionnaire (see Data-analysis).[2]

[2] For batch 2, participants also registered their working from home time. However, participants in these organizations seldomly worked from home (6 participants worked from home 1 day, 1 participants worked from home 2 days), so this data was not presented.

Primary predictors

Office design / room design. Prior to data-collection, we constructed a list of indoor design characteristics for offices, meeting rooms, and canteens/kitchens separately, based on prior research on office ergonomics and sitting behavior (Duncan et al., 2015; Löffler et al., 2015) and on observations during worksite visits to the participating organizations prior to data-collection. Each characteristic was either a count or a categorical item. See supplementary Table S2 – S3 for an overview of all design characteristics that we assessed. See Table 1 and Table 2 for an overview of characteristics that were used in the data-analysis after data-reduction (See data-preparation). All characteristics were scored on the level of the room/office, as all work spots in each office typically shared similar characteristics. If work spots within a room varied on the characteristic, work spots were coded such that the scores represented the average work spot in the room or office.

For all rooms that participants listed in the day-reconstruction questionnaires (57 offices, 11 meeting rooms, and 4 canteens/kitchen), the indoor design characteristics list was scored by the researcher (PB) during additional worksite visits. Due to the low number of rooms classifying as canteen/kitchen (4 rooms) and the low number of stand-to-sit (N_{events} = 88) and sit-to-stand transitions (N_{events} = 89) observed within these rooms, we excluded this category from our analyses.

As a reliability check, the first assessment (location A2) was performed by two researchers (PB and EB). Agreement was reached on all characteristics except three, on which disagreement was resolved through discussion between PB and EB, which was in turn used to further improve the scoring procedure of the subsequent worksite visits.

Between batch 1 and batch 2, small environmental changes were made to the workplace environments (e.g., office became a meeting room, restructuring of work spots). Therefore, office design characteristics and workplace spatial layout characteristics were assessed twice, i.e., during each batch. As a result, 10 offices office had two scores (a 2020 score and a 2021 score) on each characteristic.[3]

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 (Fisher et al., 2018), which was developed by the Active Buildings study, funded by the National Institute for Health Research's School for Public Health Research (NIHR SPHR).

We followed a similar procedure as Fisher et al., (2018), 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 Figure 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 (e.g., meters), and in terms of the least number of turns (for the 'centrality' measures). (4) We calculated 15 spatial layout characteristics or *metrics* (see Table 3). Centrality refers to the shortest distance to all other

[3] Only three offices had exactly the same characteristics in 2020 and in 2021.

points on the spatial graphs in terms of number of turns (Metric 14) or in terms of angular deviation (Metric 15).

Secondary predictors

Work characteristics. Job role (professional vs clerical; see also Mullane et al., 2017) 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 Dutch Questionnaire on the Experience and Evaluation of Work (van Veldhoven & Meijman, 1994). Work pressure (6 items), mental load (4 items), job autonomy (4 items), possibilities for contact (2 items), interruptions during work (1 item), and worktime control (3 items) were assessed on a Likert scale ranging from (1) *never* to (4) *always*. For the 1-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 (1 item), organizational focus on stimulating physical activity (1 item), and organizational focus on reducing sitting time (1 item) were assessed on a scale from (1) *not at all* to (10) *very much*. See Table S1 of the supplementary materials for descriptive statistics and intercorrelations of the general work characteristics. In addition, day-level work pressure (1 item) and day-level task variation (1 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), use of paper versus digital documents (from [1] *paper only* to [10] *digital only*).

Temporal dynamics. To assess how the timing of stand-to-sit and sit-to-stand transitions varied throughout the day (ten Broeke et al., 2020), 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 (non-sitting) in the 5 hours prior to each stand-to-sit and sit-to-stand transition; in minutes). For details on calculation, see ten Broeke et al. (2020).

Participant characteristics

For descriptive purposes, individual characteristics were assessed through self-report in the intake questionnaire and included: 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 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

We performed all statistical analyses in R version 4.1.2. All data and R code that were used for the analyses in this paper, have been made publicly available at the Open Science Framework and can be accessed here.

Data-preparation

Activity monitor data. We excluded activity monitor data observations that fell outside of participants' working hours, using participants' self-reported work start and end times. First, we narrowed the work time window by 15 min on both start and end times to correct for recall bias and settling into the building, and to make sure that commuting time was not included in the dataset (Edwardson et al., 2017; Fisher et al., 2018). Next, we excluded observations that fell outside of the narrowed work time window. For observations crossing work start or end times, we only retained observations with at least 50% of the time inside the (narrowed) work time window and excluded the rest (66% of observations were excluded).

