Perceived availability of office shared spaces and workplace sitting: Moderation by organizational norms and behavioral autonomy

Abstract

A large amount of time spent sitting is a newly-identified health risk. Although desk-based workers spend much of their time at work sitting, little is known about how office spaces may be related to workplace sitting time. This study examined cross-sectional associations of the perceived availability of office shared spaces with workers' sitting time, and the potential role of workplace normative-social factors in the relationship. Participants (N=221) wore an activity monitor (activPAL3) and reported availability of shared spaces (for formal meetings, informal discussion, collaborative working), organizational norms, and workplace behavioral autonomy. No shared-space variables were associated with workplace sitting time. However, the perceived availability of sufficient informal discussion space was associated with lower levels of sitting among those who reported more-supportive organizational norms and greater behavioral autonomy. These findings highlight environmental, organizational, and psychosocial factors that will be important to address in future initiatives to reduce workplace sitting time.

Keywords: sedentary behavior, office environment, work space, desk-based work, prolonged sitting

Background

High levels of sitting have been shown to be associated with increased risk of a number of chronic diseases, including type 2 diabetes, cardiovascular disease, and some cancers (Biswas et al., 2015; Cooper et al., 2014; Healy, Matthews, Dunstan, Winkler, & Owen, 2011). Adults spend a large amount of time sitting (Matthews et al., 2008), and the trend of increasing sitting time is observed not only in developed but also developing countries (Ng & Popkin, 2012). Thus, reducing sedentary behavior, in combination with increasing physical activity, is now recognized as an important element in efforts to improve population health. A key setting to address this ubiquitous behavior is the desk-based workplace, where a large proportion of time is spent sitting. Studies using objective measures have shown that office workers spend over three quarters of their work hours sitting (Gorman et al., 2013; Hadgraft, Healy, et al., 2016; Parry & Straker, 2013; Spinney et al., 2015). Given that employed adults spend on average about eight hours on a weekday at work (Bureau of Labor Statistics, 2016; NHK Broadcasting Culture Research Institute, 2016), desk-based workers are exposed to high volumes of sitting time.

In order to assist in the development of strategies targeting workplace sitting reduction, an ecological model, which has been developed in established research on neighborhood environments and physical activity (Sallis & Owen, 2015), can be helpful. Key principles of the ecological model of health behavior are: (1) factors at multiple levels (intrapersonal, interpersonal, environmental, and policy) can influence behaviors; (2) these factors at different levels interact; and (3) interventions that involve multi-level influences are more effective (Sallis & Owen, 2015). These principles are underpinned by the *behavior settings* construct, which emphasizes the place-specific nature of human behaviors that are affected by the physical and social characteristics of the settings (Barker, 1968; Scott, 2005). It is now widely recognized that educational or motivational approaches alone are not sufficient for public health initiatives such as physical activity promotion (Schilling et al., 2009), and

that addressing knowledge and motivation will have limited success in promoting long-term behavioral changes (Marcus et al., 2000). The importance of setting attributes is also acknowledged in behavioral economics, in which “nudge” theory posits that contextual factors can unconsciously guide people into making particular choices (Thaler & Sunstein, 2008).

The framework discussed above proposes that human behaviors are shaped to some extent by physical and social factors of the environment, and suggests the possibility of inducing long-term behavior changes by modifying these factors. Contextual factors may be particularly relevant to sitting, which can be understood as an unconscious automatic response to the immediate setting. The application of the ecological model to workplace sitting is illustrated in Figure 1, which shows multiple levels of influence on this behavior (Owen et al., 2011; Sallis & Owen, 2015). Sitting at work may be conceptualized as being affected at the individual level by attributes such as demographic factors, awareness of health risks, perceived control over behavior, and motivation to change (inner circle, Figure 1); and, externally to the individual by the environmental/spatial and organizational/social factors of the contexts where sitting takes place (outer circles).

(INSERT FIGURE 1 AROUND HERE)

Cognitive-social models such as the Theory of Planned Behavior (TPB; Ajzen, 1991) can be helpful in understanding how individual-level factors may interact with behavior-settings attributes to influence workplace sitting, in the perspective of the ecological model (Owen et al., 2011; Sallis & Owen, 2015). For example, one of the TPB’s constructs, behavioral control, which reflects the perceived ease or difficulty in performing the behavior in a given context, can be linked to behavior-settings attributes of the workplace. Another key component of TPB is subjective norm, which refers to the perceived social or organizational pressure relating to performing or not performing a particular

behavior. Some of the factors in the social/organizational domain in Figure 1 may thereby encourage or discourage particular workplace behaviors – in this case, sitting time.

A recent review on workplace approaches to reduce sitting reported that interventions focusing on individual-level approaches (e.g., providing information about health impacts of prolonged sitting; goal setting; self-monitoring) often produced non-significant or small effects, whereas those including environmental interventions typically yielded larger reductions in sitting time (Chu et al., 2016). The typical environmental intervention examined has been provision of a height-adjustable workstation, which is known to lead to reductions in sitting time, particularly when combined with strategies that also address organizational-, intrapersonal-, and interpersonal-level influences (Chau et al., 2014; Healy et al., 2016; Neuhaus, Healy, Dunstan, Owen, & Eakin, 2014). However, considering that interrupting sitting time with movement such as walking is known to provide health benefits (Dunstan et al., 2012), there is room for exploring alternative environmental initiatives that promote not only breaks in sitting but also movement during such breaks.