In addition, we excluded all sitting and standing episodes that were > 8 h, as these were considered to indicate no non-wear (i.e., as a time period in which the participant did not wear the activPAL monitor; Edwardson et al., 2017) or extreme values. We removed 0 sitting episodes and 8 standing episodes.

Office design / room design data. We conducted the following data-reduction steps for offices and meeting rooms separately: (1) We explored the variance on each individual design characteristics using histograms and bar plots. (2) We categorized numerical (e.g., count) characteristics with low variance. (3) We excluded dichotomous characteristics with <5 observations in one category. (4) For characteristics with three of more categories, we merged categories with little variance.

(5) We explored interrelations amongst categories using violin plots (for categorical – numerical variable combinations) and Cramer's V statistics (for categorical – categorical variable combinations). (We handled characteristics that were strongly associated (6) by excluding redundant characteristics (e.g., we excluded office type [shared vs private-enclosed] because it was embedded in number of work spots) or (7) by merging characteristics together (e.g., we merged 'additional chairs' [present vs absent] and 'additional tables' [present vs absent]' into 'additional chairs and tables' [additional chairs and tables vs additional chairs vs absent]).

Merging activity data to design data. For each participant, all sitting episodes and standing episodes that fully (i.e., 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.

Data preparation for time-to-event analysis. The event-based summary data file resulting from the activPAL software has a new row for each new activity episode, indicating (a) the start time of the episode, and (b) an activity code, i.e., sitting/lying down, standing, or walking. We recoded standing and walking into *active*. We coded a new variable *event*, indicating for each episode the transition that happens at the end of the episode: 'sit-to-stand' for each sitting episode, and 'stand-to-sit' for each active episode. We then computed *event time* (in minutes; precision in seconds) as the timing of the transition (i.e., event) since the previous transition (i.e., how long a participant had been standing before a stand-to-sit transition; or how long a participant had been sitting before a sit-to-stand transition). For model fitting, we split the dataset based on event of interest: one including only event times for stand-to-sit transitions; one including only event times for sit-to-stand transitions.

Cluster analysis

We performed an exploratory cluster analysis to cluster rooms based 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 distance-metric, as this metric is suitable when using both dichotomous and continuous data (Pavoine et al., 2009). A log transformation was used for 'room size' (m^2) to correct for negative skewness of the distribution. 'Air-conditioning' and 'copy machine' were treated as asymmetric binary because of a non-equal distribution of observations over categories (i.e., ratio > 1:5; see Table 1).

We explored multiple clustering methods: partitioning around medoids (PAM), divisive hierarchical clustering, and agglomerative hierarchical clustering (see Supplementary Text 4 for details). Based on silhouette width plots, elbow plots and descriptive statistics for clusters, we selected a clustering method and 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 (Lougheed et al., 2018) to model the timing of stand-to-sit and sit-to-stand transitions (ten Broeke et al., 2020). Specifically, we used the coxph function from the survival package (Therneau, 2015) to fit shared frailty Cox regression models predicting the *hazard* of a stand-to-sit transition (i.e., the momentary likelihood of sitting down while standing at any given minute) or the *hazard* of a sit-to-stand transition (i.e., the momentary likelihood of standing up while sitting at any given minute). The cox approach is well-established for continuous time-to-event data (Singer & Willet, 2003) and is suitable in case no prior knowledge about the shape of the hazard function is available (Lougheed et al., 2018; Stoolmiller & Snyder, 2006).

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 predictor. Second, we fitted two Cox models with *office design cluster* as 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.

To take into account that our data had a multi-level structure (stand-to-sit and sit-to-stand 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 a random intercept 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 (Singer & Willet, 2003). For all models, the proportionality assumption was met, based on examination of Schoenfeld residuals (Singer & Willet, 2003).

To draw conclusions, we interpreted Hazard Ratio's (HR) and 95% confidence intervals for our predictors. For individual office design and workplace spatial layout characteristics, HRs and 95% CIs were summarized in a dot-whisker diagram. To further interpret significant associations, we used model estimations of the marginal model (without frailty term)[4] to calculate P(time-to-event > 7.5 min) for stand-to-sit transitions and P(time-to-event > 30 min) for sit-to-stand transitions, for meaningful values of the predictors. The choice of 7.5 and 30 min as meaningful values for relatively long standing and sitting episodes was based on a previous study (Biddle & Bennie, 2017) and on the distribution of episode duration in our data.

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

[4] Unfortunately, at the time of data-analysis no R packages or functions were available to calculate predicted survivor functions for Cox regression models including a frailty term.