The presence and location of shared spaces within a workplace, such as meeting rooms, discussion/work areas, and kitchen/lounges, could be related to workers' behaviors (sitting, standing, and moving), and thus could potentially be modified to facilitate reductions in workers' sitting time. Sitting in the office-based workplace is often the default behavior for many hours of the working day. With the individual workspace typically configured for a seated posture and workplace cultural norms that reinforce sitting (Hadgraft, Brakenridge, et al., 2016), workers tend to sit whenever there is an opportunity, with sitting time being interrupted only when they have to move to other areas within the office. Thus, sitting and movement within an office environment are likely to be determined to some extent by the presence and arrangement of shared spaces in which various workplace functions are to be performed. To date, one study has shown that proximity of such shared spaces to the desk is associated with more walking steps but not with sitting time (Hua & Yang, 2014). Another study also

reported that better connection to such spaces through defined pathways was associated with a greater number of breaks in sitting time in open and semi-open plan offices (Duncan et al., 2015). However, no research has examined the extent to which the availability of such spaces is related to workplace sitting.

When considering the potential role of environmental factors in shaping behavior, it is important to recognize that these influences can be further divided into two layers: perceived and actual (objectively-measured). This distinction goes beyond an issue of measurement. Individual perceptions of the environment are often different from the physical reality. Research on the neighborhood environment and physical activity has shown poor agreement between perceived and objective environmental measures, which are nonetheless independently associated with physical activity (McGinn, Evenson, Herring, Huston, & Rodriguez, 2007). This suggests that both perceived and actual environmental characteristics can play a unique role in environment-behavior relationships. It can be argued that environmental perceptions are particularly relevant in the context of this study. As discussed above, perceptions of the surroundings influence the sense of behavioral control (ease or difficulty of performing the behavior). A study on pro-environmental behaviors in the workplace, for instance, has identified the availability of video conferencing facilities as a factor influencing behavioral control over communication methods (Greaves, Zibarras, & Stride, 2013).

The construct of subjective norms is a key element in the Theory of Planned Behavior (TPB). It can be argued that the effect of shared spaces on workplace sitting time may be moderated by factors related to normative beliefs, such as organizational norms and behavioral autonomy in relation to sitting at work. In other words, having spaces that allow workers to stand may have limited impact on sitting time, if workers believe that sitting is the norm in the workplace and that they have less autonomy over their choices to sit, or to stand and move. Previous research has found that subjective norms favorable towards sitting were positively associated with higher levels of sitting at work

(Prapavessis, Gaston, & DeJesus, 2015). It is also suggested that typical organizational culture, which regards sitting as a norm, makes it difficult to reduce sitting time (Gilson, Burton, van Uffelen, & Brown, 2011; Hadgraft, Brakenridge, et al., 2016). Findings from qualitative research also suggest that having insufficient autonomy over job tasks may be a barrier to reducing workplace sitting (Bort-Roig et al., 2014). However, it is unknown how these factors influence the use of shared working spaces. Experts on occupational sedentary behavior recommend investigating the interaction of environmental, organizational, and individual-level factors as influences on workplace sitting (Buckley et al., 2015), which is consistent with ecological models (Owen et al., 2011; Sallis & Owen, 2015). The TPB also assumes interactions between behavioral control (perceived ease) and subjective norms in affecting behavior. However, there are no studies examining such combined effects in the workplace context.

We examined associations of the perceived availability of shared spaces in the workplace with Australian office workers' objectively-assessed sitting time (total and accumulated through prolonged bouts), and the potential role of workplace normative-social factors in such relationships. As shown in Figure 2, perceived availability of shared spaces in the workplace was expected to be associated with workplace sitting time. The direction of associations may differ, depending on the nature of shared spaces. Four hypotheses were proposed: 1) the higher the perceived availability of formal meeting spaces, the greater the total and prolonged sitting time; 2) the higher the perceived availability of informal discussion spaces, the lower the total and prolonged sitting time; 3) the higher the perceived availability of collaborative working spaces, the lower the total and prolonged sitting time; and 4) the associations in Hypotheses 1–3 will be moderated by organizational norms and by behavioral autonomy.

(INSERT FIGURE 2 AROUND HERE)

Method

Data Source and Participants

This cross-sectional study used baseline data collected for a cluster randomized controlled trial aimed at reducing workplace sitting: the Stand Up Victoria (SUV) study. The methods (Dunstan et al., 2013), intervention development (Neuhaus, Healy, Fjeldsoe, et al., 2014), main outcomes (Healy et al., 2016), and worksite-level characteristics (Hadgraft, Healy, et al., 2016) of the trial from which data for the present study were obtained, have been reported previously. However, no SUV studies published to date have examined how office-space characteristics are related to workplace sitting. The intervention, detailed elsewhere (Dunstan et al., 2013; Neuhaus, Healy, Fjeldsoe, et al., 2014), comprised organizational-, environmental- (height-adjustable workstation), and individual-level strategies. Fourteen geographically separate worksites were recruited from a single government department in Victoria, Australia. At each site, a work team (i.e., a distinct group with dedicated team leader(s) and regular group meetings) was selected (if team size was smaller than 10, two teams were combined). The teams' roles mostly involved telephone-based or clerical/administrative tasks. Eligibility criteria for participants included: aged 18–65 years, English-speaking, worked 0.6 full time equivalent (FTE) or greater, and had designated access to a telephone, internet, and desk within the workplace. Of the 278 who originally expressed interest, 33 were ineligible and 14 were no longer eligible or were unwilling to participate at the intervention commencement, leaving 231 participants. Ethics approval was granted by Alfred Health Human Ethics Committee (Melbourne, Australia).

Data Collection Procedure

The current study used baseline data collected before the intervention. Thus, no participants had access to height-adjustable workstations. At baseline, trained staff conducted onsite assessments to

collect anthropometric measurements, provide participants with activity monitors and logbooks, and give instructions on activity monitor use (see below). Thereafter, participants completed a self-administered online questionnaire, containing questions relating to demographic, work, health-related and organizational/social characteristics.