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. To assess the association between time of the day and activity in the preceding 5 hours on the one hand, and stand-to-sit and sit-to-stand transitions on the other hand, we fitted two shared frailty Cox models (one for the hazard of a stand-to-sit transition and one for the hazard of a sit-to-stand transition) for both time of the day as predictor and for activity in the preceding 5 hours as predictor. We interpreted Hazard Ratio's (HR) and 95% confidence intervals to determine whether associations were significant.

Assumptions.

Examination of Schoenfeld residuals indicated no violations of the proportionality assumption. Deviance residuals were within an appropriate range for each model. We examined dfbeta residuals to assess influential / high-leverage observations. Observations with a dfbeta residuals with an absolute value > $2/\sqrt{n}$ were considered influential observations (Belsley et al., 2005). Influential observations were visually examined, and for each model with influential observations we conducted a sensitivity analysis refitting the model while excluding these observations. When refitting the model changed the interpretation of the results, we report this.

Sensitivity analyses

As sensitivity analyses, we visually explored the distributions of event times and fitted two shared frailty Cox regression models for each of the following between-participants predictors: medical condition (yes vs no), height-adjustable desk (sit-stand desk vs sit-only desk), and batch (2020 vs 2021). Results indicated that these predictors were not significantly associated with the hazard of a stand-to-sit transition and the hazard of a sit-to-stand transition, and therefore unlikely to have affected our findings.

Table S1

Means (M), Standard Deviations (SD) and Intercorrelations for All Included General Work Characteristics

Work characteristics	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Work pressure (1)									
Mental load (2)	**0.44**								
Autonomy (3)	0.16	-0.03							
Contact possibility (4)	-0.11	-0.01	0.24						
Interruptions (5)	**0.41**	**0.48**	0.27	0.22					
Worktime control (6)	-0.12	0.04	**0.32**	0.12	-0.01				
Task variation (7)	-0.09	0.18	**0.31**	0.12	0.23	0.15			
Organizational focus on activity (8)	-0.16	**-0.29**	0.11	0.14	-0.2	0.25	**0.42**		
Organizational focus on sitting (9)	0.08	-0.19	0.0	-0.12	-0.03	-0.1	0.28	**0.69**	
M	2.22	3.68	3.06	3.03	2.79	2.97	6.91	3.94	3.02
SD	0.57	0.50	0.71	0.84	0.74	0.79	1.86	2.24	1.98

Note: Correlation coefficients in bold are significant (p < .05)

Supplementary text 2: Model equations

Primary analyses

Room-function

The shared frailty Cox model to test the time-varying predictor roomfunction (0 = office, 1 = meeting room) as predictor of the hazard of sitting down when standing or the hazard of standing up when sitting was

$$h_{ij}(t) = h_0(t)\, exp(v_i)\, exp\left(\beta_1 roomfunction_{ij}(t)\right)$$

In this equation, $h_{ij}(t)$ is the hazard of sitting down when standing or of standing up when sitting, respectively, for episode j within each individual i, $h_0(t)$ is the baseline hazard function, v_i is the individual-specific random effect (or "frailty"), $roomfunction_{ij}(t)$ is the time-varying predictor room-function associated with β_1.

Office design cluster

The shared frailty Cox model to test the time-varying predictor office design cluster (cluster 1, cluster 2, cluster 3, cluster 4, cluster 5, cluster 6, cluster 7[reference category]; sum-to-zero contrasts) as predictor of the hazard of sitting down when standing or the hazard of standing up when sitting was

$$h_{ij}(t) = h_0(t)\, exp(v_i)\, exp\Big(\beta_1 cluster1_{ij}(t) + \beta_2 cluster2(t) + \beta_3 cluster3(t)$$

$$+ \beta_4 cluster4(t) + \beta_5 cluster5(t) + \beta_6 cluster6(t)\Big)$$

In this equation, $h_{ij}(t)$ is the hazard of sitting down when standing or of standing up when sitting, respectively, for episode j within each individual i, $h_0(t)$ is the baseline hazard function, v_i is the individual-specific random effect (or "frailty"), $cluster1_{ij}(t)$ is the time-varying dummy variable comparing cluster 1 to the average of the other clusters associated with β_1, and the remaining dummy variables for each clusters 2-6 associated with β_2 - β_6. To calculate the regression coefficient for the comparison of cluster 7 to the average of the other clusters, the model was refit with cluster 1 as reference category for the office design cluster variable.

Office design, meeting room design, and workplace spatial layout characteristics

The shared frailty Cox model to test the office design characteristics, meeting room characteristics, and workplace spatial layout characteristics as time-varying predictors of the hazard of sitting down when standing or the hazard of standing up when sitting was

$$h_{ij}(t) = h_0(t)\, exp(v_i)\, exp\big(\beta_1 X_{ij}(t) + \cdots\big)$$

In this equation, $h_{ij}(t)$ is the hazard of sitting down when standing or of standing up when sitting, respectively, for episode j within each individual i, $h_0(t)$ is the baseline hazard function, v_i is the individual-specific random effect (or "frailty"), $X_{ij}(t)$ is the time-varying office design characteristic, meeting room characteristic, or workplace spatial layout characteristic predictor associated with β_1. $+\cdots$ indicates possible additional dummy variables in case of a predictor with three or more categories.

Secondary analyses

General work characteristics and worksite habits

The shared frailty Cox model to test general work characteristics and worksite habits as time-invariant predictors of the hazard of sitting down when standing or the hazard of standing up when sitting was

$$h_{ij}(t) = h_0(t)\, exp(v_i)\, exp(\beta_1 X_i)$$

In this equation, $h_{ij}(t)$ is the hazard of sitting down when standing or of standing up when sitting, respectively, for episode *j* within each individual i, $h_0(t)$ is the baseline hazard function, v_i is the individual-specific random effect (or "frailty"), X_i is the time-invariant general work characteristics or worksite habits predictor associated with β_1.

Daily work characteristics and temporal dynamics

The shared frailty Cox model to test daily work characteristics, time of the day, and activity in the preceding 5 hours as time-varying predictors of the hazard of sitting down when standing or the hazard of standing up when sitting was

$$h_{ij}(t) = h_0(t)\, exp(v_i)\, exp\left(\beta_1 X_{ij}(t)\right)$$

In this equation, $h_{ij}(t)$ is the hazard of sitting down when standing or of standing up when sitting, respectively, for episode *j* within each individual i, $h_0(t)$ is the baseline hazard function, v_i is the individual-specific random effect (or "frailty"), $X_{ij}(t)$ is the time-varying predictor (daily work pressure, daily task variation, time of the day, or activity in the preceding 5 hours) associated with β_1.

Supplementary text 3: A-priori sensitivity analysis

For the between-participants predictors, we conducted a post-hoc sensitivity analyses to explore the magnitude of the effect sizes that we could detect with a power of $1 – \beta = .80$ given our sample size of $N = 48$.

We ran a power simulation in R, using the *paramtest* package. We simulated a set of datasets with $N = 48$, with varying positive and negative effect sizes (Hazard Ratios; HRs). Each simulated data set was characterized by (a) the respective number of participants, (b) a normally-distributed between-subjects predictor with a mean of 0 and a standard deviation of 1, and (c) an event time variable, such that in each dataset there was a slightly different HR for the association between the predictor and the hazard of the event. The number of events per participant was randomly drawn from a gamma distribution with scale and shape parameters that were based on the distributions of events we observed from participants in previous research (ten Broeke et al., 2020).

Next, for each of the different HRs, we ran 1000 shared frailty cox models on the event times using the *coxph* function, including the predictor and a frailty term for participant. We used Efron’s method for handling ties (Singer & Willet, 2003). Based on these 1000 simulations, we calculated the power for detecting each HR as the proportion of tests with $p < 0.05$ for the association between the predictor and the hazard of the event. The R code for the sensitivity analysis is available at the Open Science Framework and can be accessed here.

Finally, we selected the minimal HR for a positive association and the maximal HR for a negative association for which power was closest to .80. Results are indicated in Table S2. Based on suggestions by Azuero and colleagues (Azuero, 2016) that “small, medium, and large HRs comparing 2 groups would be approximately 1.3, 1.9, and 2.8, respectively”, these effects can be considered small to medium for comparing two groups. Based on the suggestion that “small, medium, and large HRs for a standard deviation increase in the predictor would be 1.14, 1.47, and 1.9, respectively”, these effects can be considered medium to effects for continuous between-participant predictors.

Table S2

The Minimal Hazard Ratio's that Could be Detected with a Power of .80 Given the Sample Size of N = 48

HR	1/HR	power
1.550	0.645	0.84
1.558	0.642	0.84
1.555	0.643	0.78

Table S3

List of All Assessed Office Design Characteristics (Before Data Reduction).