Measures and Instruments

Sitting time. The primary outcome of the intervention study was sitting time at work, measured objectively using the activPAL3 activity monitor (PAL Technologies Limited, Glasgow, UK). The monitor provides highly accurate measures of sitting time on the basis of the wearer's posture (Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011). Participants were asked to wear the monitor for seven consecutive days (24 h/day) following the onsite assessment. The monitor was waterproofed and secured to the anterior mid-line of the right thigh, about one third down from the hip, using hypoallergenic adhesive material. Participants were asked to record the start and end time at work, as well as sleep/wake and non-wear time in a paper-based logbook. Research assistants checked logs for missing data (e.g., work hours) and contacted participants for clarification where possible. Any missing sleep or wake times were estimated and imputed during the data processing period. Data corresponding to time at the workplace (including lunch time) were analyzed. Two measures of sitting time were calculated for this study: total workplace time spent sitting (total sitting time) and workplace time accrued sitting in bouts ≥ 30 min (prolonged sitting time), both averaged for all work days. Prolonged sitting time in addition to total sitting time was used as an outcome, as sitting time accumulated in prolonged bouts over 30 minutes (but not sitting time accumulated in bouts shorter than 30 minutes) has been found associated with adiposity-related measures (Healy, Winkler, Brakenridge, Reeves, & Eakin, 2015). Since shared spaces may encourage occasional visits to these spaces and breaks from sitting, it was considered that their availability may be related not only to the

volume but also to the pattern of workplace sitting.

Perceived availability of shared spaces in workplace. The study used perceived availability of office shared spaces, which refer to spaces or areas used for meeting or collaboration work. They include spaces for formal meetings and informal work, but do not include individual workspace in common areas such as hot desks. As discussed above, perceptions of these spaces were used as they can be conceptualized to affect individual behaviors via behavioral intention. Participants were asked to respond to the following statements about shared spaces in their workplace: There is a sufficient amount of space (1) for formal meetings, (2) for informal discussion, and (3) for collaborative working in my workplace. The questionnaire provided additional information regarding the functions of these spaces. Formal meeting space was defined as being for "pre-scheduled meetings with colleagues and external parties, including telephone and video conferences". Two types of spaces were considered for informal work. Space for informal discussion was defined as being for "ad-hoc meetings or conversations (not necessarily related to work) taking place away from your desk (e.g., in work space, lounge, printer/copier areas, corridor, kitchen, tea room)". Collaborative working space was defined as being for "working together with colleagues while sharing the same space". The response options for each space ranged from 1 (strongly disagree) to 5 (strongly agree). These items were developed based on the Workplace Collaborative Environment Questionnaire, a survey instrument aiming to assess the perceived availability and quality of the workplace environment that support collaboration (Hua, Loftness, Heerwagen, & Powell, 2011).

Workplace normative-social factors. Two measures of participants' belief or perception with regard to workplace sitting were assessed through self-reported questionnaires. Organizational norms—the perceived acceptability of sitting less/moving more in the workplace—were measured as the mean response to eight items, such as "My workplace is committed to supporting staff choices to stand or move more at work", "My supervisor/s would not mind if I chose to stand up while working

at my desk", and "My colleagues would not mind if I chose to stand during a work meeting". The response option ranged from 1 (strongly disagree) to 5 (strongly agree). The internal consistency of this scale (Cronbach's alpha) was .81 (Hadgraft, Healy, et al., 2016). Behavioral autonomy—perceived independence over choices of sitting less/moving in the workplace—was measured as the mean response to five items, such as "It is my choice whether I stand up or sit at my desk while at work" and "It is my choice whether I stand up or sit during a meeting with my supervisor/s at work". The internal consistency of this scale was .72 (Hadgraft, Healy, et al., 2016). These items for organizational norms and for behavioral autonomy were adapted from physical activity literature or developed for the trial to be specific to workplace sitting (Dunstan et al., 2013).

Worksite characteristics. There were 14 worksites in this study. The worksite characteristics examined in this study were office size (small; large) and predominant work type (non phone-based; mixed; phone-based). Worksites with 50 or fewer workers were categorized as small. The study included nine small offices (125 participants) and five large offices (106 participants). There were seven non phone-based worksites (65 participants), three mixed worksites (62 participants), and four phone-based worksites (104 participants).

Individual characteristics. Individual-level covariates included gender, age, education, occupation category (managers; professionals; clerical), smoking at work or not, and body mass index (BMI). These were self-reported at the baseline survey, except for BMI, which was calculated at baseline using measured weight and height.

Statistical Analyses

Since participants from the same worksite are likely to be similar in their workplace behaviors, multilevel linear regression analyses, using worksites as a random intercept, were conducted. To assess Hypotheses 1–3, four models were fitted for each outcome to examine the main effect. Model 0

was the null model to identify the level of clustering (Intraclass correlation coefficient: ICC). In Model 1, the shared space variables were entered simultaneously. Model 2 adjusted for individual-level covariates (age, gender, education, job category, smoking at work, BMI). Model 3 further adjusted for worksite-level factors (office size and predominant work type). All models adjusted for total work time, as workplace sitting time is directly related to how long participants worked. To assess Hypothesis 4, interactions between shared space variables with perceived organizational norms and behavioral autonomy were also examined to test effect modification by these workplace normative-social factors. Stratified analyses were conducted when interactions were significant. Data were analyzed in Stata 12 (StataCorp LP, College Station, TX). Significance level was set at $p < .05$. It was set at $p < .1$ for interaction terms on the basis that interaction analyses tend to have less power (Twisk, 2006).

Results

Table 1 shows the characteristics of participants. After excluding those who did not have data on the outcome or exposure measures (n=10), 221 were retained for analyses. The majority were women, had tertiary education (vocational or Bachelor or higher), and had a clerical job. Average time spent at work was 8.5 hours/day. As reported previously (Hadgraft, Healy, et al., 2016), 80% of the work time was spent sitting, with more than 50% of the sitting time accumulated in prolonged bouts (≥ 30 min). Worksites differed in sitting time: worksite-level mean total sitting time ranged from 349 to 422 min/day ($p < .05$), and mean prolonged sitting time ranged from 113 to 283 min/day ($p < .001$). Perceptions of shared spaces also differed between worksites. The mean score ranged from 3.36 to 4.29 (out of 5) for formal meeting space, from 2.88 to 4.20 for informal discussion space, and from 3.00 to 4.21 for collaborative work space (all $p < .05$). These shared space variables were also correlated to each other: the correlation coefficient was .72 between formal meeting space and

informal discussion space, .70 between formal meeting space and collaborative work space, and .77 between informal discussion space and collaborative work space.