Characteristic	Description	Values
Room size	Calculated from digital floor plans	continuous (m^2)
Office type	Type of office	private enclosed shared open plan
Work spots	Number of desk – chair – pc combinations being used by employees	continuous
Floor		continuous
Primary chair	Characteristics of the primary chair used by the office workers when working at their desk	
Back support		present absent
Casters		present absent
Arm support		present absent
Height adjustable		yes no
Desk size	one unit corresponds to approximately $1m^2$	continuous (nr of units)
Small cabinet with desk	Individual cabinet with two to four drawers, usually under the desk	present absent
Laptop or PC	Type of computer hardware primarily used for work at the work desk	laptop PC
Trash can	Trash can for normal trash	present within reach present out of reach absent
Waste paper bin	Bin for paper waste	present within reach present out of reach absent
Work telephone	Additional telephone apart from one's personal mobile phone, located in the office	present cabled out of reach present cables within reach present out of reach present within reach absent
Lamp on desk		present within reach

		present absent
Additional chairs	Number of chairs additional to individual work spots	continuous
Additional tables	Number of tables additional to individual work spots	continuous
Plexiglass barriers	Portable, see-through walls made of plexiglass materials that can be placed between work spots to protect against the spread of the covid-19 virus	present absent
Large cabinets	Number of large cabinets, usually positioned against the walls	continuous
Whiteboard / bulletin board	Standing or hanging on the wall	present absent
Presentation screen	Standing or hanging on the wall	present – directly controlled present – remotely controlled absent
Copy machine	Including copy machine, printers, or scanners	present within reach present out of reach absent
Hygiene equipment	Cleaning wipes and hand disinfectant	present absent
Beverages provision	General (non-personal) provision of beverages (e.g., tea, coffee, sodas, water)	present within reach present out of reach absent
Tableware provision	General (non-personal) provision of tableware (e.g., cups, plates, cutlery)	present within reach present out of reach absent
Air-conditioning		present – manually controlled present – centrally controlled absent
Light switches		present within reach present outside reach absent
Windows can be opened		yes no

Sunscreens	Any window coverage that reduces sunlight shining into the office (e.g., screens or curtains)	present-automatic present-manual absent
Paintings	Hanging or standing, for decorative purposes	present absent
Framed pictures	Personal pictures of employees, for decorative purposes	present absent
Plants	For decorative purposes	present absent
Mirrors	Hanging or standing, for decorative purposes	present absent
Wall color	‘Colored’ when part of the walls are not white	white colored
Windows		present absent
Lighting	Subjective estimation of the researcher	bright dark
Screen or board	A presentation screen, bulletin board or whiteboard	present absent
Visual signals indicating distance	Visual signals (e.g., stickers on the floor) indicating social distancing (to protect against the spread of the covid-19 virus)	present absent
Visual signals indicating walking routes	Visual signals (e.g., stickers on the floor) indicating walking routes that ensure appropriate distancing (to protect against the spread of the covid-19 virus)	present absent

Table S4

List of All Assessed Meeting Room Design Characteristics (Before Data Reduction)

Characteristic	Description	Values
Room size	Calculated from digital floor plans	continuous (m^2)
Chairs	Number of chairs	continuous (count)
Chair variation	Different types of chairs	yes no
Tables	Number of tables	continuous (count)
Table variation	Different types (e.g., size, height) of tables	yes no
Trash can	Trash can for normal trash	present within reach present out of reach absent
Waste paper bin	Bin for paper waste	present within reach present out of reach absent
Work telephone	Additional telephone apart from one’s personal mobile phone, located in the meeting room	present cabled out of reach present cables within reach present out of reach present within reach absent
Lamp on table		present within reach present absent
Plexiglass barriers	Portable, see-through walls made of plexiglass materials that can be placed between work spots to protect against the spread of the covid-19 virus	present absent
Large cabinets	Number of large cabinets, usually positioned against the walls	continuous
Whiteboard / bulletin board	Standing or hanging on the wall	present absent
Presentation screen	Standing or hanging on the wall	present – directly controlled

		present – remotely controlled absent
Copy machine	Including copy machine, printers, or scanners	present within reach present out of reach absent
Hygiene equipment	Cleaning wipes and hand disinfectant	present absent
Beverages provision	General (non-personal) provision of beverages (e.g., tea, coffee, sodas, water)	present within reach present out of reach absent
Tableware provision	General (non-personal) provision of tableware (e.g., cups, plates, cutlery)	present within reach present out of reach absent
Air-conditioning		present – manually controlled present – centrally controlled absent
Light switches		present within reach present outside reach absent
Windows can be opened		yes no
Sunscreens	Any window coverage that reduces sunlight shining into the office (e.g., screens or curtains)	present-automatic present-manual absent
Paintings	Hanging or standing, for decorative purposes	present absent
Plants	For decorative purposes	present absent
Mirrors	Hanging or standing, for decorative purposes	present absent
Wall color	'Colored' when part of the walls are not white	white colored

Windows		present absent
Lighting	Subjective estimation of the researcher	bright dark
Screen or board	A presentation screen, bulletin board or whiteboard	present absent
Visual signals indicating distance	Visual signals (e.g., stickers on the floor) indicating social distancing (to protect against the spread of the covid-19 virus)	present absent
Visual signals indicating walking routes	Visual signals (e.g., stickers on the floor) indicating walking routes that ensure appropriate distancing (to protect against the spread of the covid-19 virus)	present absent

Table S5

List of All Assessed Canteen/Kitchen Design Characteristics (Before Data Reduction)

Characteristic	Description	Values
Room size	Calculated from digital floor plans	continuous (m^2)
Chairs	Number of chairs	continuous (count)
Chair variation	Different types of chairs	yes no
Tables	Number of tables	continuous (count)
Table variation	Different types (e.g., size, height) of tables	yes no
Trash can	Trash can for normal trash	present within reach present out of reach absent
Waste paper bin	Bin for paper waste	present within reach present out of reach absent
Lamp on table		present within reach present absent
Plexiglass barriers	Portable, see-through walls made of plexiglass materials that can be placed between work spots to protect against the spread of the covid-19 virus	present absent
Large cabinets	Number of large cabinets, usually positioned against the walls	continuous
Whiteboard / bulletin board	Standing or hanging on the wall	present absent
Presentation screen	Standing or hanging on the wall	present – directly controlled present – remotely controlled absent
Hygiene equipment	Cleaning wipes and hand disinfectant	present absent
Beverages provision	General (non-personal) provision of beverages (e.g., tea, coffee, sodas, water)	present within reach present out of reach absent
Tableware provision	General (non-personal) provision of tableware (e.g., cups, plates, cutlery)	present within reach present out of reach

		absent
Air-conditioning		present – manually controlled present – centrally controlled absent
Light switches		present within reach present outside reach absent
Windows can be opened		yes no
Sunscreens	Any window coverage that reduces sunlight shining into the office (e.g., screens or curtains)	present-automatic present-manual absent
Paintings	Hanging or standing, for decorative purposes	present absent
Plants	For decorative purposes	present absent
Mirrors	Hanging or standing, for decorative purposes	present absent
Wall color	‘Colored’ when part of the walls are not white	white colored
Windows		present absent
Lighting	Subjective estimation of the researcher	bright dark
Screen or board	A presentation screen, bulletin board or whiteboard	present absent
Visual signals indicating distance	Visual signals (e.g., stickers on the floor) indicating social distancing (to protect against the spread of the covid-19 virus)	present absent
Visual signals indicating walking routes	Visual signals (e.g., stickers on the floor) indicating walking routes that ensure appropriate distancing (to protect against the spread of the covid-19 virus)	present absent

Supplementary text 4: Details on cluster analysis

We explored multiple clustering methods to achieve the most relevant and meaningful interpretation of different categories of offices with different typical design characteristics. Data-analysis code for the cluster analysis can be found at the Open Science Framework (https://osf.io/8u4ev/?view_only=39f0dd9237464faa85671a058ee088de).

We explored: divisive (top down) hierarchical clustering, agglomerative (bottom up) hierarchical clustering and partitioning around medoids (PAM). For the hierarchical clustering algorithms, we assessed dendograms, silhouette plots and elbow plots, to assess the fit of the algorithm to our data and to determine the most relevant number of clusters. For the agglomerative clustering algorithm, one can use three different methods for calculating distances between clusters: single linkages, average linkages, and complete linkages. We explored dendograms for all three methods and the 'complete linkages' method yielded the most balanced dendogram. For the PAM algorithm, we examined silhouette plots and elbow plots to determine the number of clusters. Once a cluster solution was found for each clustering algorithm, we assessed the associations between the cluster solutions on the one hand, and the timing of stand-to-sit transitions and the timing of sit-to-stand transitions on the other hand, using a shared frailty cox regression analysis (See Supplementary Text 1 for more information about model fitting). We used sum contrasts for cluster.