(INSERT TABLE 1 AROUND HERE)

Table 2 shows the results of the main effects of shared space variables for total and prolonged workplace sitting time. The null models (Model 0) showed a high level of clustering (ICC = 5% for total, and 15% for prolonged sitting time). No space variables were significantly associated with sitting time in the unadjusted models (Model 1) and the adjusted models (Model 2 and 3). However, office size was associated with workplace sitting time. Participants in larger offices (50+ people) tended to spend less time in total sitting and in prolonged sitting at the workplace, than those in smaller (<50 people) offices. Predominant work type was a major factor explaining workplace sitting. Those who worked at phone-based and mixed worksites tended to spend a longer time sitting particularly in prolonged bouts, compared to those at non phone-based worksites. As reported previously (Hadgraft, Healy, et al., 2016), organizational norms and behavioral autonomy were not significantly associated with total or prolonged workplace sitting time (data not shown). None of the individual variables (age, gender, education, job category, smoking status, BMI) were associated with sitting time.

(INSERT TABLE 2 AROUND HERE)

The results of stratified analyses, which were conducted when interactions between each space variable and workplace normative-social factors were significant at $p < .1$, are shown in Table 3 (stratified for organizational norms) and Table 4 (stratified for behavioral autonomy). Having

sufficient space for informal discussion was associated with less total sitting time only when organizational norms were supportive of less sitting (Table 3). Having sufficient space for informal discussion was also associated with less total and prolonged workplace sitting time only when participants had high levels of autonomy relating to sitting and standing in the workplace (Table 4). Effect modification by behavioral autonomy was also observed for the relationship between total sitting time and collaborative work space and for the relationship between prolonged sitting time and formal meeting space. However, the regression coefficients, which were opposite in direction for the lower and higher behavioral autonomy, were not significant (second and third rows, Table 4).

(INSERT TABLES 3 AND 4 AROUND HERE)

Discussion

This study hypothesized that higher perceived availability of formal meeting spaces in the workplace would be associated with greater amounts of total and prolonged sitting time at work, while higher perceived availability of informal discussion spaces and collaborative working spaces would be associated with lower amounts of total and prolonged sitting time. Our results did not support any of the Hypotheses 1–3 for the whole sample. However, in partial agreement with Hypothesis 4, the relationships between workplace sitting time and the perceived availability of shared space were moderated by levels of organizational support for less sitting and more movement and by levels of autonomy in these workplace behaviors. The predicted effect modification was evident for informal discussion space, in which workers can engage in casual conversations with colleagues and have a short break from work. The perceived availability of sufficient informal discussion space, combined with higher organizational support and behavioral autonomy, was associated with lower levels of total workplace sitting time. It was also associated with lower prolonged sitting time among those who

reported higher levels of autonomy in workplace behaviors. The latter finding is particularly notable considering its effect size: one unit increment (range: 1 to 5) in the perceived availability of informal discussion space was associated with 44 min/day lower prolonged workplace sitting time (Table 4), which was 20% of the average of its daily total. For those who are self-regulated in choosing different postures within the workplace, the presence of informal discussion space may facilitate moving away from the desk and breaking sitting time into shorter bouts.

Formal meeting spaces are typically designed for people to sit, and they were hypothesized to be related to longer sitting time. However, the presence of a formal meeting space was not significantly associated with workplace sitting time in this study. Given that participants would spend most of their time sitting at the desk, having sufficient formal meeting space may simply mean another place to sit, and thus not matter to their overall sitting volume. Movement from one's desk to shared spaces provides an opportunity for breaks in sitting. However, the non-significant results for prolonged sitting time appear to suggest that movement between one's desk and meeting spaces may not be frequent enough to be related to sitting patterns. The perceived availability of collaborative work space was also not significantly associated with either of the sitting time measures. It is possible that the definition of this space was not clear enough for participants, who may have considered different types of space in responding to this item. In order to assess the effect of office spaces on workplace sitting more accurately, research needs to develop office space categories that are aligned well with the current practice of office design and use. As hypothesized, behavioral autonomy moderated the relationships of sitting time with formal meeting or collaborative work space, suggesting that these spaces may have differential impact on workplace sitting, depending on how workers are supported or their level of independence in choosing workplace behaviors. However, a definitive discussion cannot be made, since no significant result was found in the stratified analyses.

Participants working at phone-based worksites spent significantly longer time in total sitting and

prolonged sitting than those at non phone-based worksites. The difference between different work types was particularly large for prolonged sitting, suggesting that those who engage in phone-based work accumulate a large amount of sitting without many breaks. There is a need to develop interventions that facilitate phone-based workers to regularly change their postures. It was found that those who worked in larger offices (more than 50 workers) tended to spend less time in total sitting and in prolonged sitting, compared with those in smaller offices. The findings suggest that those in smaller (≤50 workers) offices may be more confined to their desk with limited opportunities to have a break from sitting. However, office size in this study was determined by the number of workers without accounting for physical size. The actual office size and the density of individual workstations are likely to affect workplace behaviors. Further research needs to examine how the physical size of workplace and density of workstations are related to workplace sitting time.

The study of workplace environments and office sitting can be likened to the established body of research on neighborhood environments and walking. In particular, a framework of "destinations and routes" that conceptualizes environmental attributes relevant to walking (Sugiyama, Neuhaus, Cole, Giles-Corti, & Owen, 2012) has potential applicability to workplace settings. Research on neighborhood environments has shown consistent associations of the presence of local destinations with residents' walking behavior. The present study showed the relevance of destinations in a small-scale environment of office settings to workers' sitting time. On the basis of the framework, it is of interest to examine how "routes" in the workplace are related to sitting at work. Researchers in environmental psychology have been examining how people perceive spaces and navigate through them, using approaches such as spatial cognition and wayfinding. Routes are an important element in spatial navigation, and how spaces are used can depend not only on the attributes of the spaces but also on access to them. For instance, Duncan et al. (2015) reported that better connectivity to shared space (kitchen) and better visibility of co-workers were associated with more sitting breaks. Unlike

neighborhood streets, which are laid out first and determine the structure of local areas, routes in workplace are often formed as a consequence of arrangement of other office elements such as workstations and furniture. Thus, in the case of the workplace, access or visual connection to shared spaces may be more relevant. Space syntax, which is concerned with topological (rather than metric) properties of routes, has been used to assess connectivity within the workplace and examine how it is related to workers' movement and face-to-face interaction (Rashid, Kampschroer, Wineman, & Zimring, 2006). Research using virtual reality has suggested that the topological, metric, and visual access to spaces are inter-related in affecting people's route choices (Barton, Valtchanov, & Ellard, 2014; Chrastil & Warren, 2014). Further studies are warranted to examine the impact of these different aspects of connection to shared spaces on workplace sitting.

Strengths of this study include the use of objectively-measured sitting time (total and accumulated in prolonged bouts), examination of multiple factors that can affect workplace behaviors (environmental, organizational, and psychosocial), and the diversity of study settings (14 worksites, which differed in size and work type). From a theoretical point of view, the study emphasizes the importance of examining interactions of multi-level factors, which is one of the central principles of the ecological model. Limitations include the use of self-report measures for shared spaces, for which no reliability test was conducted. In particular, participants may not have a clear idea about what a space for collaborative work is like. Although environmental perception is a theoretically valid measure used in previous research on environment and physical activity (McGinn et al., 2007; Sugiyama et al., 2012) and on workplace pro-environmental behaviors (Greaves et al., 2013), objectively-measured size (both total and size per person) for different shared spaces also needs to be examined in future studies to confirm the findings of this study and to produce more concrete information for practitioners. As mentioned above, the physical size of office floor area is also needed to determine basic workplace characteristics such as density of workers. In addition, in light of a

previous study that shows the association of proximity to shared spaces and walking in workplace (Hua & Yang, 2014), spatial arrangement of shared spaces (central or peripheral, clustered or scattered, single or multiple) may also affect workplace sitting, and is worthy of investigation. Since this was secondary analysis of an intervention study, it may not have sufficient power to detect the associations of interest. Some large regression coefficients were not significant due to the wide confidence intervals. Future studies should be designed to have enough statistical power to accurately identify workplace attributes relevant to sitting at work. Research may also examine how workplace behaviors (sitting, standing, and moving) are related to interactions between workers, and how shared spaces may contribute to creating a collaborative workplace. As organizations increasingly value collaboration among members, and office space design and layout seem to play a role in workers' interaction (Kabo, 2017), future research can examine other work-related benefits of office design that promotes less sitting and more movement. From a workplace design perspective, it is also important to examine what characteristics of shared spaces can induce more frequent use of such spaces, which is expected to contribute beneficially to reducing and breaking up sitting time.

Conclusions

The findings of this study suggest that workplace environmental or organizational factors alone may not be enough to facilitate less sitting in workplace: both may need to be engaged within the relevant initiatives. This is aligned well with an ecological model of sedentary behavior, which highlights the importance of engaging multi-level influences. The effectiveness of combined approaches in reducing workplace sitting has been confirmed in the intervention trial in which those in our study participated (Healy et al., 2016), although the environmental intervention in the trial was the introduction of height-adjustable desks. Natural experimental studies, in which participants relocated to a new "movement-friendly" office, have found that they lowered sitting time after relocation

(Gorman et al., 2013; Jancey et al., 2016). The new offices used in these studies appeared to have some shared space for informal discussion, suggesting its potential role in changing workers' behaviors. Future research can examine the effect of office renovation, in particular, addition of informal discussion space, to confirm the relevance of shared spaces to workplace sitting.

Based on the findings of the study, it can be argued that workplace with a variety of spaces and destinations could help workers to sit less and move more, if the organization and individuals are prepared for such a way of working. This is consistent with a new direction of workplace design. Office design has gone through several stages of evolution from enclosed/private offices, semi-open cubicles, to open-plan offices. A more recent trend is a transition from the traditional ownership of space (fixed location for each worker) to access to various spaces for predetermined functions. Activity-Based Working (ABW), which embodies this principle (Wohlers & Hertel, 2017), recommends that offices have a combination of non-assigned workstations with task-oriented spaces. Such office design allows workers to choose a space that is best suited to their tasks, and provides employers with flexible workplace to comply with increasingly diverse work styles. Research has shown that workers who moved to an office designed with ABW principles reported less distraction, more interaction with colleagues, and higher workplace satisfaction (Gerdenitsch, Korunka, & Hertel, in press). It is possible that ABW may also have an impact not only on workplace behaviors (by providing more destinations to move) but also on organizational norms and workers' perceived control of their behaviors (by giving them an independent choice of or a sense of freedom about where to work). Although ABW does not specifically address workers' health or health-related behaviors, design features to realize ABW can help produce movement-friendly and thus healthier workplaces.

The health of office workers may be at risk due to high levels of prolonged sitting. This study suggests that there is room for new office design to change this behavior pattern in the workplace. Given the high prevalence and ubiquity of workplace sitting, and office environments being relatively

more amenable to modify (in comparison, for example, to neighborhood environments), reduction of workplace sitting can be a realistic target for occupational health, with potential for substantial benefit. Evidence-informed office design is needed to achieve this goal. Further collaborative research involving architecture, interior design, organizational psychology, business management, and public/occupational health is warranted to further examine specific attributes of workplace environments that can help reduce workplace sitting.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior & Human Decision Processes, 50*(2), 179–211. doi:10.1016/0749-5978(91)90020-T

Barker, R.G. (1968). *Ecological psychology*. Stanford, CA: Stanford University Press.