The divisive clustering algorithm yielded a cluster solution of 4 clusters. The agglomerative clustering algorithm yielded a solution of 7 clusters. The PAM algorithm yielded a solution of 5 clusters. The results of the models predicting the hazard of sitting down when standing and the hazard of standing up when sitting, using the clustering solutions of the divisive algorithm and of the PAM algorithm, are presented in Table S6. The results for the cluster solution of the agglomerative algorithm are provided in the main manuscript (Figure 2). As can been seen in Table S6, the divisive clustering algorithm yielded a solution of 4 clusters, which was associated with the hazard of sitting down when standing (cluster 3). However, in the sensitivity analysis excluding influential cases, this association was no longer significant. The other associations between the divisive clustering algorithm solution and the PAM clustering algorithm solution on the one hand, and the timing of stand-to-sit and sit-to-stand transitions on the other hand, we not significant.

We chose to proceed with the agglomerative cluster algorithm with the 7-cluster solution, as this was the only cluster solution that showed a meaningful and robust association with office workers' sitting patterns.

Table S6

Hazard Ratio's and 95% Confidence Intervals for the Association between Different Cluster Solutions of the Divisive Clustering Algorithm and the PAM Clustering Algorithm (Within-Participant) and the Hazard of Sitting Down when Standing (Stand-to-Sit Transitions) or the Hazard of Standing up when Sitting (Sit-to-Stand Transitions).

Predictor	**HR**	**95% CI**
Divisive clustering – Stand-to-sit transitions		
cluster 1	1.12	[0.89, 1.40]
cluster 2	1.14	[0.91, 1.44]
cluster 3	0.85	[0.74, 0.97]
cluster 4	0.93	[0.80, 1.07]
Divisive clustering – Sit-to-stand transitions		
cluster 1	1.16	[0.81, 1.68]
cluster 2	1.10	[0.83, 1.45]
cluster 3	0.88	[0.73, 1.06]
cluster 4	0.89	[0.74, 1.07]
PAM clustering – Stand-to-sit transitions		
cluster 1	0.87	[0.75, 1.02]
cluster 2	1.08	[0.82, 1.42]
cluster 3	1.07	[0.94, 1.22]
cluster 4	1.10	[0.90, 1.34]
cluster 5	0.90	[0.78, 1.04]
PAM clustering –Sit-to-stand transitions		
cluster 1	1.06	[0.89, 1.27]
cluster 2	1.13	[0.80, 1.60]
cluster 3	0.99	[0.84, 1.15]
cluster 4	0.92	[0.75, 1.13]
cluster 5	0.91	[0.78, 1.08]

Table S7

Office Design Cluster Descriptives

Characteristic	Value	Cluster #1 Small – shared - screens/board (N = 7)		Cluster #2 Large desks - large cabinets (N = 10)		Cluster #3 Extra furniture - decorations (N = 13)		Cluster #4 Few large cabinets (N = 12)		Cluster #5 Large cabinets - few decorations (N = 20)		Cluster #6 Private offices (N = 7)		Cluster #7 Large – shared - trash cans out of reach- few (N = 3)	
Room size median		12.0		23.0		27.0		18.5		26.0		27.0		29.0	
Work spots	One (private)	1	14%	4	40%	9	69%	3	25%	3	15%	7	100%	0	0%
	Two	4	57%	3	30%	0	0%	5	42%	2	10%	0	0%	2	67%
	Three	0	0%	1	10%	1	8%	0	0%	8	40%	0	0%	1	33%
	Four or more	2	29%	2	20%	3	23%	4	33%	7	35%	0	0%	0	0%
Desk size	Large	0	0%	10	100%	6	46%	0	0%	2	10%	0	0%	1	33%
Small cabinet with desk	Present	7	100%	10	100%	13	100%	7	58%	18	90%	0	0%	3	100%
Trash can	Within reach	7	100%	10	100%	10	77%	7	58%	19	95%	3	43%	0	0%
Waste paper bin	Within reach	5	71%	10	100%	11	85%	7	58%	17	85%	5	71%	0	0%
Large cabinets	Two or more	3	43%	8	80%	7	54%	1	8%	16	80%	7	100%	2	67%
Copy machine	Present within reach	1	14%	1	10%	1	8%	0	0%	0	0%	0	0%	0	0%
	Present out of reach	0	0%	2	20%	1	8%	1	8%	1	5%	0	0%	0	0%

Hygiene equipment	Present	0	0%	0	0%	2	15%	9	75%	4	20%	1	14%	3	100%
Air-conditioning	Present	7	100%	4	40%	13	100%	12	100%	20	100%	7	100%	3	100%
Paintings	Present	5	71%	7	70%	13	100%	6	50%	2	10%	2	29%	3	100%
Framed pictures	Present	1	14%	1	10%	9	69%	0	0%	4	20%	7	100%	0	0%
Plants	Present	2	29%	3	30%	9	69%	7	58%	8	40%	2	29%	1	33%
Wall color	Colored	0	0%	2	20%	8	62%	10	83%	18	90%	7	100%	2	67%
Screen or board	Present	7	100%	1	10%	2	15%	0	0%	2	10%	5	71%	2	67%
Additional chairs/tables	Chairs + tables	1	14%	3	30%	11	85%	0	0%	2	10%	7	100%	0	0%
	Only chairs	3	43%	5	50%	2	15%	4	33%	2	10%	0	0%	1	33%

Figure S1

Hazard Ratio's and 95% Confidence Intervals for the Associations Between General Work 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).