Barton, K. R., Valtchanov, D., & Ellard, C. (2014). Seeing beyond your visual field: The influence of spatial topology and visual field on navigation performance. *Environment & Behavior*, *46*(4), 507–529. doi:10.1177/0013916512466094

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., & Alter, D. A. (2015). Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: A systematic review and meta-analysis. *Annals of Internal Medicine, 162*(2), 123–132. doi:10.7326/M14-1651

Bort-Roig, J., Martin, M., Puig-Ribera, A., Gonzalez-Suarez, A., Martinez-Lemos, I., Martori, J. C., & Gilson, N. D. (2014). Uptake and factors that influence the use of 'sit less, move more' occupational intervention strategies in Spanish office employees. *International Journal of Behavioral Nutrition & Physical Activity*, *11*, 152. doi:10.1186/s12966-014-0152-6

Buckley, J. P., Hedge, A., Yates, T., Copeland, R. J., Loosemore, M., Hamer, M., . . . Dunstan, D. W. (2015). The sedentary office: An expert statement on the growing case for change towards better health and productivity. *British Journal of Sports Medicine, 49*(21), 1357–1362. doi:10.1136/bjsports-2015-094618

Bureau of Labor Statistics. (2016). *American Time Use Survey — 2015 Results*. Retrieved from https://www.bls.gov/news.release/pdf/atus.pdf

Chau, J. Y., Daley, M., Dunn, S., Srinivasan, A., Do, A., Bauman, A. E., & van der Ploeg, H. P. (2014). The effectiveness of sit-stand workstations for changing office workers' sitting time: Results from the Stand@Work randomized controlled trial pilot. *International Journal of*

Behavioral Nutrition & Physical Activity, 11, 127. doi:10.1186/s12966-014-0127-7

Chrastil, E. R., & Warren, W. H. (2014). From cognitive maps to cognitive graphs. *PLoS One, 9*(11): e112544. doi:10.1371/journal.pone.0112544

Chu, A. H. Y., Ng, S. H. X., Tan, C. S., Win, A. M., Koh, D., & Muller-Riemenschneider, F. (2016). A systematic review and meta-analysis of workplace intervention strategies to reduce sedentary time in white-collar workers. *Obesity Reviews, 17*(5), 467–481. doi:10.1111/obr.12388

Cooper, A. J., Brage, S., Ekelund, U., Wareham, N. J., Griffin, S. J., & Simmons, R. K. (2014). Association between objectively assessed sedentary time and physical activity with metabolic risk factors among people with recently diagnosed type 2 diabetes. *Diabetologia, 57*(1), 73–82. doi:10.1007/s00125-013-3069-8

Duncan, M. J., Short, C., Rashid, M., Cutumisu, N., Vandelanotte, C., & Plotnikoff, R. C. (2015). Identifying correlates of breaks in occupational sitting: A cross-sectional study. *Building Research & Information, 43*(5), 646–658. doi:10.1080/09613218.2015.1045712

Dunstan, D. W., Kingwell, B. A., Larsen, R., Healy, G. N., Cerin, E., Hamilton, M. T., . . . Owen, N. (2012). Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes Care, 35*(5), 976–983. doi:10.2337/dc11-1931

Dunstan, D. W., Wiesner, G., Eakin, E. G., Neuhaus, M., Owen, N., LaMontagne, A. D., . . . Healy, G. N. (2013). Reducing office workers' sitting time: Rationale and study design for the Stand Up Victoria cluster randomized trial. *BMC Public Health, 13*, 1057. doi:10.1186/1471-2458-13-1057

Gerdenitsch, C., Korunka, C., & Hertel, G. (in press). Need-supply fit in an activity-based flexible office: A longitudinal study during relocation. *Environment & Behavior*. doi:10.1177/0013916517697766

Gilson, N. D., Burton, N. W., van Uffelen, J. G., & Brown, W. J. (2011). Occupational sitting time: Employees' perceptions of health risks and intervention strategies. *Health Promotion Journal of Australia, 22*(1), 38–43. doi:10.1071/HE11038

Gorman, E., Ashe, M. C., Dunstan, D. W., Hanson, H. M., Madden, K., Winkler, E. A., . . . Healy, G. N. (2013). Does an 'activity-permissive' workplace change office workers' sitting and activity time? *PLoS One, 8*(10), e76723. doi:10.1371/journal.pone.0076723

Greaves, M., Zibarras, L. D., & Stride, C. (2013). Using the theory of planned behavior to explore environmental behavioral intentions in the workplace. *Journal of Environmental Psychology, 34*(Supplement C), 109–120. doi: https://doi.org/10.1016/j.jenvp.2013.02.003

Hadgraft, N. T., Brakenridge, C. L., LaMontagne, A. D., Fjeldsoe, B. S., Lynch, B. M., Dunstan, D. W., . . . Lawler, S. P. (2016). Feasibility and acceptability of reducing workplace sitting time: A qualitative study with Australian office workers. *BMC Public Health, 16*, 933. doi:10.1186/s12889-016-3611-y

Hadgraft, N. T., Healy, G. N., Owen, N., Winkler, E. A., Lynch, B. M., Sethi, P., . . . Dunstan, D. W. (2016). Office workers' objectively assessed total and prolonged sitting time: Individual-level correlates and worksite variations. *Preventive Medicine Reports, 4*, 184–191. doi:10.1016/j.pmedr.2016.06.011

Healy, G. N., Eakin, E. G., Owen, N., Lamontagne, A. D., Moodie, M., Winkler, E. A., . . . Dunstan, D. W. (2016). A cluster randomized controlled trial to reduce office workers' sitting time: Effect on activity outcomes. *Medicine & Science in Sports & Exercise, 48*(9), 1787–1797. doi:10.1249/MSS.0000000000000972

Healy, G. N., Matthews, C. E., Dunstan, D. W., Winkler, E. A., & Owen, N. (2011). Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003–06. *European Heart Journal, 32*(5), 590–597. doi:10.1093/eurheartj/ehq451

Healy, G. N., Winkler, E. A., Brakenridge, C. L., Reeves, M. M., & Eakin, E. G. (2015). Accelerometer-derived sedentary and physical activity time in overweight/obese adults with type 2 diabetes: Cross-sectional associations with cardiometabolic biomarkers. *PLoS One, 10*(3), e0119140. doi:10.1371/journal.pone.0119140

Hua, Y., Loftness, V., Heerwagen, J. H., & Powell, K. M. (2011). Relationship between workplace spatial settings and occupant-perceived support for collaboration. *Environment & Behavior, 43*(6), 807–826. doi:10.1177/0013916510364465

Hua, Y., & Yang, E. (2014). Building spatial layout that supports healthier behavior of office workers: A new performance mandate for sustainable buildings. *Work-a Journal of Prevention Assessment & Rehabilitation, 49*(3), 373–380. doi:10.3233/wor-141872

Jancey, J. M., McGann, S., Creagh, R., Blackford, K. D., Howat, P., & Tye, M. (2016). Workplace building design and office-based workers' activity: A study of a natural experiment. *Australian & New Zealand Journal of Public Health, 40*(1), 78–82. doi:10.1111/1753-6405.12464

Kabo, F. W. (2017). A model of potential encounters in the workplace: The relationships of homophily, spatial distance, organizational structure, and perceived networks. *Environment & Behavior, 49*(6), 638-662. doi:10.1177/0013916516658501

Kozey-Keadle, S., Libertine, A., Lyden, K., Staudenmayer, J., & Freedson, P. S. (2011). Validation of wearable monitors for assessing sedentary behavior. *Medicine & Science in Sports & Exercise, 43*(8), 1561–1567. doi:10.1249/MSS.0b013e31820ce174

Marcus, B. H., Dubbert, P. M., Forsyth, L. H., McKenzie, T. L., Stone, E. J., Dunn, A. L., & Blair, S. N. (2000). Physical activity behavior change: Issues in adoption and maintenance. *Health Psychology, 19*(1S), 32–41. doi: 10.1037//0278-6133

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R., & Troiano, R. P. (2008). Amount of time spent in sedentary behaviors in the United States,

2003–2004. *American Journal of Epidemiology, 167*(7), 875–881. doi:10.1093/aje/kwm390

McGinn, A. P., Evenson, K. R., Herring, A. H., Huston, S. L., & Rodriguez, D. A. (2007). Exploring associations between physical activity and perceived and objective measures of the built environment. *Journal of Urban Health, 84*(2), 162–184. doi:10.1007/s11524-006-9136-4

Neuhaus, M., Healy, G. N., Dunstan, D. W., Owen, N., & Eakin, E. G. (2014). Workplace sitting and height-adjustable workstations: A randomized controlled trial. *American Journal of Preventive Medicine, 46*(1), 30–40. doi:10.1016/j.amepre.2013.09.009

Neuhaus, M., Healy, G. N., Fjeldsoe, B. S., Lawler, S., Owen, N., Dunstan, D. W., . . . Eakin, E. G. (2014). Iterative development of Stand Up Australia: A multi-component intervention to reduce workplace sitting. *International Journal of Behavioral Nutrition & Physical Activity, 11*, 21. doi:10.1186/1479-5868-11-21

Ng, S. W., & Popkin, B. M. (2012). Time use and physical activity: A shift away from movement across the globe. *Obesity Reviews, 13*(8), 659–680. doi:10.1111/j.1467-789X.2011.00982.x

NHK Broadcasting Culture Research Institute. (2016). *The 2015 NHK Japanese Time Use Survey (2015 Kokumin Seikatsu Jikan Chosa)*. Retrieved from https://www.nhk.or.jp/bunken/research/yoron/pdf/20160217_1.pdf

Owen, N., Sugiyama, T., Eakin, E. E., Gardiner, P. A., Tremblay, M. S., & Sallis, J. F. (2011). Adults' sedentary behavior determinants and interventions. *American Journal of Preventive Medicine, 41*(2), 189–196. doi:10.1016/j.amepre.2011.05.013

Parry, S., & Straker, L. (2013). The contribution of office work to sedentary behaviour associated risk. *BMC Public Health, 13*, 296. doi:10.1186/1471-2458-13-296

Prapavessis, H., Gaston, A., & DeJesus, S. (2015). The Theory of Planned Behavior as a model for understanding sedentary behavior. *Psychology of Sport & Exercise, 19*, 23–32. doi:10.1016/j.psychsport.2015.02.001

Rashid, M., Kampschroer, K., Wineman, J., & Zimring, C. (2006). Spatial layout and face-to-face interaction in offices: A study of the mechanisms of spatial effects on face-to-face interaction. *Environment and Planning B-Planning & Design, 33*(6), 825–844. doi:10.1068/b31123

Sallis, J., & Owen, N. (2015). Ecological models of health behavior. In K. Glanz, B. Rimer, & K. Viswanath (Eds.), *Health behavior: Theory, research, and practice (5th ed.)* (pp. 43–64). San Francisco: Jossey-Bass.