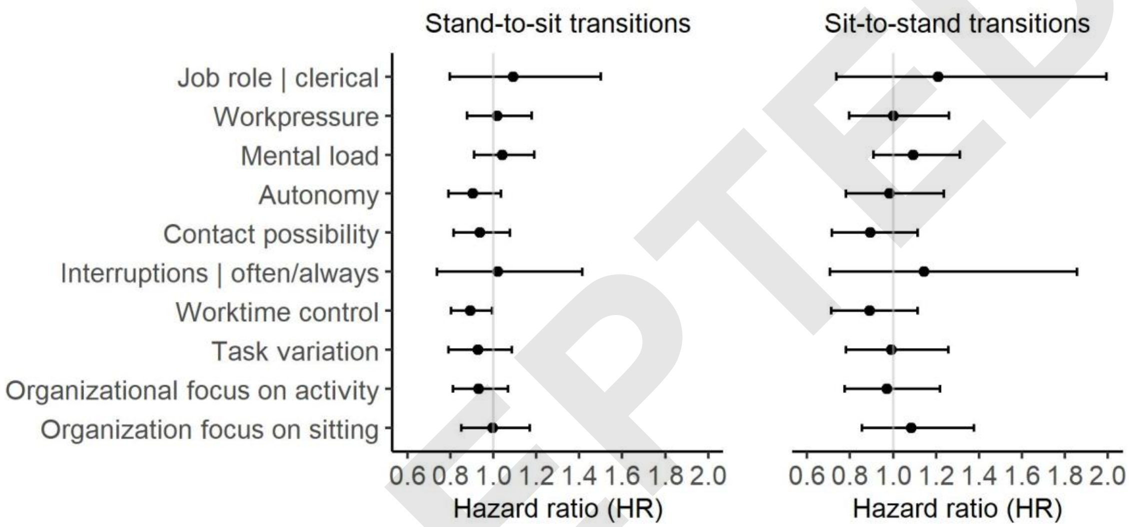


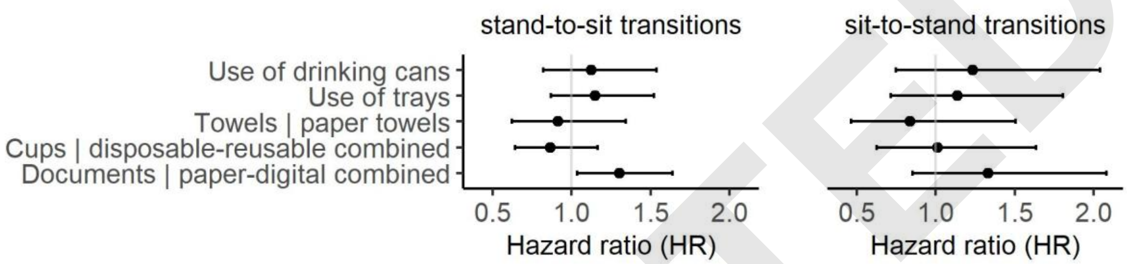
Table S7

Hazard Ratio's and 95% Confidence Intervals (CI) for the Association Between Daily (Within-Participant) Work Characteristics and the Hazard of Sitting Down when Standing (Stand-to Sit Transitions) or the Hazard of Standing up When Sitting (Sit-to-Stand Transitions).

Predictor and outcome	**HR**	**95% CI**
Daily work pressure		
stand-to-sit transitions	1.01	[0.96, 1.06]
sit-to-stand transitions	1.03	[0.98, 1.09]
Daily task variation		
stand-to-sit transitions	1.00	[0.95, 1.05]
sit-to-stand transitions	1.04	[0.99, 1.09]

Figure S2

Hazard Ratio's and 95% Confidence Intervals for the Associations Worksite Habits and the Hazard of Sitting Down when Standing (Stand-to-Sit Transitions) and the Hazard of Standing Up when Sitting (Sit-to-Stand Transitions).



Visual Abstract