Schilling, J. M., Giles-Corti, B., & Sallis, J. F. (2009). Connecting active living research and public policy: Transdisciplinary research and policy interventions to increase physical activity. *Journal of Public Health Policy, 30*(S1), 1–15. doi: 10.1057/jphp.2008.59

Scott, M. M. (2005). A powerful theory and a paradox: Ecological psychologists after Barker. *Environment & Behavior, 37*(3), 295–329. doi:10.1177/0013916504270696

Spinney, R., Smith, L., Ucci, M., Fisher, A., Konstantatou, M., Sawyer, A., . . . Marmot, A. (2015). Indoor tracking to understand physical activity and sedentary behaviour: Exploratory study in UK office buildings. *PLoS One, 10*(5), e0127688. doi:10.1371/journal.pone.0127688

Sugiyama, T., Neuhaus, M., Cole, R., Giles-Corti, B., & Owen, N. (2012). Destination and route attributes associated with adults' walking: A review. *Medicine & Science in Sports & Exercise, 44*(7), 1275–1286. doi:10.1249/MSS.0b013e318247d286

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: Improving Decisions about Health, Wealth, and Happiness*. New Haven, CT: Yale University Press.

Twisk, J. (2006). *Applied multilevel analysis*. Cambridge: Cambridge University Press.

Wohlers, C., & Hertel, G. (2017). Choosing where to work at work: Towards a theoretical model of benefits and risks of activity-based flexible offices. *Ergonomics, 60*(4), 467–486. doi:10.1080/00140139.2016.1188220

Tables

Table 1. Sample characteristics (*N*=221)

Individual	
Gender, %women	68
Age, mean (*SD*)	45.5 (9.4)
Education	
%high school or less	33
%vocational	28
%Bachelor's or higher	39
Job category	
%managerial	7
%professional	14
%clerical	79
Smoking at work, %yes	14
BMI in kg/m^2, mean (*SD*)	28.0 (6.0)
Perceived sufficiency of shared space [a]	
Formal meeting space, mean (*SD*)	3.94 (0.99)
Informal discussion space, mean (*SD*)	3.86 (0.92)
Collaborative work space, mean (*SD*)	3.77 (0.99)
Time spent at work and in workplace sitting	
Total time at work in min/day, mean (*SD*)	510 (56)
Total sitting time in min/day, mean (*SD*)	402 (67)
Prolonged sitting time in min/day, mean (*SD*) [b]	216 (102)

[a] Range: 1 (strongly disagree) to 5 (strongly agree)
[b] Accumulated in bouts ≥ 30 min

Table 2. Associations of workplace sitting time (min/day) with shared space variables and worksite characteristics, unstandardized regression coefficients (95%CI)

	Total sitting time			Prolonged sitting time		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Fixed effects						
Share space for [a]						
Formal meetings	4.1 (-5.9, 14.2)	4.2 (-5.8, 14.2)	7.2 (-2.7, 17.1)	2.6 (-18.2, 23.4)	0.1 (-20.8, 21.0)	4.8 (-15.8, 25.4)
Informal discussion	-1.9 (-12.9, 9.1)	-1.7 (-12.7, 9.2)	-3.2 (-14.2, 7.7)	-7.4 (-30.1, 15.2)	-5.5 (-28.2, 17.1)	-10.3 (-33.0, 12.4)
Collaborative work	0.9 (-11.5, 9.7)	-0.1 (-10.5, 10.4)	-1.9 (-12.3, 8.5)	2.8 (-19.0, 24.6)	3.0 (-18.7, 24.6)	-0.1 (-21.7, 21.4)
Office size						
Smaller (ref)			1.00			1.00
Larger			-16.0 (-31.5, -0.4)*			-39.2 (-71.5, -6.9)*
Predominant work type						
Non phone-based (ref)			1.00			1.00
Mixed			31.9 (14.8, 49.0)***			64.6 (29.0, 100.1)***
Phone-based			24.6 (6.8, 42.4)**			85.5 (48.4, 122.5)***
Random effects						
ICC in %	13.6 (3.5, 34.8)	13.6 (3.3, 35.7)	0.0	15.0 (4.5, 35.4)	17.0 (5.3, 38.5)	0.0

* $p < .05$, ** $p < .01$, *** $p < .001$

[a] Range: 1 (strongly disagree) to 5 (strongly agree)

ICC in the null models: 10.0 (2.1, 30.1) % for total sitting time, 14.1 (4.1, 33.9) % for prolonged sitting time
Model 1: shared space variables examined simultaneously, adjusting for total time at work
Model 2: further adjusting for individual-level covariates (age, gender, education, job category, smoking at work, BMI)
Model 3: further adjusting for worksite-level factors (office size and predominant work type)

Table 3. Associations of workplace sitting time with shared space variables, stratified by organizational norms, unstandardized regression coefficients (95%CI)

Sitting time	Space for	Organizational norms		Interaction (*p*)
		Not supportive (*n*=113)	Supportive (*n*=106)	
Total	Informal discussion	2.4 (-11.9, 16.7)	-19.0 (-37.1, -0.9)*	0.06
Prolonged	Informal discussion	9.4 (-21.5, 40.4)	-30.3 (-64.8, 4.3)	0.08

* $p < .05$

Shared space attributes examined simultaneously, adjusting for individual-level covariates (age, gender, education, job category, smoking at work, BMI, total time at work), office size, and predominant work type. Two participants did not report organizational norms.

Table 4. Associations of workplace sitting time with shared space variables, stratified by behavioral autonomy, unstandardized regression coefficients (95%CI)

Sitting time	Space for	Behavioral autonomy		Interaction (*p*)
		Lower (*n*=100)	Higher (*n*=118)	
Total	Informal discussion	13.8 (-0.1, 27.8)	-20.9 (-37.7, -4.1)*	0.002
Total	Collaborative work	-11.7 (-23.9, 0.5)	10.7 (-6.0, 27.4)	0.06
Prolonged	Formal meeting	-16.6 (-48.2, 15.0)	23.8 (-2.7, 50.3)	0.06
Prolonged	Informal discussion	26.3 (-7.4, 60.0)	-44.2 (-74.5, -13.9)**	0.004

* $p < .05$, ** $p < .01$

Shared space attributes examined simultaneously, adjusting for individual-level covariates (age, gender, education, job category, smoking at work, BMI, total time at work), office size, and predominant work type. Three participants did not report behavioral autonomy.